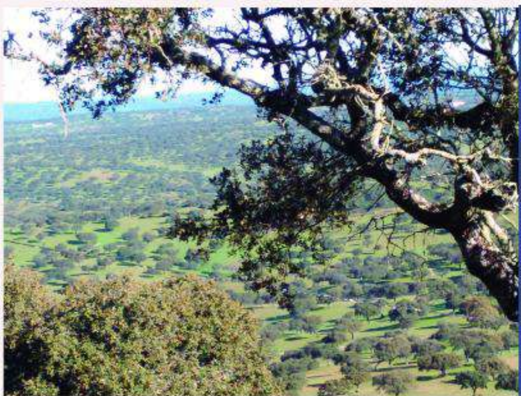
EURAF
EUROPEAN AGROFORESTRY FEDERATION

4th EUROPEAN AGROFORESTRY CONFERENCE

“Agroforesty as Sustainable Land Use”

CONFERENCE PROCEEDINGS



28-30 MAY 2018 · NIJMEGEN - THE NETHERLANDS

Proceedings of the 4th European Agroforestry Conference

Agroforestry as Sustainable Land Use

28-30 May 2018, Nijmegen, The Netherlands

Published by the European Agroforestry Federation and the University of Santiago de Compostela in Lugo (Spain), 2018

ISBN: 978-84-09-02384-4

Distributed by the European Agroforestry Federation

Editors-in-Chief

Nuria Ferreiro-Domínguez
María Rosa Mosquera-Losada

Associate Editors

Adolfo Rosati
Anastasia Pantera
Andrea Pisanelli
Andrea Vityi
Bert Reubens
Bohdan Lojka
Christian Dupraz
Felix Herzog
Gerry Lawson
Joana Amaral Paulo
João HN Palma
Jo Smith
María Pilar González-Hernández
Mercedes Rois-Díaz
Norbert Lamersdorf
Pierluigi Paris
Robert Borek
Vania Georgieva Kachova
Vasiliy Yukhnovskyi
Victoria Nelissen

Organising Committee

President Louis Dolmans (President Stichting Van Akker naar Bos (Foundation From Arable field to Forest), natural farmer, The Netherlands)

Members Mark Vonk (EURAF-representative for The Netherlands, representative Stichting van Akker naar Bos, board member Foundation Agroforestry Nederland, co-owner Boshoeve Sprankenhof, The Netherlands)

Han Derckx (Municipality of Nijmegen, advisor, project manager theme Vital City “Nijmegen European Green Capital 2018”, The Netherlands)

Boki Luske (Louis Bolk Institute and president Foundation Agroforestry Nederland, The Netherlands)

Kees van Veluw (Wageningen University, Louis Bolk Institute, The Netherlands)

Lex Roeleveld (Hedgerows and Landscape Foundation, The Netherlands)

Mariska Slot (board member Stichting Van Akker naar Bos, natural farmer at Boeren in het Bos, The Netherlands)

María Rosa Mosquera-Losada (University of Santiago de Compostela, Spain)

Nuria Ferreiro-Domínguez (University of Santiago de Compostela, Spain)

Anastasia Pantera (Technological Educational Institute, Greece)

Scientific Committee

Chairs Nuria Ferreiro-Domínguez (University of Santiago de Compostela, Spain)

María Rosa Mosquera-Losada (University of Santiago de Compostela, Spain)

Members Adolfo Rosati (Consiglio per la Ricerca in Agricoltura, Italy)

Anastasia Pantera (Technological Educational Institute, Greece)

Andrea Pisanelli (Istituto di Biologia Agroambientale e Forestale, Italy)

Andrea Vityi (University of West Hungary, Hungary)

Bert Reubens (Instituut voor Landbouw en Visserijonderzoek, Belgium)

Bohdan Lojka (Faculty of Tropical AgriSciences, Czech Republic)

Christian Dupraz (Institut National de la Recherche Agronomique, France)

Felix Herzog (Agroscope Research Center, Switzerland)

Gerry Lawson (Centre for Ecology and Hydrology, UK)

Joana Amaral Paulo (Instituto Superior de Agronomia, University of Lisbon, Portugal)

João Palma (Instituto Superior de Agronomia, University of Lisbon, Portugal)

Jo Smith (Organic Research Centre, UK)

María Pilar González-Hernández (University of Santiago de Compostela, Spain)

Mercedes Rois-Díaz (European Forest Institute, Finland)

Norbert Lamersdorf (Georg-August-Universität, Germany)

Pierluigi Paris (Consiglio Nazionale delle Ricerche, Italy)

Robert Borek (Institute of Soil Science and Plant Cultivation, Poland)

Vania Georgieva Kachova (Bulgarian Academy of Sciences, Bulgaria)

Vasiliy Yukhnovskyi (National University of Life and Environmental Sciences of Ukraine)

Victoria Nelissen (Instituut voor Landbouw en Visserijonderzoek, Belgium)

Foreword

It is a great pleasure to share with you the excellent book of abstracts of the 4th European Agroforestry Conference carried out in the beautiful city of Nijmejen (The Netherlands) during the European Green Capital 2018. The book is plenty of extraordinary information and experiences about agroforestry practices and systems around the world including Africa, America and Europe. Silvopastoralism is the most relevant agroforestry practice shown in the book, but also silvoarable or alley cropping practices become important. Sessions and topics deal with the enhancement of productivity of both the woody perennial and the lower storey component of the agroforestry practice trying to cope with an increasing primary sector products demanded by the world, but also highlighting the importance of the ecosystem services delivery and considering the fulfillment of the United Nations Sustainable Development Goals. The importance of agroforestry as one of the best tools available to mitigate and adapt to climate change is also discussed in different papers. Biodiversity preservation and enhancement through locally adapted agroforestry practices is also tackled as well as water and soil quality and health. Social aspects and innovation promotion, needed to successfully reach the necessary transition towards an extensive use of agroforestry, are also outreached in several papers. The needed change of international, national, regional and local policies is described as a mean to provide insights to foster the transition to agroforestry practices spread. As President of EURAF, I wish you a successful 4th European Agroforestry Conference and an enjoyable reading!

Rosa Mosquera-Losada

President of EURAF

TABLE OF CONTENTS

Keynotes

Factors of success and failure in the transition into agroforestry

Oral Presentations

Poster Presentations

Costs and revenues of agroforestry on the scale of the individual farm, a region and a state; proven practice and theoretical models

Oral Presentations

Poster Presentations

Agroforestry policies

Oral Presentations

Poster Presentations

Agroforestry as a form of sustainable land use to fight against climate change

Oral Presentations

Poster Presentations

Testimonies of farmers from Europe

Oral Presentations

Poster Presentations

Environmental benefits of agroforestry

Oral Presentations

Poster Presentations

Biodiversity and added value

Oral Presentations

Poster Presentations

Innovations in agroforestry

Oral Presentations

Poster Presentations

Social and economic aspects in developing agroforestry

Oral Presentations

Poster Presentations

Tree-Crop-Animal competition and facilitation

Oral Presentations

Poster Presentations

Agroforestry and multiple products value chain

Oral Presentations

Poster Presentations

Education and tools to investigate agroforestry

Oral Presentations

Poster Presentations

Keynotes

WE HAVE A DREAM: FOSTERING AGRICULTURAL TRANSITION TOWARDS AGROFORESTRY

Mosquera-Losada MR[1*]

(1) Department of Crop Production and Engineering Projects, Escuela Politécnica Superior de Lugo, University of Santiago de Compostela, Campus Universitario s/n, 27002 Lugo, Spain

*Corresponding author: mrosa.mosquera.losada@usc.es

Abstract

Agroforestry is a sustainable land use that involves a woody perennial component (tree or shrub) and an agricultural product that should be fostered across Europe. Fostering agricultural transition towards agroforestry is complex as it should be based on farmers, multipliers, policy makers and researchers. This paper shows the current opinions of farmers about challenges to be overcome to foster agroforestry in Europe in a description of the current situation based on the AGFORWARD and AFINET interviews. Main aspects coming from farmers are discussed such as the better understanding of the agroforestry definition and the tools provided by the European Commission to foster innovation including agroforestry. We finally end with a set of proposals provided by the European Agroforestry Federation (EURAF) thanks to the work within a large set of relevant stakeholders across Europe in the AGFORWARD framework.

Keywords: woody perennial; farmers; interviews; opinions; solutions

The current situation

Many farmers and scientists have realized the advantages of using agroforestry practices all over the world, considering production enhancement but also ecosystem services delivery both linked to the fulfillment of the Sustainable Development Goals. Both scientists and farmers have shown that the adequate combination of a woody component with a lower story agricultural product increase land productivity and farm resilience. On the contrary, an unsuitable combination could reduce production mostly when the practices are not adapted to local conditions. However, the inertia of unsustainable intensive production systems is still deeply assumed by a lot of farmers grown with the idea that intensification is the way to go to feed the planet. Intensification is strongly based on the natural capital deployment of previously sustainably handled agricultural lands. This fertility deployment is initially compensated by the capacity of farmers to buy external inputs in developed countries, mainly explained by the different market and man-power prices we have in different parts of the world. However, and in spite of those inputs, intensification has lead, in many cases, to a land potential productivity deployment that can be directly associated to the reduction of soil organic matter and that finally reaches the status of degraded land. Anthropogenic activity has also become relevant in the processes of climate change conducting to a more unpredictable weather that fosters a lot of farmers to adopt practices that transform their properties in more resilient farms.

Health and ecosystem services delivery from agricultural management has become also an issue for consumers and society in general that advocate policy makers to find adequate solutions able to combine increasing land production and farmer incomes while preserving the natural capital and providing ecosystem services and society claims.

Understanding the problems: asking farmers

As a sustainable land use agroforestry should be fostered. However changes of land use are not usually easy, they should consider excellent and imaginative forms to enable a social movement that, at the same time, should more profitable and showing a benefit for future harvests. The best form to understand problems linked to the agroforestry transition is asking those farmers. This is what has been done in the two last European Union Agroforestry projects: AGFORWARD and AFINET. Rois et al. (2017) pointed out that after asking 183 farmer interviews in 14 case study systems in eight European countries and a great diversity of agroforestry practices that one major problem is that farmers are not aware of the agroforestry term, despite implementing the practice in their own farms. While only few farmers mentioned eligibility for direct payments in the CAP as the main reason to remove trees from their land, to avoid the reduction of the funded area, the tradition in the family or the region, learning from others, and increasing the diversification of products play the most important role in adopting or not agroforestry systems. A more specific questionnaire and meetings was done within the AFINET project (Table 1).

Table 1: Overall summary of the survey results (ponderate mean) of the priority European bottlenecks/challenges (Respondents could give scores ranging from 1 (being not important at all) up to 6 (very important)) from 283 respondents. SP: Spain, BE: Belgium, PT: Portugal, PL: Poland, HU: Hungary, IT: Italy, FR: France, FI: Finland.

	SP	UK	BE	PT	PL	HU	IT	FR	FI	Mean
Improving Policy Support	5.7	5.1	3.8	5.0	5.3	5.6	5.1	4.8	4.9	5.37
Optimal Combinations	5.7	5.6	4.9	6.0	5.2	5.2	5.8	4.5	5.4	5.64
Practical guidelines	5.5	5.6	4.6	5.0	5.2	5.4	5.2	4.9	5.3	5.51
Informing consumers	5.5	4.9	4.5	5.0	5.2	5.4	5.6	4.3	4.6	5.27
Legislative uncertanty	5.4	4.9	4.6	5.0	5.0	5.5	5.1	5.1	4.9	5.27
cost/benefit insights	5.4	5.4	3.9	5.0	5.4	5.1	5.4	4.5	5.1	5.35
demonstration farms	5.3	5.4	4.2	5.0	5.4	5.5	5.6	4.3	5.6	5.44
Value chain	5.2	5.2	3.8	5.0		5.2	5.4	5.2	5.1	4.57

AFINET results from farmers are clear, they have 8 major concerns when thinking of agroforestry promotion in Europe. Technical issues are prevalent from those (optimal combinations, demonstration farms and practical guidelines) followed by improving policy support and legislative uncertainty. The cost benefit insights are also claimed as important and ending with the promotion of the products through the value chain. Differences between countries can also be appreciated in the table. Countries on which agroforestry intensification has been carried out in a smaller way such as Spain, Portugal, Poland, Italy and Hungary (with values above five) scored higher all problems than countries on which intensification was part of the strong modernization for a longer period of time (i.e. Belgium, UK and France with values below 5).

Providing solutions: understanding what agroforestry is

One of the most important problems that agroforestry has to be fostered is the lack of knowledge by the huge majority of European stakeholders of a clear definition of what agroforestry is. The recognition of agroforestry is essential for farmers to move on specific questions such as techniques to be applied but also for policy makers to foster it in a specific way. Agroforestry is defined as a woody perennial (trees and/or shrubs) and an agricultural product always provided by the lower storey and in Europe recognized as part of the Annex 1 of the CAP. Agroforestry is a type of land use that can be applied in all types of land cover such as forest and agriculture (in Europe divided as arable land, permanent grassland and permanent crop) but also urban and peri-urban areas. Common mistakes regarding agroforestry definition is the lack of consideration of agroforestry when shrubs are combined with pasture or arable crops in spite of the agreement of most of the world agroforestry associations (FAO 2015 and ICRAF 2017). Including shrubs as the unique woody component of agroforestry is key to simplify the inventory of agroforestry across Europe and the world due to (i) the lack of an harmonized of a tree definition among countries (for Europe it can be seen in the Annex 5 of the Decision 529/2013/EU) as some of them consider a tree as woody component above 2 meters and others above 5 meters (ii) the consideration of agroforestry of young forest lands (with trees below 2 meters height) (iii) the possibility of a shrub to reach heights over 3 or even 5 meters (iv) the different forms of cropping a tree (short rotation coppice could be below 2 meters and have aspect of a shrub), the possibility of some trees to grow below two meters when adults in some countries or altitudes due to the harsh weather conditions (v) the need of harmonize the agroforestry definition with institutions such as the FAO that provides definitions to international bodies such as United Nations and Intergovernmental Panel of Climate Change that are key for the carbon market balance (vi) the role played by a shrub is similar to that provided by a tree from a productive point of view: at least two products are delivered from the land (i.e. fuel wood, fruits from the woody component and the agricultural crop from the lower storey) and increases crop resilience against climate change and extreme weather events (vii) the role played by a shrub is similar to that provided by a tree from an environment point of view enhancing use of the resources (light, nutrients), increasing biodiversity and improving soils.

Agroforestry definition is also confusing due to the words that are part of its name as it includes “forestry”, but it is extensively accepted including by the FAO (2015) and ICRAF (2017) that any kind of fruit tree can be considered as a woody perennial and therefore when combined with the agricultural product from the lower storey it is also agroforestry, in spite that a fruit tree may be not a timber tree (a good exception is chestnut that has a dual purpose). The main reason for this is that the fruit tree can play the same role than the timber tree from a productive (i.e. fuel wood production) and environment point of view). Moreover, a lot of current forests such as the Black Forest were originated with the aim of providing feed (acorns) to the animals and not timber trees. It is especially relevant to consider fruit trees as the component of agroforestry and always combined with a lower storey agricultural production as permanent crops have no tree density limit to receive Pillar I payments.

Providing solutions: enabling transition environments

Transition towards agroforestry extensively use should be lead by farmers helped by scientists to find technical solutions, by well formed advisors to foster knowledge and by policy makers providing enabling environments to allow farmers to extensively adopt agroforestry practices and systems across the world and therefore Europe. Farmers leadership of the transition should be catalyzed by social and technical experts and multipliers able to understand the main problems that farmers have to overcome agroforestry use barriers. EIP-Agri has indeed understood that agricultural transition towards more sustainable practices should be based in a bottom up approach, but also in the knowledge held by researchers and in the job carried out by advisory and extension services, multipliers and NGOs. On this regard, the EIP-Agri has initially provided three main tools to foster innovations towards a more sustainable agricultural practices and systems: Focus Groups, Thematic Networks and Operational Groups. On this regard agroforestry have had its own European Union focus groups, where the participation of 20% farmers, 20% multipliers, 20% farmers NGOs and 40 %scientists provided insights about the main challenges for agroforestry to be adopted. A set of nine minipapers dealing with technical issues (Practical tree knowledge on farm level, Tools for optimal design and management, Territorial landscape management), financial aspects (Financial impact of agroforestry, Added value of agroforestry), environment (Ecosystem services assessment in agroforestry, Agroforestry as a mitigation and adaptation tool), and education (Education in agroforestry, Databases on agroforestry) were show the global aspects that agroforestry have to fulfill. The second tool of the EIP-Agri dealing with the thematic networks also fosters agroforestry transition as a thematic network named “Agroforestry Innovation Network” with acronym AFINET which is one of the 17 thematic network approved in Europe. AFINET is based on the multiactor approach concept on which 9 RAINs placed in 9 different countries of Europe (Spain, Italy, Poland, Hungary, Portugal, UK, France, Belgium and Finland) have meetings with all needed actors (farmers, multipliers, researchers, policy makers) to understand the main challenges and problems why agroforestry is not extensively used in Mediterranean, Atlantic, Continental and Boreal regions of Europe. Four simple group of problems and challenges where directly highlighted by farmers: technical, economical, communication and dissemination and political as can be seen in Villada et al. (2018). Next steps within the AFINET project will be to develop innovations that allow agroforestry to be better known and fostered across Europe, therefore favoring transition. The third important activity used by EIP-Agri to enhance innovation promotion across Europe is development the operational groups from which those related to agroforestry can be linked to the thematic network and that are currently funded by most of the 118 national and regional Rural Development Network. At international level, and as agroforestry is seen as part of the solution of increasing sustainable land use systems it is part of the agenda of international bodies related with climate change such as the Global Research Alliance and the Global Alliance for a Climate Smart Agriculture.

Providing solutions: EURAF proposals

After a deep evaluation of the current agroforestry situation in the European Union, where it is clearly seen that most agroforestry practices and systems are placed in the South of Europe and that there agroforestry can be used in more than 90% of the European agricultural area (Mosquera-Losada et al. 2016, 2018a, 2018b; Santiago-Freijanes 2018a, 2018b) a set of policy solutions have been provided (Mosquera-Losada et al. 2017). Among them it is important to highlight again the lack of identification of the most of agroforestry practices across the CAP in spite of its promotion. The first recommendation is about simplification: Agroforestry clear recognition across the EU CAP is essential to identify and foster it in an adequate way and in a reduced number of measures. Silvoarable or silvopasture practices including hedgerows are part of the cross-compliance, greening and rural development measures, being money allocated to the same activities in these three sections depending on the country. This indeed makes difficult to evaluate agroforestry promotion in Europe and therefore to construct on previous policies. Another relevant suggestion deals with the promotion of agroforestry in the Pillar I, allocated to agricultural lands as far as at least one agricultural product (Annex 1 of the CAP) is delivered. Moreover, the fully recognition of agroforestry either if established or not under 222 (CAP 2007-2013) and 8.2 measures is essential to promote agroforestry within the greening. Agroforestry could be recognized with a management plan as it is a type of land use that last more than the CAP period. In Pillar II, a clear measure with all agroforestry practices linked to the different types of land use to foster agroforestry at land level. Moreover, aspects related to education, farm agroforestry systems promotion, ecosystem services agroforestry systems recognition, landscape agroforestry promotion and innovation, among others, are also key to promote agroforestry in Europe (Mosquera-Losada et al. 2016). AFINET will keep the job initiated in AGFORWARD helping the European Commission to foster agroforestry in the post 2020 CAP.

Conclusions

Agroforestry is a sustainable land use system that should be fostered. Agroforestry transition should be lead by farmers helped by other key stakeholders. Farmers indicated that better knowledge and policies are needed to facilitate the transition from intensive to ecointensive farming including agroforestry. European Commission through the EIP-Agri has provided a set of excellent tools to foster innovation including agroforestry innovation. Agroforesters of Europe will continue having a European voice thanks to AFINET and EURAF.

Acknowledgements

We are grateful to the European Commission through the AGFORWARD project (FP7-contract 613520) and the AFINET project from the European Union´s H2020 Research and Innovation Programme under grant agreement no 727872. The views and opinions expressed in this article are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

References

FAO (2015) Agroforestry. http://www.fao.org/forestry/agroforestry/80338/en/ (accessed 13/05/2018).

ICRAF (2017) Corporate Strategy 2017-2026. Transforming lives and landscapes with trees. https://www.worldagroforestry.org/sites/default/files/users/admin/Strategy%20Report_2017.pdf (accessed 13/05/2018).

Mosquera-Losada MR, Santiago Freijanes JJ, Pisanelli A, Rois M, Smith J, den Herder M, Moreno G, Malignier N, Mirazo JR, Lamersdorf N, Ferreiro Domínguez N, Balaguer F, Pantera A, Rigueiro-Rodríguez A, Gonzalez-Hernández P, Fernández-Lorenzo JL, Romero-Franco R, Chalmin A, Garcia de Jalon S, Garnett K, Graves A, Burgess PJ (2016) Extent and success of current policy measures to promote agroforestry across Europe. Deliverable 8.23 for EU FP7 Research Project: AGFORWARD 613520. (8 December 2016). http://www.agforward.eu/index.php/en/extent-and-success-of-current-policy-measures-to-promote-agroforestry-across-europe.html (accessed 13/05/2018).

Mosquera-Losada, MR, Santiago Freijanes JJ, Pisanelli A, Rois M, Smith J, den Herder M, Moreno G, Lamersdorf N, Ferreiro-Domínguez N, Balaguer F, Pantera A, Papanastasis V, Rigueiro-Rodríguez A, Aldrey JA, González-Hernández P, Fernández-Lorenzo JL, Romero-Franco R, Lampkin N, Burgess PJ (2017). Deliverable 8.24: How can policy support the appropriate development and uptake of agroforestry in Europe? 7 September 2017. https://www.agforward.eu/index.php/es/how-can-policy-support-the-uptake-of-agroforestry-in-europe.html (accessed 13/05/2018).

Mosquera-Losada MR, Santiago-Freijanes JJ, Pisanelli A, Rois M, Smith J, den Herder M, Moreno G, Ferreiro-Domínguez N, Malignier N, Lamersdorf N, Balaguer F, Pantera A, Rigueiro-Rodríguez A, Aldrey JA, Gonzalez-Hernández P, Fernández-Lorenzo JL, Romero-Franco R, Burgess PJ (2018a) Agroforestry in the European Common Agricultural Policy. Agroforestry systems (in press)

Mosquera-Losada MR, Santiago-Freijanes JJ, Rois M, Moreno G, den Herder M, Aldrey JA, Ferreiro-Domínguez M, Pantera A, Pisanelli A, Rigueiro-Rodríguez A (2018b) Agroforestry in Europe: a land management policy tool to combat climate change. Land Use Policy (in press).

Rois-Diaz M, Lovric N, Lovric M, Ferreiro-Dominguez Nuria, Mosquera-Losada MR, den Herder, Graves A; Palma J, Paulo J, Pisanelli A, Smith J, Moreno G, Garcia S, Varga A, Pantera, A, Mirck J, Burgess P (2017) Farmers' reasoning behind the uptake of agroforestry practices: evidence from multiple case-studies across Europe. Agroforest Syst. https://doi.org/10.1007/s10457-017-0139-9.

Santiago-Freijanes JJ, Pisanelli A, Rois-Díaz M, Aldrey-Vázquez JA, Rigueiro-Rodrígueza A, Pantera A, Vity A, Lojkag B, Ferreiro-Domínguez N, Mosquera-Losada MR (2018a) Agroforestry development in Europe: Policy issues. Land Use Policy 76: 144–156.

Santiago-Freijanes JJ, Mosquera-Losada MR, Rois-Díaz M, Ferreiro-Domínguez N, Pantera A, Aldrey JA, Rigueiro-Rodríguez A (2018b) Global and European policies to foster agricultural sustainability: agroforestry. Agroforest Syst. https://doi.org/10.1007/s10457-018-0215-9.

Villada A, Verdonckt P, Ferreiro-Domínguez N, Rodríguez-Rigueiro FJ, Arias-Martínez D, Rois-Díaz M, den Herder M, Paris P, Pisanelli A, Reubens B, Nelissen V, Paulo JA, Palma JHN, Vityi A, Szigeti N, Borek R, Galczynska M, Balaguer F, Smith J, Westaway S, Rigueiro-Rodríguez A, Mosquera-Losada MR (2018) AFINET: Agroforestry Innovation Thematic Network IV EURAF Conference (this volume).

RECENT ADVANCES IN AGROFORESTRY: SUPPORTING THE TRANSITION FROM CONVENTIONAL TO CLIMATE-RESILIENT FARMING

Nair PKR[1*]

(1) University of Florida, Gainesville, FL, USA

*Corresponding author: pknair@ufl.edu

Abstract

The significant advances made in agroforestry (AF) during the past four decades make it a prominent strategy for sustainable, Climate Resilient Farming (CRF). Although Europe ranks low in the area under AF (an estimated 20 million ha vs. 1.6 billion ha globally), there has been an emergence (or, re-emergence) of enthusiasm in AF across the continent during the past two decades. In the context of research support for AF as a strategy for CRF, the most prominent areas are carbon (C) sequestration, especially Soil C Sequestration (SCS), and related ecosystem services. Scientific support is crucial for the success of any significant development agenda; it seems doubtful, however, if the science of these crucial ecosystem processes is adequately understood. Learning from the experience of some setbacks that occurred while pushing ambitious AF development agenda in the tropics, it is critical that AF development programs in Europe are backstopped by high-quality research.

Keywords: biodiversity; ecosystem services; meta-analysis; research-based knowledge; soil carbon sequestration

Agroforestry: Increasing Enthusiasm in Europe

After agroforestry debuted on the global land-use scene four decades ago, it used to be characterized for quite some time as “a new name for an old set of practices.” While some historians argue that agroforestry (AF) is as old as agriculture, others quote more recent initiatives and publications to have provided the foundations upon which “modern” agroforestry was built up. No matter when, where, and how agroforestry originated, there is a consensus that the seeds of “modern” agroforestry were sown in 1977 by the international effort that led to the establishment of ICRAF, now the World Agroforestry Centre (www.icraf.cgiar.org). Today, AF is prominently mentioned in most of the common development paradigms and rallying themes. To quote from Nair et al. (2017), these include, in alphabetical order: agroecology, carbon farming, climate-smart agriculture, conservation agriculture, ecoagriculture, evergreen agriculture, multifunctional agriculture, organic agriculture, permaculture, regenerative agriculture, sustainable agriculture, sustainable intensification, and so on. Almost all of them aim at building on the efficient use of locally available resources and integrating different components of the overall production system. Agroforestry systems (AFS) including tree cover on agricultural land are estimated to be practiced over one billion ha of land in the tropics (Zomer et al. 2009), and 1.6 billion ha globally (Nair 2012). Zomer et al. (2016) estimated that the area of agricultural land with at least 10% tree cover – currently 43% of all agricultural land – had increased by 2% over the past 10 years globally.

Europe, in particular, has witnessed a remarkable emergence (or, re-emergence) of enthusiasm in AF during the past two decades; the area under AF in Europe is currently estimated at about 20 million ha (Mosquera-Losada et al. 2012; AGFORWARD 2017). A December 2017 report “*Agroforestry: introducing woody vegetation into specialised crop and livestock systems*” by the EDI-AGRI Focus Group consisting of 20 experts from 15 EU countries noted the growing interest in developing modern, viable agroforestry systems within the EU, and placed emphasis on five examples of AFS that needed pointed attention: the sheep orchard, steep diverse production, chickens under the willows, shaping the landscape, and differentiation in the flatlands.

Climate Resilient Farming

In the scenario of heightened enthusiasm in agroforestry systems (AFS) in Europe (and elsewhere), it is quite appropriate that this conference theme is "Transition from Conventional to Climate Resilient Farming" (CRF). But, what exactly is CRF?

Like sustainability, climate resilience is a much-abused or differently interpreted word and is often understood more by intuition than definition. It is generally understood as the capacity for a socio-ecological system to: (1) absorb stresses and maintain function in the face of external stresses imposed by climate change and (2) adapt, reorganize, and evolve into more desirable configurations that improve the sustainability of the system, leaving it better prepared for future climate change impacts (Folke 2006; Nelson et al. 2007). As far as the importance of AF as a strategy for CRF and the research in support of that are concerned, the prominent ones are those related to carbon (C), especially Soil C Sequestration (SCS) and other ecosystem services. Indeed, there has been an increasing volume of press and media coverage on the importance of soil health (and C sequestration) vis à vis agroforestry and tree-based farming systems as opportunities for climate-change mitigation and CRF; for example, "*Soil Power! The Dirty Way to a Green Planet*" https://www.nytimes.com/2017/12/02/opinion/sunday/soil-power-the-dirty-way-to-a-green-planet.html New York Times, 02 Dec 2017;

"Can Dirt Save the Earth?" https://mobile.nytimes.com/2018/04/18/magazine/dirt-save-earth-carbon-farming-climate-change.html New York Times, 18 April 2018.

Soil Carbon Sequestration

The fundamental premise is that AFS have a higher potential to sequester C because of their perceived ability for greater capture and utilization of growth resources (light, nutrients, and water) than in single-species crop- or pasture systems. AFS offer greater opportunities than monocultural (single-component) agricultural systems for capture and storage of atmospheric CO_2 in biomass and soils. This has been attributed to several reasons including efficient C (and nutrient) cycling within the soil–plant system, increased return of biomass C to soil, decreased biomass decomposition and soil organic matter (SOM) destabilization in the tropics, and sequestration of soil C in deeper layers of soil (Montagnini and Nair 2004; Nair 2012; Saha et al. 2010)

Although several studies on C sequestration under AFS are reported in the literature, they are highly variable in the study procedures as well as the nature of systems and locations. This makes it difficult to extrapolate the results to broader contexts of systems and locations outside the specific locations of the individual studies. One way of addressing this problem is to undertake a meta-analysis, a statistical procedure for comparing and synthesizing result from different studies for finding common patterns, discrepancies, or other interesting relationships that may not be detectable from individual studies (Borenstein et al. 2009). In a recent meta-analysis that we undertook (Chatterjee et al. unpublished), data were synthesized from 78 peer-reviewed studies that generated 858 data points on SOC stock under various AFS from 25 countries in Asia, Africa, Europe, North America and South America. The data points were used to assess the variations in SOC stocks under AFS in comparison with Agriculture, Forestry, Pasture or Uncultivated Land, in four soil-depth classes (0–20, 0–40, 0–60, and 0–100 cm) in four major agroecological regions (arid and semiarid, ASA; lowland humid tropics, LHT; Mediterranean, MED; and temperate, TEM) around the world. Comparing AFS vs. Agriculture or AFS vs. Pasture, SOC stocks under AFS were higher by +27% in the ASA region, +26% in LHT, and +5.8% in TEM, but –5.3% in the TEM in the 0–100 cm soil depth. Improvement of SOC stocks under AFS varied across agroecological regions, the highest being under lowland humid tropics. Additionally, older agroforests contributed to higher SOC stocks than newly established systems. The results indicated a general pattern of Forest – Agroforest – Agriculture – Pasture continuum in SOC stock decline during land-use changes in all ecological regions.

Biodiversity

Biodiversity is being recognized as one of the best defenses against climate change; protecting it is important for keeping the ecosystems working for us and providing food as well as environmental services (Duffy et al. 2017). The inherently high level of biodiversity of multispecies systems offers several possibilities for arrangement of various tree/shrub/and grass components according to the needs and preferences of farmers. Based on an extensive study in Bangladesh, where the ubiquitous homegardens cover more than 12% of the land area, Webb and Kabir (2009) reported that homegardens provided majority of tree-dominated habitats across the country and therefore represented the only real opportunity to conserve plant and wildlife populations outside of the beleaguered protected-area system. It remains unclear, however, whether few or many of the species in an ecosystem are needed to sustain the provisioning of ecosystem services. Isbell et al. (2011) showed, based on a study of 17 biodiversity experiments, that although species diversity may appear functionally redundant for one set of environmental conditions, many species are needed to maintain multiple functions at multiple times and places in a changing world.

Yet another issue that is being discussed currently is the “C sequestration – Biodiversity connection.” Although there is a prevailing pre-conceived notion about positive correlation between C sequestration and species diversity, the relationship between tree C stock and species diversity is not always significant (Richards and Mendez 2014). The existing literature on this relationship is also rather nebulous: both positive and no relationships have been reported. Nevertheless, IPBES (Intergovernmental Science-policy Platform on Biodiversity and Ecosystem Services) has recently (March 2018) recognized AF as a biodiversity-promoting activity (https://goo.gl/oJ4DRq).

Research Directions in Agroforestry

Computer modeling and large-scale global estimations are two rapidly progressing procedures in climate change research. Applications of such techniques in agroforestry have, however, been rather limited, which could be a cause or effect of the lack of unanimity of views on the extent to which significant gains can be expected in the immediate future from such efforts in agroforestry. Most of the seemingly reliable crop models are limited to single-species systems where the interaction between plants are restricted to resource utilization among same species (Steduto et al. 2009). The complex nature of arrangement of species within agroforestry systems and the unevenness of plant types and growth habits between different components of AFS (trees, shrubs, herbaceous crops, etc.) hinder progress in their modeling (Luedeling et al. 2014; Bayala et al. 2015). Research-based knowledge on the specific management for each component while grown in combination with other species, and the scope for development of varieties are two important management-related research priorities; these are equally challenging to both modelers and field-oriented researchers (Nair 2017).

The increasing importance being given to largescale computer models and predictions is also noteworthy. Numerous global and country- and regional estimates are available on the potential and magnitude of various ecosystem services; for example, global estimations and predictions on C sequestration (Costanza et al. 2014; Paustian et al. 2016; Kubiszewski et al. 2017). Given the extremely site-specific nature of AFS, studies at the field level should be the starting points for valuing the benefits of their ecosystem services. Furthermore, outputs from AFS are expressions of interactions involving not only easily measurable biophysical factors but also difficult-to-quantify sociocultural factors.

Concluding Comments

Growing enthusiasm in AF is indeed a very welcome trend. We need to be cautious and conscientious, however, about our ability to fulfill the high expectations that are being raised about providing the numerous goods and services. Experience from tropical AF development could be an eye-opener in this context. Enormous levels of enthusiasm and expectations were built up when AF was heralded in the 1980s and 1990s almost as a panacea for land management problems of the tropics, and substantial human and financial resources were expended in fulfilling those aspirations. Soon AF was perceived as an oversold commodity, and it became clear that many land-management advances, especially in the social-political milieu of the tropics, were unrealistic, pie-in-the sky type of illusions. The reality sank in soon after, that the root cause of those setbacks was that the science of AF had not been understood adequately, and consequentially the scientific foundations upon which the euphoria was built up were not strong enough to support the expected quantum leap. We are caught up in a real dilemma: development efforts cannot wait until all the science has been figured out, but if past results are any indication, development efforts involving huge financial outlays and public-relation showcases that are not based on solid principles and foundations are unlikely to be successful.

References

AGFORWARD (2017) Extent and success of current policy measures to promote agroforestry across Europe. Work package 8: Agroforestry policy development. www.agforward.eu (accessed 20/04/2018).

Bayala J, Sanou J, Teklehaimanot Z, Sinclair F. (2015). Adaptation of crops to partial shade in mixed cropping systems. In: Black C, Wilson J, Ong CK (eds) Tree- crop interactions: Agroforestry in a changing climate. CABI, Wallingford, UK, pp. 309–325.

Borenstein M, Hedges L, Rothstein H (2009) Introduction to Meta-Analysis. In Introduction to Meta-Analysis. John Wiley, Chichester, UK.

Costanza R, de Groot R, Sutton PC, van der Ploeg S, Anderson S, Kubiszewski I, Farber S, Turner RK (2014) Changes in the global value of ecosystem services. Global Environ Chang 26: 152–158.

Duffy JE, Godwin CM, Cardinale BJ (2017) Biodiversity effects in the wild are common and as strong as key drivers of productivity. Nature 549: 261-264.

Folke C (2006) Resilience: The emergence of a perspective for social-ecological systems analyses. Global Environ Chang 16: 253–267.

Isbell F, Calcagno V, Hector A, Connolly J, Harpole, WS, Reich PB, Scherer-Lorenzen M, Schmid B, Tilman D, van Ruijven J, Weigelt A, Wilsey BJ, Zavaleta ES, Loreau M (2011) High plant diversity is needed to maintain ecosystem services**.** Nature 477: 199–202.

Kubiszewski I, Costanza R, Anderson S, Sutton P (2017) The future value of ecosystem services: Global scenarios and national implications. Ecosyst Serv 26: 289–301.

Luedeling E, Huth NI, Kindt R, König K (2014) Agroforestry systems in a changing cli- mate – challenges in projecting future performance. Curr Opin Env Sust 6: 1–7.

Montagnini F, Nair PKR (2004) Carbon sequestration: An underexploited environmental benefit of agroforestry systems. Agroforest Syst 61–62: 281–295.

Mosquera-Losada MR, Moreno G, Pardini A., McAdam JH, Papanastasis V, Burgess PJ, Lamersdorf N, Castro M, Liagre F, Rigueiro-Rodríguez A (2012) Past, present, and future of agroforestry in Europe. In: Nair PKR, Garrity DP (eds) Agroforestry: The Future of Global Land Use. Springer, Dordrecht, The Netherlands, pp. 285–312.

Nair PKR (2012) Climate change mitigation and adaptation: A low hanging fruit of agroforestry. In: Nair PKR, Garrity D P (eds) Agroforestry: The future of global land use. Dordrecht, The Netherlands, Springer, pp 31–67.

Nair PKR (2017) Managed multi-strata Tree + Crop Systems: An agroecological marvel. Front Environ Sci 5: 1–5.

Nair VD, Nair PKR, Dari B, Freitas AM, Chatterjee N, Pinheiro F (2017) Biochar in the agroecosystem – Climate-change – Sustainability nexus. Perspective. Frontiers in Plant Science, December 2017, Volume 8, Article 2051. https://www.frontiersin.org/journals/plant-science. Doi: 10.3389/fpls.2017.02051

Nelson DR, Adger WN, Brown K (2007) Adaptation to Environmental Change: Contributions of a Resilience Framework (PDF). Annu Rev Env Resour 32: 395–419.

Paustian K, Lehmann J, Ogle S, Reay D, Robertson GP, Smith P (2016) Climate-smart soils. Nature 532: 49–57.

Richards MB, Mendez VE (2014) Interactions between carbon sequestration and shade tree diversity in a smallholder coffee cooperative in El Salvador. Conserv Biol 28: 489–497.

Saha SK, Nair PKR, Nair VD, Kumar BM (2010) Carbon storage in relation to soil size-fractions under tropical tree-based land-use systems. Plant Soil 328: 433–446.

Steduto P, Hsiao TC, Raes D, Fereres E. (2009). Aquacrop-the FAO crop model to simulate yield response to water: I. concepts and underlying principles. Agron J 101: 426–437.

Webb EL, Kabir ME (2009) Home gardening for tropical biodiversity conservation. Conserv Biol 23: 1641-1644.

Zomer R J, Trabucco A, Coe R, Place F (2009) Trees on farm: analysis of global extent and geographical patterns of agroforestry. ICRAF Working Paper No. 89, (World Agroforestry Centre (ICRAF), 2009). http://www.worldagroforestry.org/downloads/Publications/PDFs/WP16263.PDF (accessed 08/05/2018).

Zomer RJ, Neufeldt H, Xu J. Ahrends A, Bossio D, Trabucco A., van Noordwijk M, Wang M (2016) Global tree cover and biomass carbon on agricultural land: The contribution of agroforestry to global and national carbon budgets. Sci Rep 6: 29987 (www.nature.com/scientific reports)

CURRENT AND FUTURE COMMON AGRICULTURAL POLICY

Hodosi R[1*], Szedlak T[1]

(1) Directorate General of Agriculture and Rural Development. European Commission. Brussels, Belgium

*Corresponding author: Robert.HODOSI@ec.europa.eu

Abstract

The Common Agricultural Policy (CAP) is one of the most important policies funded by the European Union. The European Union has promoted agroforestry in both the previous (2007-2013) and the current (2014-2020) budgetary period. This paper reflects on the evolution of this measure over the time, and provides some insights on lessons learnt.

Keywords: agroforestry; CAP; rural development programmes; Omnibus regulation

CAP 2007-2013

Agroforestry was introduced for the first time as a “new” topic supported by the CAP 2007-2013 and it formed part of the forestry measures, labelled as “Measure 222: First establishment of agroforestry systems on agricultural land”. Measure 222 was programmed in 19 Rural Development Programmes (RDPs). However, in 8 RDPs this measure was eventually not applied. Reported Expenses of the European Agricultural Fund for Rural Development (EAFRD) amounted by the end of 2015 to 1.5 million € of EAFRD resource and 2.1 million euro of total public expenditure which includes Member State contributions. The measure supported 275 beneficiaries, establishing 2904 ha of new agroforestry systems.

CAP 2014-2020

Based on the experience from the preceding programming period, the legal framework for Rural Development, laid down in Regulation (EU) 1305/2013, includes a revised agroforestry measure. Amendments introduced by Regulation (EU) 2017/2393, the so-called Omnibus regulation, provided for the possibility to support the regeneration or renovation of existing agroforestry systems under the title “Measure 8.2 Establishment, regeneration or renovation of agroforestry systems”, covering:

a) the costs of establishment, regeneration and/or renovation 80%

b) the annual premium per hectare to cover the costs of maintenance for a maximum period of 5 years.

In the context of rural development, the following definition applies: "Agroforestry systems" means land use systems in which trees are grown in combination with agriculture on the same land, that has been expanded in the sub-measure fiche (EU 2014) describing Measure 8.2 (as a deployment of the Regulation 1305/2013) on the establishment of agroforestry, as “*land-use systems and practices where woody perennials are deliberately integrated with crops and/or animals on the same parcel of land management unit without the intention to establish a remaining forest stand. The trees may be arranged as single stems, in rows or in groups, while grazing may also take place inside parcels (silvoarable agroforestry, silvopastoralism, grazed or intercropped orchards) or on the limits between parcels (hedges, tree lines)*”.

The minimum and maximum number of trees per hectare shall be determined by Member States, taking into account local pedo-climatic and environmental conditions, forestry species, and the need to ensure sustainable agricultural use of the land.

After 2 years of implementation of RDPs, there is no information by Management Authorities as regards the implementation of the measure. However, considering the current state of programming, including more recent RDP amendments, we can state that 34 RDPs from 8 MS foresee the establishment of altogether 71 thousand hectares of new agroforestry systems, requiring a support amount of 120 € million of total public expenditure.

Post 2020 CAP

The Communication "Future of Food and Farming" (EU 2017), issued by the European Commission in November 2017, provides orientations for the CAP post-2020. The Communication underlines the need for giving more flexibility and responsibility to Member States as regards the design of their CAP support schemes, laid down in national CAP Strategic Plans. The EU will establish the common EU objectives to be pursued by all national CAP Strategic Plans in order to ensure “common” achievements of this common policy. The EU objectives address, among other, the contributions of agriculture to climate change mitigation and adaptation, improving resource efficiency, and increasing competitiveness of EU agriculture. The EU will also define only broad types of interventions which are to be fine-tuned by Member States according to their needs.

References

EU (2014) Regulation (EU) Nº 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) Nº1698/2005. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013R1305. (accessed 15/05/2018).

EU (2017) Future of food and farming communication. https://ec.europa.eu/agriculture/sites/agriculture/files/future-of-cap/future_of_food_and_farming_communication_en.pdf (accessed 15/05/2018).

Session

Factors of success and failure in the transition into agroforestry

SUSTAINABLE LAND RESOURCE MANAGEMENT WITH AGROFORESTRY: EMPIRICAL EVIDENCE FROM THE SUNYANI WEST DISTRICT OF GHANA, WEST AFRICA

Ashiagbor G[1], Oduro W[1], Thevathasan N[2*], Gordon A[2], Gray R[3], Hambly Odame H[4]

(1) Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, University Post Office, PMB, Kumasi, Ghana (2) School of Environmental Sciences, University of Guelph, Guelph, Ontario, Canada N1G 2W1 (3) School of Environment and Natural Resource Sciences, Fleming College, 200 Albert St S, Lindsay, ON, Canada K9V 5E6 (4) School of Environmental Design and Rural Development, University of Guelph, Guelph, Ontario, Canada N1G 2W1

*Corresponding author: nthevath@uoguelph.ca

Abstract

The concept of enhancing economic assets on community farms in order to maintain Sustainable Land Resource Management via the adoption of agroforestry land-use systems has not been tested widely in the Sub-Saharan African Countries. The end line survey revealed that households practicing various agroforestry technologies (AT) increased from 53.4% in 2007 to 155% in 2013. Top four AT that were adopted by the communities are farmland planting, livestock rearing, household plantings and fruit tree production. Results also suggested that a number of socio-economic factors such as age, primary occupation, skill training, material support / incentives, membership to livelihood groups, number of farmlands and access to extension services all significantly influenced the adoption of AT. The land-use land cove change map within the project catchment indicated that in the coming years there could be an increase in food availability, accessibility and utilization; the three pillars of food security.

Keywords: agroforestry technologies, land-use change, food security, Ghana, Sub-Saharan Africa

Introduction

Agroforestry is a recognized strategy for addressing sustainable management and development of the natural-resource base of rural communities. Agroforestry systems may be defined as land-use systems in which woody perennials (trees, shrubs, palms, and bamboos) are deliberately used on the same land management unit as agricultural crops (woody or annual), animals or both, in some form of spatial arrangement or temporal sequence (Huxley and Van Houten 1997). Agroforestry is considered a sustainable development model throughout the world due to benefits they bring not only to the economy and society but also to the ecosystem (Thanh et al. 2005).

However, the concept of enhancing potential economic value or assets on community farms in order to maintain Sustainable Land Resource Management (SLRM) via the adoption of agroforestry land-use systems has not been tested widely in the Sub-Saharan African Countries (SSA). Environmental goals alone do not result in sustainable land-use adoptions in SSA countries unless sustainable land-use systems also provide economic returns or build assets in the respective small-holder farms. In this context, in 2007, a Canadian government funded project entitled, “Agroforestry Practices to Enhance Resource-poor Livelihoods (APERL)” led to the introduction of various agroforestry technologies in six communities of Sunyani West in the Brong Ahafo Region of Ghana in furtherance of Ghana’s Growth and Poverty Reduction Strategy. The adoption of agroforestry practices were expected to reduce land degradation and reduce forest fire susceptibility in the six farming communities (Kwamekrakrom, Adoe, Ayakomaso, Mantukwa, Dumasua and Fiapre), while enhancing property assets in the respective small-holder farms. No studies have been carried out to-date to verify this hypothesis. In this abstract, we discuss how evidence from the communities support agroforestry land-use as a viable technology to achieving SLRM. In order to achieve the above, we (1) assessed farmers' awareness and adoption of agroforestry; and (2) related adoption of agroforestry to reduced forest degradation and forest fire susceptibility in the six APERL implementation sites.

Materials and methods

The selection of study sites

The six selected communities fall within the dry semi-deciduous forest zone of Ghana. With a bimodal rainfall pattern (ranging between 1000 mm – 1500 mm), the area also experiences a short dry season in August and the mean annual temperature and humidity are about 24 ^{o}C and 68%, respectively.

GIS analysis and socio-economic surveys

In order to assess land cover change, the following steps were executed: 1. use of GIS and remote sensing technologies to identify areas / communities of forest degradation and forest fire risk, 2. introduction of various agroforestry technologies to communities, 3. final assessment of change in forest cover and forest fire susceptibility using GIS and remote sensing technologies. A baseline socio-economic survey using questionnaires and focus group discussions was conducted in 2008 in the selected communities. In 2013, a final socio-economic survey was conducted using a sample size of 1475 households (one respondent per household; 1475 households) with questions consistent with the initial baseline survey to determine the overall impact of the introduced agroforestry technologies. The survey assessed the awareness and adoption potential of the introduced agroforestry technologies among farmers in the project catchment area. Satellite Images of 2013 were also acquired and classified using the same classification scheme developed for the baseline Land-use Land Cover (LULC) map (Figure 1). Post-classification analysis method of change detection was used to determine changes in LULC classes. Land cover change was detected as a change in land cover between the two image dates based on the independent true land cover classification, which was achieved by supervised classification.

The Statistical Package for Social Sciences (SPSS) was used to analyze data and to generate the relevant information that could best describe the socio-economic profile and other characteristics of the communities.

Results and discussion

Two criteria, "able to remember" and "describe the technology", were used to assess farmers' awareness of agroforestry. A farmer was therefore regarded as being aware of an agroforestry technology when they were at least able to remember the technology and describe it. Farmers' awareness of introduced agroforestry technologies in the study area increased from 26% to 90% by the close of the project in 2013 with about 76% practicing the technologies. Households were classified to have adopted the agroforestry technologies if they were practicing any of the introduced technologies: boundary planting; planting N-fixing species in fields; fruit tree production; woodlot; taungya; alley cropping; alley farming; proka (slashing without burning); biomass transfer (fodder); household planting; farmland planting and livestock keeping. The end line survey revealed that households practicing various agroforestry technologies increased from 53.4% in 2007 to 155% in 2013 (Table 1). Top four agroforestry technologies that were adopted by the communities are farmland planting, livestock rearing, household plantings and fruit tree production (Table 1).

Table 1: Households practicing various agroforestry technologies, Sunyani west district, Ghana.

AF Technologies	Number of households (N = 1475)			
	Before APERL	Percentage	After APERL	Percentage
Boundary planting	41	2.8	124	8.4
Planting N-fixing species in fields	25	1.7	93	6.3
Fruit tree production	20	1.4	129	8.7
Woodlot	10	0.7	48	3.3
Taungya	21	1.4	54	3.7
Alley Cropping	84	5.7	108	7.3
Alley Farming	64	4.3	93	6.3
Proka	41	2.8	52	3.5
Biomass transfer	6	0.4	15	1.0
Household planting	34	2.3	316	21.4
Farmland planting	317	21.5	785	53.2
Livestock rearing	125	8.5	469	31.8

Adoption of the agroforestry technologies was measured against the following parameters: awareness of the technologies, age, sex (gender), educational level, social status, primary occupation, availability of market, membership to livelihood groups created by the project and number of farmlands. Tested parameters such as age, membership in local livelihood groups, skill training, material support, number of arable farmlands, size of farmland, main occupation that contributed to household income and access to agricultural extension services had significant effects on the likelihood of adoption of introduced agroforestry technologies (Table 2).

Table 2. Factors influncing the adoption of technologies, Sunyani west district, Ghana.

Factors of adoption	Chi^2	df	P value	Phi/Cramer's V
Age	21.974	9	0.009*	0.122
Sex	0.06	1	0.806	-0.008
Educational Level	14.439	8	0.071	0.099
Place of Origin	3.564	4	0.468	0.05
Awareness of AF Technologies	0.002	1	0.962	0.003
Ready Market	0.547	1	0.460	-0.022
Membership to Livelihood group	232.294	1	0.000*	0.413
Skill Training	10.442	1	0.001*	0.086
Material Support/Inputs	298.226	1	0.000*	0.479
Female Headed Household	1.436	1	0.231	0.034
Primary Occupation	63.627	8	0.000*	0.330
Number of farmlands	12.043	4	0.017*	0.791
Land Tenure Arrangement	9.015	8	0.341	0.084
Size of farmland	11.564	5	0.041*	0.077
Access to Agricultural Extension Services	23.89	4	0.000*	0.145

*means significant at $p \leq 0.05$

Local livelihood groups served as the main source of information and thereby increased awareness of the introduced agroforestry technologies. Community livelihood groups also offered effective communication channels on the long term benefits of agroforestry technologies. Among the households tested (n =1475), 70.8% belonged to livelihood groups and were practicing agroforestry technologies. This is in agreement with Parwada et al. (2010) who reported that the likelihood to adopt agroforestry technologies is influenced by the membership in a livelihood group as these groups serve as source of information on introduced agroforestry technologies.

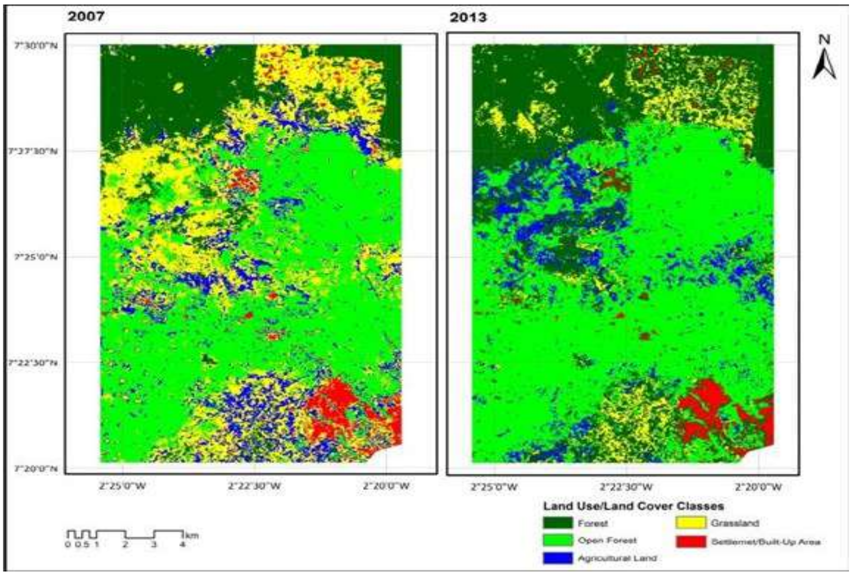


Figure 1: Classification of LULC map in 2007 before the APERL project interventions and a LULC map in 2013, after the project interventions.

The land use land cover classification for 2007 from MSS satellite image showed that majority of the study area was under open Forest and Grassland, accounting for 7861.41 ha (41.21%) and 5047.47 ha (26.49%), respectively. Closed Forest, Agricultural land and Built-up area amounted to about 3375.54 ha (17.71%), 2195.46 ha (11.52%) and 575.78 ha (3.02%), respectively. The land use land cover classification for 2013 from TM satellite image showed open Forest, closed Forest and Agricultural land accounting for 8037.96 ha (42.18%), 4202.22 ha (22.05%) and 4224.9 ha (22.17%), respectively, while Grass land and Built-up area amounted to about 1819.99 ha (9.55%) and 770.59 ha (4.04%), respectively. The slight improvement in forest cover may be due to the significant reduction ($p<0.05$) in forest fire within the project catchment from 40 forest fire occurrences per year in 2007 to one in 2013. The second possible reason for the increase in forest cover is the increase in adoption of the introduced agroforestry technologies thereby contributing to enhanced environmental sustainability. Many studies around the world have shown enhanced environmental sustainability through the adoption of agroforestry technologies. For example, FAO in 2013 recommended that all Sub-Saharan African Countries (SSAC) should incorporate agroforestry land-use into their national agricultural policy in order to derive food and income securities and environmental stability in the respective SSACs. According to Hoekstra (1983), the adoption of agroforestry has the potential to halt land degradation, improve soil fertility and solve fodder problems among smallholder farmers. Adoption of agroforestry provides an alternative means of addressing land degradation since it offers opportunities for improving the quality of life of resource poor farmers, from products derived from these systems, while ensuring the sustainability of the natural resources base and the environment (Parwada et al. 2010).

Conclusion

Results from this study demonstrate that a number of socio-economic factors that hinder wider adoption of agroforestry land-use among smallholder farmers need to be addressed appropriately. To induce adoption among farming households, there is the need to use existing community livelihood groups or form active livelihood groups for each agroforestry initiative and also enhance networking amidst these groups. From the trend and dynamics of LULC change within the project catchment, it is obvious that in the coming years we will see a substantial increase in food availability, accessibility and utilization; the three pillars of food security.

References

FAO (2013) Advancing Agroforestry on the Policy Agenda: A guide for decision-makers, by Buttoud G. in collaboration with Ajayi O, Detlefsen G, Place F and Torquebiau E. Agroforestry Working Paper no. 1. Food and Agriculture Organization of the United Nations. FAO, Rome.

Hoekstra D (1983) The Use of Economics in Agroforestry, Working Paper No. 2, ICRAF, Nairobi.

Huxley P, Van Houten H (1997) Glossary for Agroforestry. Nairobi, Kenya: International Centre for Research in Agroforestry (ICRAF).

Parwada C, Gadzirayi CT, Muriritirwa WT, Mwenye D (2010) Adoption of agro-forestry technologies among small holder farmers: A case of Zimbabwe. J Dev Agric Econ 2: 351-358.

Thanh MV, Thao VT, Huong PM, Lan PT, Phuong LT, Anh TN (2005) Factors influencing farmers' adoption of agroforestry models. Center for Agricultural Research and Ecological Studies, Hanoi Agricultural University.

TREES TO AVOID OR TREES TO SUPPORT THE USE OF FERTILIZERS ON CROPS?

Breman H[1]*

(1) AgroBioAfrica. Terwolde, The Netherlands

*Corresponding author: henkbreman@gmail.com

Abstract

Agroforestry is often promoted as a production system for which fertilizer use can be avoided. Indeed, a limited number of systems exist where the presence of trees in the field increases crop production, without the use of fertilizers. In general, however, the presence of trees among crops causes a reduction in crop production (30% lower on average). This paper presents a system developed in Africa, in which trees improve crop production thanks to improvement of the fertilizer use efficiency. For farmers in sub-Saharan Africa, interested in agroforestry for producing staples, trees supporting the use of fertilizers should be promoted. It is also a cheap alternative for otherwise very expensive erosion control investments.

Keywords: agroforestry; competition; fertilizer use efficiency; cost; benefit

Agroforestry, too often wishful thinking

Agroforestry is mainly promoted and introduced in sub-Saharan Africa by foreign organizations. The promise is higher and more sustainable crop production without the otherwise required (increased) use of chemical fertilizers. The author wonders if examples exist where farmers continue using the promoted approach after the end of the supporting projects.

The presence of trees in cropland leads, indeed, to a higher total phytomass production. But in-depth knowledge and experience as well as extra labor is required for using trees to increase crop production. On average, cereal crops produce about 30% less in agroforestry systems than on comparable fields without trees. The indirect positive effect of trees is usually lower than the direct negative effect of competition with crops for nutrients, water, and light. Size and form of trees enable them to intercept more light. They use part of the light otherwise absorbed by the crops.

Even more than the use of wood for heating and construction, it is the dominance of trees over crops as competitor for light, nutrients and water that is at the basis of the disappearance of trees under influence of population growth. Too often, this aspect is entirely neglected when promoting agroforestry. This is a serious error. Cases where trees have a positive effect on crop production include:

- Crops and trees that grow and develop at least partially in different seasons. For example in case of the *Faidherbia albida* production system in sub-Saharan Africa and the production of winter wheat in agroforestry systems in France.
- The use of trees as windbreaks, where trees do not stimulate crop growth like in the cases above, but where without trees crop production is difficult or impossible.

In the rich Western world, particular forms of agroforestry receive increasingly attention today: permaculture and food-forests. In their promotion and in describing their potential, the bottleneck of competition is neglected (Shepard 2013). I encountered a case where at least the economics are positive, but not thanks to tree supported crop growth but thanks to the choice of expensive nuts and berries, serving a niche market for the rich.

For the ideals that are formulated in promoting permaculture and food-forests, e.g. sustainable food production, carbon sequestration, and erosion control, niche markets are of limited interests. Agroforestry for the sake of more productive and more sustainable staples is required for large scale benefit. It is also this type of agriculture that serves food security in sub-Saharan Africa.

This paper describes such a system by presenting its history, a system that is not hindered by the bottleneck that the competition power of trees bypasses their positive influence on crop production. It does so thanks to improvement of the fertilizer use efficiency through the presence of trees.

Woody plants in agro-ecosystems of semi-arid regions

In “woody plants in agro-ecosystems of semi-arid regions”, Breman and Kessler (1995) analyze the interaction between trees and the surrounding vegetation, crops included, using the Sahel as illustration. Focusing on nutrients, water, and light, they show which tree properties through which processes cause a higher accessibility of nutrients and water than in case of herbaceous plant species alone, and they quantify the contribution of each of the processes with soil and climate as main variables. This knowledge is used to understand in which ways trees can contribute to an increased availability of nutrients and water for surrounding herbaceous plants, and how this contribution can overcome the competition for nutrients and water.

Two of the results are of direct interest for this paper:

- By far, the most important process through which trees can improve the availability of nutrients and water for crops is an indirect one, resulting from all direct processes: the improved soil organic matter status.
- The potential positive effect of trees on surrounding herbaceous plants decreases with i) decreasing soil fertility and with ii) increasingly unfavorable climatic conditions.

The latter, implies that beautiful examples of permacultures on fertile soils of the tropics, such as food-forests from Java (Indonesia), will have a much lower potential when “copied” on poor soils under low rainfall conditions at low temperatures.

The first result, serves as prelude for the rest of this paper. Combined with the second result, it implies that the positive effect of trees increases with increased soil fertility. Where without trees, the average natural availability of nitrogen (N) for herbaceous plants increases from 10 to 25 kg ha^{-1} $year^{-1}$ going from the southern Sahel to the southern Soudan savanna, thanks to the presence of trees these figures become 3 to 6 kg ha^{-1} $year^{-1}$ higher. The trees help avoid N losses in the order of 30% of potentially available N, thanks to improvement of the soil organic matter status. Hence, crops on land with trees receiving annual rates of 120 kg fertilizer N ha^{-1}, may be able to utilize 30 kg ha^{-1} more than without trees. For farmers it is much more interesting to use trees to improve the efficiency of fertilizer than to use them to avoid fertilizer. In this context it is useful to know that the improved availability of nutrients with trees is more pronounced for N than for phosphorus (P). In agroforestry, P is more likely than N to be or to become a limiting factor. Consequently, fertilizing with P is most beneficial and can have synergistic effects by enhancing biological N fixation.

One has to realize, however, that this potential synergistic effect does not imply that leguminous tree species are the best to be used in agroforestry. It is more logic to benefit from it through leguminous crops. The reason is the relatively limited contribution of leguminous tree species to the improvement of the soil organic matter content, the way through which trees have the highest positive effect on crop growth. Leaves and other products of leguminous trees, thanks to their high N/C (nitrogen/carbon) ratio, have a high mineralization rate.

Other conditions for obtaining the highest positive effect of trees on crops, bypassing the negative effect of competition are:

- homogeneous distribution of trees in the field, having a maximum crown cover of 20 – 25%, as in case of tree parklands;
- limiting the effects of shade by high and relatively small crowns, crowns having a diameter not more than half the length of the tree stem;
- using trees with tap roots and / or cutting regularly the superficial roots.

From this short summary of conditions required for using trees to increase the availability of nutrients and water for the surrounding vegetation, crops included, it becomes clear that, indeed, the increase in the production of staples must be considerable for convincing poor farmers in sub-Saharan Africa to accept trees on their fields; i.e. to adopt agroforestry systems. Using trees for increased fertilizer use efficiency is more attractive to them than for avoiding fertilizer use; in fact, the fertilizer otherwise lost to the environment is transformed into higher tree production, increasing the benefit for farmers. If successful, the farmers will appreciate also the additional effect of increased sustainability of crop production.

Verification of positive influences of trees on crops

The possible positive influence of trees, creating the conditions as described, has been demonstrated in Togo over a ten-year period, which is in fact a period far too short to observe the potential effects, as soil improvement takes longer time. A 4-year old *Leucena leucocephala* alley cropping trial has been transformed into a parkland as described above, and maize has been produced with and without fertilizers. The results presented in the table below are those obtained 7 years after the transformation (Tamélokpo et al. 2007). Reasons exists why the presented results have to be considered as sub-optimal. As indicated, the period has been too short and the tree species used is a leguminous one. Also, the demonstration started as an alley cropping test, in which at least once a year the alleys have been cut. Decomposition of twigs and leaves accelerated soil improvement while controlling the negative effect of shade on maize growth. However, by cutting the above ground tree biomass, the tap roots did not develop. Rooting staid superficial.

The Table 1 presents both the maize yield and the other components of the above ground phytomass after the tenth year of trees presence. Fulfilling the conditions described in the above paragraph, trees are able to double crop yield. But even a relatively low dose of fertilizer increases crop yield more. In case of fertilizer use, the trees do not provoke an extra effect on grain yield. However, as predicted by Breman and Kessler (1995), when considering the overall above ground production, the tree effect on the overall above ground production is much higher with than without fertilizer. Fertilizer appeared to double the production of tree leaves and wood, leading to better soil improvement and higher farmer's income.

Table 1: The total above ground production of parkland agroforestry during the main growing season, without and with fertilizers, compared with a treeless control.

Treatment	Yield (t ha^{-1})				
	grain	straw	tree leaves	wood	total
control	1.3	1.9	0	0	3.2
control + fertilizer	4.2	6.3	0	0	10.5
parkland	2.6	3.9	5.0	6	18.5
parkland + fertilizer	4.1	6.1	9.5	15	34.7

Sustainable energy production through woodlots and agroforestry in the Albertine Rift

The knowledge and experience summarized in the above paragraphs was used to formulate and implement a reforestation project in the Albertine Rift financed by the Dutch development cooperation. Tree planting was done for and with farmers on farmers' fields. Farmers could make a choice between small woodlots for firewood or agroforestry, while they also could make a choice regarding the tree species used (IFDC 2012).

More than 20.000 ha were planted with farmers in 3 years, with a clear preference for woodlots. About one third of planting concerned agroforestry fields, for which farmers chose, in order of importance, mainly *Maesopsis eminii*, *Cordia Abyssinia*, and *Grevillea Robusta*.

Based on the analysis and quantification of processes through which trees interact with surrounding vegetation, taking the results of the demonstration in Togo into account, an ex-ante study was done regarding the potential benefits of agroforestry systems in Burundi, Eastern DRC and Rwanda. Two situations were distinguished: i) using trees and fertilizer to increase staple production on slopes, while stopping or diminishing soil erosion, and ii) using the same system in flat high productive valleys for increased staple and wood production. It was estimated that the net benefits for farmers at the 2012 prices are in the order of 500 and 1000 $ ha^{-1} $year^{-1}$. In the first case the benefit of crops is somewhat higher than those from trees, the opposite is observed for the second case.

Without fertilizer and trees, the average annual net benefits of extensively produced maize and beans are in the order of 350 $ ha^{-1}. In other words, it seems possible to increase farmers benefits through trees aiming to improve fertilizer use efficiency on crops. Not included in the benefits is, among other effects, the increased sustainability of production, thanks to erosion control. It is worthwhile mentioning that another donor-supported intervention for erosion control in the region is terracing, which has extremely high investment costs: terraces would be hardly profitable using a cost-benefit analysis (Bizoza and de Graaff 2012).

Conclusion

For farmers in sub-Saharan Africa interested in agroforestry for producing staples, trees supporting the use of fertilizers should be promoted. It is also a cheap alternative for otherwise very expensive erosion control investments.

References

Bizoza AR, de Graaff J (2012) Financial cost–benefit analysis of bench terraces in Rwanda. Land Degrad Dev 23: 103-115.

Breman H, Kessler JJ (1995) Woody plants in agro-ecosystems of semi-arid regions with an emphasis on the Sahelian countries. Advanced series in agricultural sciences 23, Springer-Verlag, Berlin, Germany.

IFDC (2012) SEW. Sustainable energy production through woodlots and agroforestry in the Albertine Rift. IFDC-Burundi (Bujumbura) and IFDC Headquarters. Alabama, USA.

Shepard M (2013) Restoration agriculture. Real-world permaculture for farmers. Acres, USA.

Tamélokpo A, Mando A, Breman H (2007) Influences des éléments manquants et la gestion du sol en agroforesterie sur les rendements de maïs et le recouvrement de N, P et K. Rapport intern, IFDC-Togo, Lomé.

AGROFORESTRY SYSTEMS IN ROMANIA

Mihăilă E[1*], Costăchescu C[1], Dănescu F[1], Popovici L[1]

(1) National Institute for Research and Development in Forestry "Marin Drăcea", Bucharest, Romania

*Corresponding author: lilianmihaila@yahoo.co.uk

Abstract

Recent interest shown to agroforestry system in Romania is due to the effects of climate change and ecosystem degradation, agroforestry systems ensuring the long-term enhancement of environmental quality and the conservation of natural resources. Forestry shelterbelts for crops protection, pastures with trees, forestry shelterbelts for the protection of the water courses, taungya system are the main agroforestry system realised Romania but still on small areas. On a much smaller scale, other types of agroforestry systems such as: forest farms, harvesting of seeds, flowers, resin from trees, honey by bee-keeping, mushrooms - including truffles are practiced and have been developed through the initiative of farmers particularly smallholders. By presenting the results of the researches and their extension and deepening, it is intended to promote this issue persistently for the implementation of some financing support measures for agroforestry, followed by good practice manuals for their application.

Keywords: agroforestry; ecosystem degradation; support measures; good practice manuals

Introduction

In Romania, the terms of agroforestry systems is a new concept and often used with partial and inconclusive meaning, even if the association of trees and/or shrubs with crops, pasture and animal husbandry has been practiced for a long time and in different ways. The main forms of association of trees, crops and livestock from Romania with ecological, economic and social impact are: forestry shelterbelts for crops protection, forestry shelterbelts for the protection of the main rivers, pastures with trees, taungya system. Other forms of association such as: forest farms and production of non-timber food products in forest (e.g. the harvesting of seeds, flowers, resin from trees, honey by bee-keeping, mushrooms - including truffles) have been developed through the initiative of some farmers and particularly smallholders. They have not yet a regional or national character and no research has been done on them.

Materials and methods

The article is a summary of the concerns related to agroforestry systems in Romania and was based on the consultation of relevant works and on the results of its own researches.

Research on the effect of crops on forest species was carried out comparatively, aiming to highlighting the differences between increases of seedlings from forest plantations maintained in the taungya system and from the clear forest plantation. Biometric characteristics of the seedlings (diameter and height) were determined at the beginning and end of the growing season, for all the seedlings in the experimental surfaces, resulting, by the difference between the two determinations, the annual increment of seedlings.

The network of forestry shelterbelts was placed using GIS-specific techniques. The network was built on the contour of the agricultural landings, at average distances of approximately 600 m between the forestry shelterbelts and 1200 m between the secondary forestry shelterbelts. Basically, a unique forestry shelterbelts width of 10 m has been adopted.

To protect the watercourses, a 1.5 km corridor on both sides of the main waterline was analyzed to signal the presence of forests. In addition to the GIS method used a stratification of the soil information has been made, separating the soils from the waterside (haplic fluvisols, dystric fluvisols, eutric cambisols). From the area occupied by alluvial soils, the land areas without forest vegetation and those with forest vegetation were divided.

Results and discussion

The so-called ”*taungya system*”, which consists in cultivating the crops among rows of trees in the first stage of forestry plantation, has been practiced and is still practiced, in a smaller scale, in the Euramerican poplar plantations and acacia plantations installed the south of the country, along the main rivers and exceptionally for the oak plantations (Mihăilă et al. 2010). These plantations are made at large schemes (from 4 x 4 m to 7 x 7 m) and respectively medium: 2 x 1 m. The main purpose of setting up this agroforestry system is carrying out maintenance work during the establishment stage of forest plantations, improving soil properties and finally to diversify production. The immediate effect of maintenance work on young forest plantation in the agroforestry system is also seen in the increase in diameter and height of the young trees (Figure 1). It also the canopy of the trees closes faster and in the long run the productivity of the stands increase.

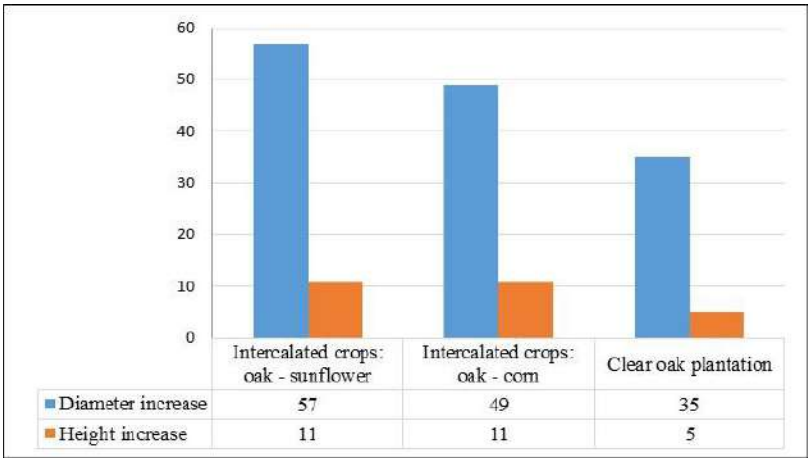


Figure 1: The growth of diameters and heights (%) for oak seedlings in "*taungya system*" vs ”clear forest plantation” - period: spring – autumn.

The forestry shelterbelts for crops protection are one of the most popular types of agroforestry system in Romania. Their achievement is done by both owners and administrators of agricultural land, pastures, farms, either individuals or companies.

The areas most affected by climate change are those in the south of the country (The Romanian Plain and Dobrogea), but agricultural areas in the western and eastern parts of the country require also protection as a result of imbalances in climate characteristics. Therefore, the forestry shelterbelts are mainly designed to mitigate climatic extremes (the analyzed areas being characterized by average annual temperatures of about 11^0C, average annual precipitation below 500 mm and de Martonne aridity index between 20 and 23), to improve the conditions for the growth of crops, to increase fertility and soil conservation.

For the southern area of the country, the network of forest protection belts would cover about 87,200 ha, which will protect about 3,500,000 ha of agricultural fields (crops and pastures) resulting in an approximate percentage of occupancy of agricultural land with forest vegetation of 2-3% (Table 1) (Costăchescu et al. 2010). It had been proposed 8 afforestation formulas, depending on the site conditions in the respective areas.

Table 1: The surface and composition of the proposed forestry shelterbelts for crops protection from The Romanian Plain and Dobrogea.

The category of land use	The composition of the forestry shelterbelts	The surface of forestry shelterbelts network (ha)	The surface of protected crops (ha)
Arable	40 Stp 20Ult 20Sl 20arb	3,915.27	156,450.05
	20Stp 20Stb 20Ult 20Sl 20arb	9,301.53	372,673.14
	40 Stp 20Mj(Pă) 20Sl 20arb	1,781.20	70,986.27
	40 Stb 20Ult 20 Sl 20arb	20,947.75	835,797.43
	40 Stb 20Ult(Tea) 20Pă 20arb	22,846.02	915,369.08
	40 Stb 20Tea(Ju) 20Pă 20arb	6,027.23	240,411.67
	40 Stb(St) 20Pa(Tea) 20Cd 20arb	14,281.58	571,079.65
	40Ce(Gâ) 30Pă 30arb	3,263.12	130,996.73
Pastures	40 Stp 20Ult 20Sl 20arb	488.32	19,754.45
	20 Stp 20Stp 20Ult 20Sl 20arb	1,255.59	50,267.18
	40 Stp 20Mj(Pă) 20Sl 20arb	244.40	9,827.34
	40 Stb 20Ult 20 Sl 20arb	1,071.15	42,630.89
	40 Stb 20Ult(Tea) 20Pă 20arb	643.11	25,639.61
	40 Stb 20Tea(Ju) 20Pă 20arb	133.75	5,097.39
	40 Stb(St) 20Pa(Tea) 20Cd 20arb	893.67	35,127.89
	40 Ce(Gâ) 30Pă 30arb	118.35	4,838.20
Total		**87,212.04**	**3,486,946.96**

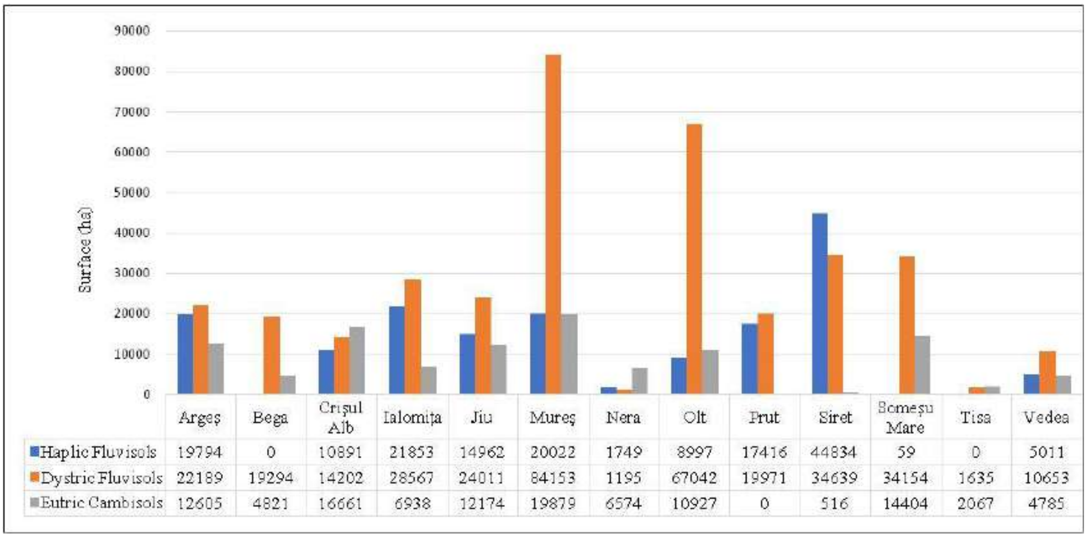
NOTE: Stp = *Quercus pubescens*, pubescent oak; Stb = *Quercus pedunculiflora*, greyish oak; St = *Quercus robur*, oak; Ce = *Quercus cerris*, Turkey oak; Gâ = *Quercus frainetto*, Hungarian oak; Ult = *Ulmus pumila*, Siberian elm; Mj = *Fraxinus ornus*, flowering ash; Pă = *Pyrus pyraster*, wild pear; Tea = Tilia *tomentosa*, silver lime; Sl = *Eleagnus angustifolia*, oleaster; Pa = *Acer platanoides*, Norway maple; Cd = *Prunus cerasifera*, cherry – plum; Arb= shrubs

In the context of efforts to reduce greenhouse gas content, the forestry plantation to be installed within this agroforestry system will store an appreciable amount of carbon (Blujdea et al. 2012).

Research and recommendations on the establishment of **forest belts for protection of the water courses** (Siret, Ialomita, Arges, Olt, Jiu, Mures) have been made since the 50s of the last century (Lonescu et al. 1960). These are included in the general issue of forestry shelterbelts.

The analysis of the main watercourses showed that the area occupied with forest vegetation in a corridor of 1,5 km width of one side and another is relatively small (ranging from 10,21% for the Siret River to 26,77 % in the case of the Jiu River) (Mihaila et al. 2010). It is believed that this corridor allows for the placement of either a single forest protection belt of a larger width, or many forest belts separated from agricultural areas. The small percentage of forest vegetation was due to its systematic removal and use of land for the extension of agricultural land or, more recently, for the development of living areas close to river.

The lack of forest vegetation have a great ecological impact, increasing the share of agricultural land more or less degraded near the watercourse. The goal of achieving forestry shelterbelts for water protection is precisely to protect both agricultural land and watercourses. For instance, the areas where forest belts for water protection are required vary from 124,054 ha (19.39%) for the Mures River, to 3,702 ha (0.58%) for the Tisa River (Figure 2). Generally the downstream of the watercourses represent a protected area, being sites included in the Natura 2000.



	Argeș	Bega	Crișul Alb	Ialomița	Jiu	Mureș	Nera	Olt	Prut	Siret	Someșu Mare	Tisa	Vedea
Haplic Fluvisols	19794	0	10891	21853	14962	20022	1749	8997	17416	44834	59	0	5011
Dystric Fluvisols	22189	19294	14202	28567	24011	84153	1195	67042	19971	34639	34154	1635	10653
Eutric Cambisols	12605	4821	16661	6938	12174	19879	6574	10927	0	516	14404	2067	4785

Figure 2: Areas to be afforested on a 1.5 km corridor both sides of main rivers from Romania.

The first stage in the realization of forest belts for water protection consists in the particular analysis of each water course in terms of climatic and site conditions, the presence or absence of forest vegetation and the main functions of these forest protective belts (bank stabilization, filtering pollutants from agriculture or industry etc.).

Pastures with trees, the most representative type of silvopastoral systems have a long tradition in our country as in many other countries. During the period between the 50s and 80s of the last century, they developed in an organized manner, and the silvopastoral development activity followed to harmonize the economic, social and environmental requirements (Sabău and Pană 1955; Motcă et al. 1994).

The trees in silvopastoral systems are from rustic forest species, resistant to climatic, edaphic, anthropic adversities, capable of exploiting the productive potential of the soil, such as: oak, walnut, cherry, wild pear etc.

Regarding the second component of silvopastoral systems, animals, the most frequent are cattle and sheep, but also horses, goats, pigs can be found.

The type of pasture (grassland), the third component of silvopastoral systems, is an important element within them, its quality and productivity being directly related to livestock production. The choice of high nutritional fodder species (*Festuca* sp., *Agrostis* sp., *Carex* sp., *Poa* sp., *Bromus* sp., etc.) as well as technological measures have the role in improving the permanent pasture by increasing the production, its quality and eventually the evolution of the blanket herbaceous (Motcă et al. 1994). Technological measures include the following categories of works: (i) land improvement works which include anti-erosion protection works on soils with slopes over 30^0; (ii) regeneration of the blanket herbaceous by fertilization and over-sowing; (iii) total regeneration of land by sowing.

The knowledge of the characteristics of grass and fodder growth, grazing time, grazing capacity and optimal numbers of animals avoid the degradation of pasture by impoverishment and deterioration of fodder species and seedlings harm. All these are more or less theoretical elements that can be the basis for the large-scale development of pastures with trees many of them currently degraded

Conclusion

Although there are measures to support agroforestry systems at EU level, in the agricultural and forestry policy of Romania have not yet been taken steps to promote support measures for the development of agroforestry systems. There are some vague references to agroforestry in the national development strategy for agriculture, but no further steps have been taken to promote measures to finance these agroforestry systems or to elaborate good practice manuals for their application.

The research (unfortunately discontinuous) carried out over the past two decades on the development of agroforestry systems and the initiatives of some farmers and especially smallholders advocates the promotion of agroforestry systems. In addition, support actions are needed to persuade landowners that agroforestry systems contain a complex land use, both from agriculture and forestry point of view and they are not supposed to replace stable, specialized and productive systems, but to improve those that are under degradation, unstable and located in areas affected by drought, aridity.

References

Blujdea VNB, Pilli R, Dutca I, Ciuvat L, Abrudan IV (2012) Allometric biomass equations for young broadleaved trees in plantations in Romania. Forest Ecol and Manag 264: 172-184.

Costăchescu C, Dănescu F, Mihăilă E (2010) Protective forest shelter belts. Forestry Publishing House (in romanian with summary in english), Bucharest.

Lonescu A, Marcu Gh, Moisuc Gh, Lupe I (1960) Research on the need for state shelter belts on water courses. In: P.R. of Romania. In: Studies and Research, vol. XXI. Agro-Forest Publishing House (in romanian with summary in french and russian), pp. 101-133.

Mihăilă E, Costăchescu C, Dănescu F, Drăgoi S (2010) Agroforestry systems. Forestry Publishing House (in romanian with summary in english), Bucharest.

Motcă Gh, Oancea I, Geamănu L (1994) The meadows of Romania. Agricultural Technical Publishing House (in romanian with summary in english), Bucharest.

Sabău V, Pană P (1955) Silvopastoral arrangement. The Forest Engineer's Manual. Technical Publishing House Bucharest (in romanian) 81: 292–306.

BENEFITS OF AGROFORESTRY SYSTEMS FOR LAND EQUIVALENT RATIO – CASE STUDIES IN BRANDENBURG AND LOWER SAXONY, GERMANY

Seserman DM[1*], Veste M[1,2], Freese D[1], Swieter A[3], Langhof M[3]

(1) Institute of Environmental Sciences, BTU Cottbus–Senftenberg, Cottbus, Germany (2) Institute of Botany, University of Hohenheim, Stuttgart-Hohenheim, Germany (3) Institute for Crop and Soil Science, Julius Kühn-Institut, Braunschweig, Germany

*Corresponding author: seserman@b-tu.de

Abstract

Transitioning towards agroforestry demands systematic productivity assessments of such systems under different climatic and edaphic conditions. In this regard, the Land Equivalent Ratio (LER) serves as a valuable productivity indicator of agroforestry since it evaluates yields from growing trees and crops together in comparison to yields from monocultures over the same period. Consequently, our objective was to evaluate the overall productivity of two agroforestry systems in Forst (Brandenburg) and Wendhausen (Lower Saxony) by means of LER. Our approach followed two assumptions: (i) the yields of trees and crops had equal economic importance and (ii) the economic importance was given solely by the annual crop, the yield of trees representing a supplementary profit. The resulted values for LER were consistently above their specific threshold, corroborating the greater efficiency of agroforestry systems rather than monoculture. Additionally, this study highlighted the importance of choosing the appropriate assumptions when calculating the LER.

Keywords: agroforestry; land equivalent ratio; land use efficiency; tree yield; crop yield

Introduction

With comparison to conventional agricultural systems, the integration of trees and arable crops on the same land has been increasingly justified by a range of environmental benefits regarding biodiversity, soil fertility, microclimatic conditions, and overall productivity, and are widely used as wind protection systems against soil erosion (Slazak et al. 2013; Kanzler et al. 2016). However, considering that agroforestry systems have a planning horizon of several decades, the productivity of such systems needs to be periodically assessed for forthcoming risk assessments and adaptation scenarios in the near future.

In this regard, the Land Equivalent Ratio (LER), defined as the relative yield of each tree and crop species in an agroforestry system in comparison to the yield of the same tree and crop species in a monoculture over the same period (Mead and Wiley 1980), was used as a method to determine the overall productivity of two agroforestry systems in Forst (Brandenburg) and Wendhausen (Lower Saxony).

Objectives

Given the fact that land-use systems have different goals, there are different methods of quantifying the LER in agroforestry systems (Ong and Kho 1996). Therefore, the main objective of this study was to evaluate the overall productivity of two agroforestry systems in Forst (Brandenburg) and Wendhausen (Lower Saxony) by means of LER with an emphasis on (i) the yield of both trees and crops (after Mead and Wiley 1980) and (ii) the yield of annual crops (after Ong and Kho 1996) as a principal economical product.

Materials and methods

Study sites

This study was carried out on two agroforestry systems established near Forst (N 51˚47'37'', E 14˚38'12'', 67 m a.s.l.) and Wendhausen (N52˚19'54'', E10˚37'52'', 85 m a.s.l.). The agroforestry system near Forst is based on a dominantly pseudogleysol type of soil with a loamy sand texture and has an annual average temperature of 9.6°C and an average annual precipitation of 568 mm (DWD Station Cottbus). The agroforestry field near Wendhausen is characterized by a pelosol with a silty clay soil texture and has an average annual temperature of 8.0°C and an average annual precipitation of 616 mm (DWD Station Braunschweig).

The agroforestry system in Forst consists of seven tree strips in a north-south orientation, having a width of 11 m and a total length of 660 m, with agricultural alleys of 96 m, 48 m, and 24 m width between the tree strips (Kanzler and Böhm 2016). The system in Wendhausen consists of four tree strips having a width of 12 m and a total length of 50 m, with agricultural alleys of 48 m width between the tree strips, as well as a control field with short rotation coppices (SRC) planted on a 70 x 70 m surface (Lamerre et al. 2015).

Based on the joint BMBF-Project SIGNAL (Sustainable Intensification of Agriculture through Agroforestry), four core- (agroforestry) and four reference-plots (monoculture) were established on these experimental sites in 2015. Two windward and two leeward core plots were set on the 48 m agricultural alleys and included the first two rows of trees. The planting density was of about 8,700 trees per hectare (1.3 m by 0.9 m within the rows) and 10,000 trees per hectare (2 m by 0.5 m within the rows) for Forst and Wendhausen, respectively (Kanzler and Böhm 2016; Lamerre et al. 2015).

Yield assessment

Regarding the tree yield, first rotation hybrid poplars (*Populus nigra* L. *x P. maximowicii* Henry, clone "Max I") were harvested at the end of vegetation period 2014 and 2013 in Forst and Wendhausen, respectively. In the second rotation, annual measurements of breast height diameter (BHD) were taken in winter 2015/2016 and 2016/2017. According to these diameter measurements, 25 shoots were chosen, manually cut 10 cm above the ground, chipped and weighted. An allometric equation of the form $M = a\ D^{\ b}$ was used in order to derive the dry matter of all measured diameters, where M is the tree biomass (kg), D is the shoot basal diameter (cm) and a and b are the intercept and slope of a least-square linear regression of ln-transformed data. The yearly tree woody biomass production per hectare was estimated for each core plot using the average number of shoots per hectare and the average dry mass of the shoots, according to the mean stool method (Lamerre et al. 2015).

Regarding the crop yield, winter wheat (*Triticum aestivum* L.) was harvested in 2016 and winter barley (*Hordeum vulgare* L.) was harvested in 2017 in Forst, whereas in Wendhausen winter rapeseed (*Brassica napus* L.) was harvested in 2016 and winter wheat in 2017. Due to the fact that different crops were grown at the agroforestry systems in Forst and Wendhausen, we used a normalized crop unit (GE; "Getreideeinheit") in order to calculate and compare the agricultural production per hectare. Accordingly, 1 dt wheat corresponded to 1.04 GE, 1 dt barley to 1.00 GE, and 1 dt rapeseed to 1.30 GE (Schulze Mönking and Klapp 2010).

Regarding the monoculture systems, we distinguished between the reference crop plot as the agricultural system and the reference tree plot as the SRC. Lacking an identical planting scheme of trees between the agroforestry systems and SRC, we assumed that the annual biomass increments of the inner rows of the agroforestry system are comparable to those in the SRC. Thus, in Forst, measurements were collected from four double-row plots with poplar trees and we assumed the inner two rows as similar to an SRC. In Wendhausen, measurements were collected from the SRC planted on the control field.

Land equivalent ratio

The land equivalent ratio (LER) is the ratio between the relative yield of each tree and crop species in an agroforestry system in comparison to the yield of the same tree and crop species in a monoculture over the same period.

Firstly, we calculated the LER for each system under the assumption that the yields of trees and crops are of equal economic importance, after Mead and Wiley (1980):

$$LER1 = \frac{Yield\ Tree\ Agroforestry}{Yield\ Tree\ Reference} + \frac{Yield\ Crop\ Agroforestry}{Yield\ Crop\ Reference} \quad \text{(Eq. 1)}$$

While LER1 ≤ 1 means that there is no productivity advantage of agroforestry over monoculture, a LER1 > 1 suggests that the production in the agroforestry system is higher than the one in a monoculture system.

Secondly, we calculated the LER for each system under the assumption that the economic importance is given solely by the annual crop, as the yield of trees is generally regarded as a supplementary profit. Consequently, the difference in crop yield resulting from the presence of trees relative to the yield of the sole crop was determined according to Ong and Kho (1996):

$$LER2 = \frac{Yield\ Agroforestry\ System - Yield\ Crop\ Reference}{Yield\ Crop\ Reference} \quad \text{(Eq. 2)}$$

In this case, LER2 > 0 suggests that the production in the agroforestry system is higher than the one in a monoculture system.

Results and discussion

The land equivalent ratios show considerable differences between the two agroforestry sites over the investigated two years (Figure 1).

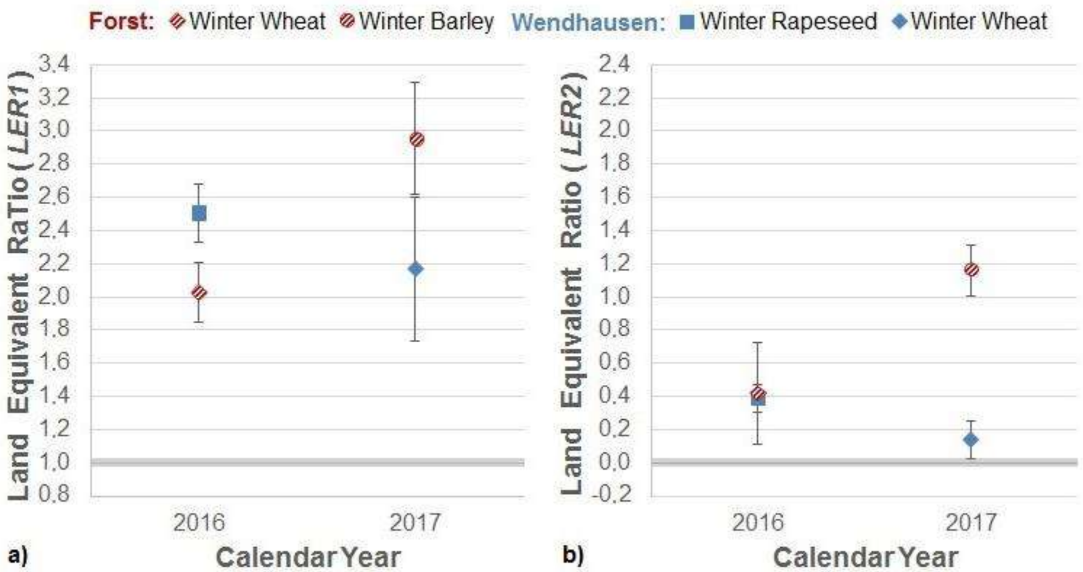


Figure 1: The land equivalent ratio with regard to the variation of data calculated for the agroforestry systems in Forst and Wendhausen after Mead and Wiley 1980 – LER1 (a) and after Ong and Kho 1996 – LER2 (b). The grey line serves as a threshold above which the agroforestry system has greater productivity than the monoculture system.

All of the obtained values for LER were consistently higher than their specific threshold, meaning that in both cases and for both locations, the agroforestry system had a greater productivity than the monoculture system. Regarding the LER calculations according to Mead and Wiley (1980), the agroforestry systems in Forst and Wendhausen achieved values between 2.0 and 2.9, respectively. Relatively lower results were reported by van der Werf et al. (2007) and Graves et al. (2007), with an LER value between 1.0 and 1.8, as calculated after Mead and Wiley (1980).

Mentionable would also be the fact that changing the purpose of land-use, i.e. the method of calculating the LER can lead to contradictory conclusions. For example, in 2016, Wendhausen was the more productive field according to LER1, whereas both sites showed similar productivity according to LER2.

Conclusion

Our results corroborate the greater efficiency of land use, i.e. greater land equivalent ratios when trees were integrated with arable crops rather than grown as sole crops and highlight the importance of choosing the appropriate method when calculating the land equivalent ratio.

Acknowledgements

We are grateful to our colleagues at the Chair of Soil Protection and Recultivation, BTU Cottbus – Senftenberg, and the Julius Kühn-Institut in Braunschweig, for their support and scientific collaboration. Additionally, we thank the Agrargenossenschaft Forst/L. e.G. for their promotion and management of the agroforestry systems at Forst. The research was carried out under the BonaRes - SIGNAL project (FKZ 031A562E, 2015-2018) and funded by BMBF - German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung).

References

Graves AR, Burgess PJ, Palma JHN, Herzog F, Moreno G, Bertomeu M, Dupraz C, Liagre F, Keesman K, van der Werf W, Koeffeman de Nooy A, van den Briel JP (2007) Development and application of bio-economic modelling to compare silvoarable, arable, and forestry systems in three European countries. Ecol Eng 29: 434–449.

Kanzler M and Böhm C (2016) Nachhaltige Erzeugung von Energieholz in Agroforstsystemen (AgroForstEnergie II): Teilvorhaben 2: Bodenschutz, Bodenfruchtbarkeit, Wasserhaushalt und Mikroklima. Schlußbericht, Brandenburgische Technische Universität Cottbus-Senftenberg, Fachgebiet für Bodenschutz und Rekultivierung, Cottbus.

Kanzler M, Böhm C, Mirck J, Schmitt D, Veste M (2016) Agroforstliche Landnutzung als Anpassungsstrategie an den Klimawandel. Mitteilungen der Gesellschaft für Pflanzenbau 28: 126–127.

Lamerre J, Langhof M, Sevke-Masur K, Schwarz KU, von Wühlisch G, Swieter A, Greef JM, Dauber J, Hirschberg F, Joormann I, Krestel N, Masur D, Reith C (2016) Nachhaltige Erzeugung von Energieholz in Agroforstsystemen: Teilprojekt 3: Standort Niedersachsen; Strukturvielfalt und Biodiversität. Schlußbericht, Julius Kühn-Institut Bundesforschungsinstitut für Kulturpflanzen (JKI) - Institut für Pflanzenbau und Bodenkunde, Braunschweig.

Mead R and Willey RW (1980) The concept of a "Land Equivalent Ratio" and advantages in yields from intercropping. Exp Agr 16: 217–228.

Ong CK and Kho RM (1996) A framework for quantifying the various effects of tree-crop interactions. In: Ong CK and Huxley P (eds) Tree–crop interactions: a physiological approach. CAB International, Wallingford, pp 1–23.

Schulze Mönking S and Klapp C (2010) Überarbeitung des Getreide- und Vieheinheitenschlüssels. Endbericht, Georg-August-Universität Göttingen - Forschungs- und Studienzentrum für Landwirtschaft und Umwelt, Göttingen.

Ślązak A, Böhm C, Veste M (2013) Kohlenstoffspeicherung, Nährstoff - und Wasserverfügbarkeit. In: Wagener F, Heck P, Böhmer J (eds) Nachwachsende Rohstoffe als Option für den Naturschutz. Naturschutz durch Landbau? Schlussbericht, ELKE III, Hochschule Trier, Umwelt-Campus Birkenfeld, pp 130–149.

Van der Werf W, Keesman K, Burgess PJ, Graves AR, Pilbeam D, Incoll LD, Metselaar K, Mayus M, Stappers R, van Keulen H, Palma J, Dupraz C (2007) Yield-SAFE: A parameter-sparse, process-based dynamic model for predicting resource capture, growth, and production in agroforestry systems. Ecol Eng 29: 419–433.

HYBRID WALNUT (*JUGLANS MJ209*) FOR TIMBER PRODUCTION IN AN AGROFORESTRY SCHEME: SOME EXPERIENCES LEARNT IN SPAIN

Urban I[1]*, Fernández-Moya J[1], Licea R[1], Santacruz D[1],Gutiérrez-Tejón E[1]

(1) Bosques Naturales SA, Alcobendas, Spain

*Corresponding author: ignaciourban@bosquesnaturales.com

Abstract

The models of hardwood production in Europe have been under evaluation for the last 20 years with different experiences of plantation frameworks, pure or mixed species production and different agroforestry models. The communication explores the experiences of the company Bosques Naturales SA regarding different approaches to the management of walnut trees associated to agroforestry systems and how the company transitioned from the “pure” forest plantations established around 20 years ago to the agroforestry management perform nowadays. Work is currently being carried out on the Woodnat Second Generation of Planted Hardwood Forest in the EU with the evaluation of the different systems and the intention of providing the best production models presenting the lessons learned.

Keywords: walnut plantations; silvopastoral; silvoarable; wood quality production

Introduction

Walnut trees are species of the genus *Juglans* sp. L., traditionally characterized by their highly valued nuts and timber. The main walnut species are Persian walnut (*Juglans regia* L.), also known as European, English or Common walnut, and American or Black walnut (*Juglans nigra* L.) and different hybrids between them and/or other species. In addition, many clones have been selected during recent decades to improve timber production. During the last decades, many forest plantations oriented for timber production have been established with Hybrid or with Persian Walnut in Europe, which are usually intensively managed and allow managers to sustain relatively high growth rates. Timber is in most of the cases the main economic income in a walnut (*Juglans* sp.) forest plantation such as the ones that have been treated along the WOODNAT project. Walnut timber has been traditionally highly appreciated and mainly used for furniture, flooring and paneling. It generally has two main uses: wood veneer and sawn wood. However, some other uses have been explored to obtain the maximum profit from either small trees or big trees with irregular shapes: carefully designed small objects (art, fashion, kitchen and decoration) and slabs tables (Figure 1).

Figure 1: Details about different uses of walnut (*Juglans* sp.) wood: carefully designed small objects (art, fashion, kitchen and decoration) and slabs tables (more details in www.woodna.es).

Agroforestry systems is a name used to described a continuum of systems varying from the ones obtained by planting trees on agricultural or pasture land or introducing agriculture or pasture in existing woodland/orchards. Hence, even though here agro-forestry systems are considered as a different system from the others, it is more a concept of the integration of the different objectives and approaches into a system. To this respect, depending on the considered conceptual framework, the same agroforestry system of walnut trees planted on the field associated with other agronomic uses might be considered as a forest plantation with an associated secondary use of pasture or crop or a crop or pasture farm which has introduced some trees to benefit from their environmental and socio-economic advantages.

Walnut silvopastoral systems: sheep as "gardeners"

Weed control is one of the main management issues in a "pure" forest plantation and one of the most important expenses. Traditional weed control techniques are mechanical (e.g. ploughing between the plantation lines) and chemical (using herbicides between the plantations lines and between trees in the lines). Hence, grazing animals in the plantations turns the negatively considered "weeds" into positively valued pasture used under a silvopastoral system approach.

To this respect, the company Bosques Naturales SA participated years ago in several research projects (in collaboration with Universidad de Santiago de Compostela and Universidad de Extremadura) to evaluate the effect of sheep grazing on their planted forests. After these research experience, the company has embraced the silvopastoral approach and sheep grazing is used in most of the farms from the company. Indeed, the company has incorporated sheep grazing as one of their commercial activities in Galicia (NW Spain) (Figure 2), while it is performed in collaboration (rental approach) with independent shepherds in the farms from Cáceres and Toledo (Central Spain).

Figure 2: Sheep grazing under hybrid walnut (*Juglans x intermedia*) planted forests in Galicia (NW Spain), from the company Bosques Naturales SA.

Walnut silvoarable systems: maize in humid areas of NW Spain

An important drawback when considering the investment in a forest plantation is the long-term approach as a big investment needs to be done in the establishment of the plantation and the management along many years until the timber harvesting gives back the financial profit.

Walnut "pure" forest plantations have been traditionally established with tree densities around 300-400 trees ha^{-1} in regular spacings (e.g. 5 x 5 m, 5 x 6 m, etc.). However, establishing the plantations with a lower density makes them compatible with a silvo-arable system approach which, in addition to some environmental advantages (and reducing the weeding expenses), it gives a yearly profit from the annual crop.

To this respect, every new plantation of the company Bosques Naturales SA since some years ago is established with this silvoarable approach (Figure 3). This system consists in maize with sparse hybrid walnut (222 trees ha^{-1}) with pairs of 2 plantation lines spaced 6 m (with 5 m distance between trees in the same line) separated by bigger clearances for agriculture of 12 m wide. In this system, the 6-m corridor between the plantation lines allow managers to work within the trees without make any disturbances to the agricultural fields.

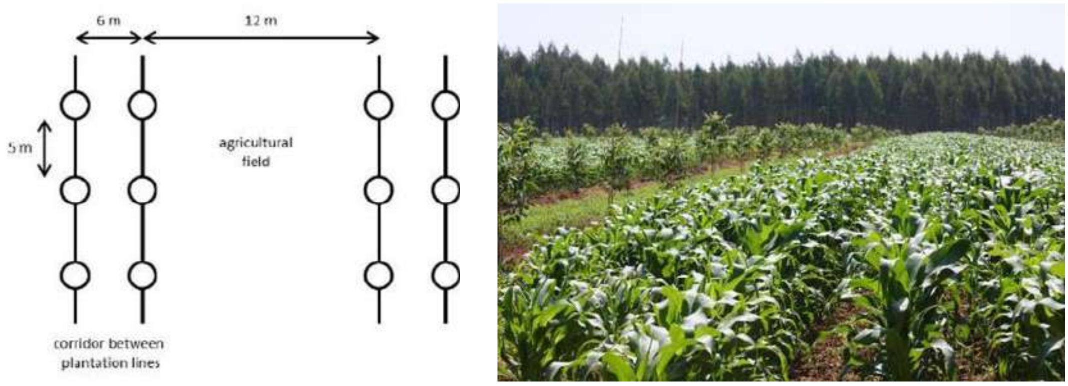


Figure 3: On the left, scheme proposed for an agroforestry system including sparse walnut (*Juglans* sp.) planted forests and on the right, details from an agroforestry system combining maize (*Zea mays* L.) and hybrid walnut (*Juglans x intermedia*) in the Bosques Naturales farm in Galicia (NW Spain).

Walnut silvoarable systems: cereal crops below tree cover in Mediterranean areas

Considering the above-mentioned benefits from the silvo-arable approach, cereal intercropping has been also tested in research projects (in collaboration with Universidad de Santiago de Compostela, Universidad de Extremadura and Centro Tecnológico Forestal de Cataluña) between the 5-6 m wide plantation lines in the “pure” forest plantations originally established during the first years of the company. These research projects have showed that cereal harvests are good enough below the shadow of the planted forests and, in some cases, better than in the open conditions. This is especially relevant in the Mediterranean areas with long dry-hot periods.

These between rows intercropping approach shows some positive results as a good harvest and a weed control expenses reduction. However, it has a major inconvenient regarding agricultural machinery used for the agricultural crops. Hence, even though the 5-6 m wide space between the plantation lines result in a planted forest with relatively low-density from a forest perspective, it is very narrow for working with the common agricultural machines and, consequently, this practice has not been adopted in the routine management of Bosques Naturales. However, it might be considered in the establishment of new plantations in Mediterranean areas with wider between lines spacing which may allow the work of common machinery.

The importance of being clonal

Select the right plant source is one of the main issues once one has decided to establish a new walnut plantation in a site. Even though plenty of options could be available depending on the budget and dimensions, the plant quality and the genetic potential should be considered as one of the key investments when establishing a commercial planted forest.

The management experience in walnut planted forests shows how a good plant material from a seed orchards planted in relatively homogeneous site turn out in a forest where differences between trees are much larger than expected both in shape and size (e.g. in a 19 years old hybrid walnut planted forest established from good quality plant material from seeds is relatively common to find trees with diameter around 15 cm adjacent to ones with around 35 cm and very different shapes, while 13 clonal plantations in Galicia have a very homogeneous growth, with average diameter of 20 cm and good shape).

When the silvicultural scheme is changed and the tree density is reduced to follow a silvo-arable approach, there is a need of ensuring that, as your plantation has fewer trees, they need to be of much better quality. To this respect, the use of clones are highly recommended when walnut are planted under agro-silvo-pastoral approaches.

The balance between agroforestry uses, timber market prices and tree density

Walnut planted forests have usually been established with a relatively low density (around 300-400 trees ha^{-1}) where only 1 or 2 thinnings are needed in order to harvest around 100-150 trees ha^{-1} at the end of the rotation period. These 1 or 2 thinnings have been usually considered as “commercial thinnings” as the removed trees would have a marketable diameter at breast height (15-25 cm) which would turn the thinnings into small incomes prior to the main harvest of the plantation. However, market prices and interests are very variable and fluctuates a lot depending on final-consumer demands. Indeed, during recent years the market demand has been lower than expected and these “commercial thinnings” that were regarded as an intermediate small income by many forest managers had turned into investments needed in order to achieve in the future the objectives fixed for the final harvest at the end of the rotation period. Hence, the expected market price is a key issue regarding the initial establishment of a planted forests as the idea of a thinning regarded as an income or as an investment would directly influence the decision about the initial tree density planted at establishment. To this respect, a financial balance needs to be done and evaluate if having a denser plantation where you are going to have 2 thinnings is more or less profitable than establishing fewer trees and have a yearly income from companion crop.

New perspectives

Projects are being considered for the management of agroforestry systems based on walnut trees for timber. Hence, intercropping with medicinal and aromatic crops are being considered, as well as mushroom and truffle harvesting.

USING A SYSTEM INNOVATION'S APPROACH FOR STIMULATING AGROFORESTRY ADOPTION

Cuperus F[1*], Schoutsen M[1], Sukkel W[1], Selin Noren I[1], Wijnands F[1]

(1) Wageningen University & Research, Applied Arable and Vegetable Research, Lelystad, The Netherlands

*Corresponding author: fogelina.cuperus@wur.nl

Abstract

In the Netherlands, agroforestry is still in its infancy with silvoarable agroforestry systems being the most rarely adopted form of agroforestry. In order to reach a broader adoption of agroforestry, many regulatory and practical obstacles have to be overcome. By using a systems innovation approach we show that this transition process can be facilitated and accelerated in a targeted manner. System innovations in agriculture are multi-objective changes on the technological, social, economic and institutional level. These changes span over the public and private sector, necessitating team coalitions with many different stakeholders. In this paper we illustrate how during the different phases of system innovation different strategies and interventions can be used for removing obstacles and developing the needed innovations. We also discuss innovation networks as an important structure for bringing all available expertise and experience together in one cooperation platform, consisting of advice organizations, farmers, governmental institutions and other stakeholders.

Keywords: The Netherlands; silvoarable agroforestry; system innovation; transition paths; transition points; practice networks

Introduction

In the Netherlands, agroforestry is still in its infancy. According to den Herder et al. (2017) the Netherlands currently practices agroforestry on 1.5% of the Utilized Agricultural Area (UAA). This estimation is based upon LUCAS data (Land Use and Land Cover survey (Eurostat 2015)). The Dutch UAA consists of two well-known forms of agroforestry: livestock agroforestry and high value tree agroforestry. Professional arable agroforestry systems (also called; silvoarable agroforestry) are not yet found in the Netherlands according to the LUCAS database (den Herder et al. 2017) and our knowledge of the current farming practices. Silvopastoral agroforestry systems have gained some momentum in one province (Noord Brabant), however their development is hampered by practical and regulatory obstacles that have to be overcome, before a broader adoption in practice becomes interesting for different actors. Silvoarable agroforestry systems are seen as realistic and high-potential cropping systems, containing various synergies between farming and societal and environmental goals. Our envisioned future for agroforestry is not (solely) a niche system for small-scale entrepreneurs, but a profitable alternative for professional farmers (conventional and organic), and to the current large scale, low diversity farming landscapes throughout arable farming landscapes in Europe and elsewhere (Figure 1). Wageningen University and Research (WUR) has engaged itself in the challenge to bring this system innovation forward, working with the relevant stakeholders in the private industry and the public services. In order to achieve an increase in adoption of agroforestry systems in the Netherlands, we show the experience we gained in the last decades on how system innovation can be fostered and facilitated.

Figure 1: Agroforestry future vision featuring production, ecology, modern technology and education.

The innovation trajectory

System innovations in agriculture are multi-objective changes that transcend the individual entrepreneurs. It comprises usually a combination of technological, social, economic and institutional changes. Such more or less simultaneous trajectories require dedicated actions of different actors with an action perspective on the challenges at hand. This is why such innovations can only be successful when the different stakeholders (including agricultural entrepreneurs, NGO's, knowledge and research institutes, national and regional authorities as well as the whole value chain) that have something at stake in this change, collaborate and learn to work together. That usually starts with common meetings to debate the challenges and create a common vision on where to go as inspiration source for the immediate actions that need to be taken. We as WUR take the role of facilitator of this process to make vital connections, finding shared ambitions and forming alliances by organizing different forms of meetings, farm visits, demonstrations and workshops.

During the trajectory of transition four different phases can be distinguished according to Beers (2011). The invention phase is the first, where a new innovation is developed by a small number of actors that has the potential to influence the whole sector. In The Netherlands, such examples of silvopastoral agroforestry systems are present and silvoarable examples are currently being established. In the second phase, where the agroforestry innovation is today, the innovation is prepared for the whole market by overcoming obstacles that limit the expansion of the innovation. In this phase and the next one it is important to find parties that want to associate with the innovation. Besides agricultural entrepreneurs that can directly apply agroforestry, also other stakeholders have reasons wanting to associate and participate in the innovation. Dutch water boards take part in the discussion, since agricultural activities influence water quality and water holding capacities. Regional governments are interested in agroforestry because of their policy assignment to do more with nature-inclusive agriculture and to make agriculture more environmentally friendly; landscape authorities are interested in landscape qualities of agricultural, productive landscapes; energy companies are interested due to the carbon sequestration potential and biomass production and NGO's take part in the discussions due to biodiversity conservation. In this way, all stakeholders have their own intrinsic motivation to contribute. Subsequently, the innovation moves into the third phase, when the first agricultural entrepreneurs adopt the innovation due to the perceived high importance and urgency. These pioneers show that the concepts are actually working for the wider group of agricultural entrepreneurs as well. The fourth step is making the wider sector see the benefits of the innovation and implement it (Beers 2011).

To support this innovation trajectory and accelerate the transition, one can work along two different but complementary pathways; according to of Wijnands (2005). One pathway connects the future vision towards the present, the other moves from the current practice towards the future (Figure 2). Both of these developments are important in the mid-long term and can together accelerate the process of change (Wijnands 2005). Logically, a long-term approach to this transition is crucial for stimulating long-term farming systems, such as agroforestry.

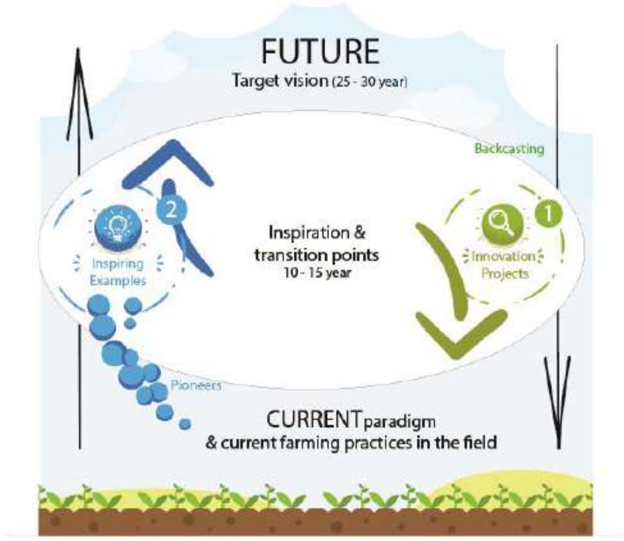


Figure 2: Schematic representation of the two transition paths (original from: Vogelezang and Wijnands 2011).

Following innovation path 1

When following pathway one, the stakeholders' common future vision of agroforestry is the starting point. From there we "back cast" to the present situation to identify what obstacles have to be removed and what innovations will be needed to realize the desired future together. The obstacles that seem almost un-removable often are called transition points, since finding solutions for them requires often innovations or novel approaches. Each transition point, which can be technical, socio-economic, cultural or institutional, is a possible topic for an innovation project to address. Together these transition points form an innovation agenda in which each point can be classified under either hardware (technology), orgware (collaborations, regulations) or software. By targeting all these transition points the future can become within reach in a practicable manner (Vogelezang and Wijnands 2011). Dutch stakeholders identified the transition points for agroforestry to be; laws and regulations, system knowledge, mechanization and knowledge of and availability of suitable species varieties (Cuperus 2017). Each transition point requires its own approach involving the relevant stakeholders and expertise. Technical obstacles are overcome by experiments, finding new agricultural practices and showing that these work. The social/economical obstacles can for example be overcome by finding new payment mechanisms for the services and functions of agriculture. On this path, government funding is often needed because the systems are still relatively far from practical use and adoption. New mechanisms are not yet in place, and in this market failure temporary solutions are needed to help the niches to become mature. The second step on path 1 is optimization and transformation of the innovations into economically profitable applications. This focus on solving problems by innovations has a pulling and stimulating function on the transition trajectory. (Wijnands 2005; Meijer 2010). Following this approach, we involve regional and national governments to find a common target and cooperation. In addition, we are working on a

'*Wetenschapswinkel'* project (an initiative of Wageningen University and Research to support societal organizations in research) to map the bottlenecks when it comes to laws and regulations.

Following innovation path 2

On pathway two the focus is on current innovation and innovators. The agroforestry pioneers are an important source of inspiration and practical knowledge and are paving the way to the future. They make promising development strategies available and insightful for others, but they also show, often at high transaction costs, where the difficulties are that they are facing and struggling with. This positions this group to co-shape the agenda for "maturing" (breakthough agenda) of the new systems. Given the role of the pioneers it is important in this pathway to support them when they are trapped in the transition. By facilitating interactions between different partners, the agenda can be introduced and joint trajectories designed to address these issues and work on them. By facilitating the formation of coalitions, innovation networks can be created where applied knowledge can be shared and important experiences are gathered. Later, this knowledge and experience can be used to mobilize support for the uptake of the innovation more widely (Klerkx et.al. 2010). The networks are bringing all available expertise and experience together in one cooperation platform and can consist of advice organizations, agricultural entrepreneurs and different other stakeholders. The results of previous experiences with innovation groups within 'Organic farmers networks' (1997-2003) were, among others; new initiatives, fast knowledge circulation, improved cooperation, innovated farming methods, new techniques, improved yield and less required labor (Sukkel n.d.).

Following this model we have established contact with several agricultural entrepreneurs and other stakeholder groups. We are working on creating valuable agroforestry practice networks, beyond and together with the ones already existing. At our own experimental farms we pioneer to translate and test theories on agroforestry in demo silvoarable agroforestry systems. With this approach we can, as a research institute, contribute to system innovation by answering relevant questions such as: how is a value chain for agroforestry products created? Which combinations of species are suitable and can we develop a model that can simulate design choices and the effect on yield and ecosystem services? How do partnerships between entrepreneurs look like? Which technologies and mechanization is available or has to be developed in order to make agroforestry suitable for large farming operations?

Conclusion

Innovation projects and agricultural pioneers contribute to the collective pool of knowledge with opportunities and threats to transition and innovation. When this network is connected to knowledge and education institutions, such as WUR an inspiring agroforestry learning network can grow. We as WUR take the role of facilitator of this process to make vital connections, finding shared ambitions and forming alliances. We are still in the invention phase, since we started agroforestry research since one year. We need to go through several phases, in order to let the wider sector see the benefits of the innovation and being able to implement it at large scale. We are well ahead on pathway 2; the existing networks consisting of advice organizations, agricultural entrepreneurs and different other stakeholders are currently leading with inspiring examples. However, to be able to fully support them with sound fundamental and applied research and inspire the full width of the agro-food sector and national and regional policy makers with independent, reliable results we need to explore and invest in pathway 1. The two pathways of system innovation combined, both creation of innovation and the practical application of the innovations, can lead the way to the future.

References

Beers PK (2011) Met netwerken innovaties stimuleren. Syscope magazine, autumn pp. 13-15.

Cuperus F (2017) Verslag inspiratiebijeenkomst November 2017, Almere, staff publication, Applied Plant Research, Wageningen University & Research, Lelystad.

den Herder MD, Moreno G, Mosquera-Losada RM, Palma JH, Sidiropoulou A, Freijanes JJ, Burgess PJ (2017) Current extent and stratification of agroforestry in the European Union. Agr Ecosyst Environ 241: 121-132.

Eurostat (2015) LUCAS Land Use and Land Cover Survey. Eurostat Statistics explained. http://ec.europa.eu/eurostat/statistics-explained/index.php/LUCAS_-_Land_use_and_land_cover_survey (accessed 16/04/2018).

Klerkx L, Aarts N, Leeuwis C (2010) Adaptive management in agricultural innovation systems: The interactions between innovation networks and their environment. Agr Syst 103: 390–400.

Meijer BJM, Wijnands FG, Vogelezang JVM (2010) Systems Innovations in Agriculture in the Netherlands, report nr. 340. Applied Plant Research, Lelystad, The Netherlands.

Sukkel W (n.d.) Networks and innovation in agriculture, staff presentation. Applied Plant Research, Wageningen University and Research.

Vogelezang JVM, Wijnands FG (2011) Working methodologically on system innovations. Syscope magazine, summer edition. http://library.wur.nl/WebQuery/wurpubs/fulltext/185014 (accessed 16/04/2018).

Wijnands F (2005) Transitie en innovatie, Syscope magazine.

CONSTRAINTS TOWARDS ORGANIC CONVERSION IN AGROFORESTRY SYSTEMS: THE CASE OF DEHESA LIVESTOCK FARMS IN EXTREMADURA (SW SPAIN)

Horrillo A[1], Elghannam A[1], Gaspar P[1*], Escribano M[1], Mesías FJ[1]

(1) Research Institute of Agricultural Resources (INURA), University of Extremadura. Avda. Adolfo Suarez, s/n – 06007, Badajoz, Spain

*Corresponding author: pgaspar@unex.es

Abstract

The dehesa is a unique ecosystem within the European territory; it provides an important set of environmental, cultural, aesthetic, and economic values. This paper presents the preliminary results of a research project carried out in the Spanish region of Extremadura, region highly covered by dehesa agroforestry system. The first objective of the project is to analyse the situation of livestock production systems that are located in such agroforestry with the aim to identify what are the main limitations that livestock farmers find for their conversion to organic production. Implementation of sustainable management techniques guarantees the dehesa's economic viability and organic model can be a suitable strategy. A participatory research has been conducted: four focus group sessions were carried out with a total of 33 participants. Preliminary results have shown that limitations can be classified in 8 categories: raw material availability, training, production techniques, processing, product certification, marketing, consumption and regulations.

Keywords: organic, extensive livestock, participatory research, conversion

Introduction

The dehesa is a unique ecosystem within the European territory; it provides an important set of environmental, cultural, aesthetic, and economic values. Unfortunately, these systems are in decline as a result of multiple factors among them the lack of profitability is highlighted (Gaspar et al. 2007).

Currently, all stakeholders involved in such ecosystems consider that the implementation of sustainable management techniques guarantees the dehesa's economic viability in order to obtain products efficiently (López-Sánchez et al. 2016). These systems are characterized by a wide range of products among them the extensive livestock systems, such as cattle, sheep and pigs, in addition to goats, poultry and horses, are found to be the most important.

In Europe, dehesa is the most widespread agroforestry system, counting around 5.5 million hectares in Spain and 1.2 million of hectares in Portugal (den Herder et al. 2017). In Spain, Extremadura is the region with the largest areas of dehesas. The most recent estimates of forestry reported 2.2 million hectares of dehesas in Extremadura which is considered the basis of socio-economic and cultural activities in this region (CAYMA 2003)

This paper presents the preliminary results of a research project carried out in the region of Extremadura. The objective of the project is to foster the conversion of livestock farms located in dehesa ecosystems in a model of sustainable organic livestock production in the region. The extensive livestock production systems located on dehesas are very close to the organic production models. Although its conversion is possible from a technical point of view, its practical applicability is rather limited (Horrillo et al. 2016). Marketing of products certified as organic is a tool that could add value to all livestock productions of these systems and consequently increase its profitability.

As a first stage of the project, a diagnosis of the situation of livestock production systems that are located in dehesas is to be carried out with the aim to identify what are the main limitations that dehesa farmers would find for their conversion to organic models, then to search for participatory solutions that are applicable at the regional level. Livestock farms are located in the same environmental, social and administrative context. Therefore, the problems and solutions are shared, and in many cases the policy makers at the regional level are those who will have to adopt policies and take decisions.

Materials and methods

The project begins with a participatory process through qualitative research using focus group techniques, in which different dynamics are working. Figure 1 shows the process followed in this first phase of diagnosis. The four focus group sessions were carried out with a total of 33 participants who were selected among stakeholders involved in the management of livestock systems that is located in dehesas of Extremadura. Each focus group session was developed with six to ten participants of both genders (72.8% men and 27.2% women) with ages ranging between 30 and 69 years, among them there were farmers of different species (sheep, cattle, pigs goats and poultry) both organic and conventional, representatives of management, technicians and operations consultants, researchers and representatives of agricultural associations. The sessions were developed during the month of February 2018, in four municipalities of Extremadura, in order to facilitate the participation of stakeholders from the whole region. The participants were located in large rooms comfortably seated around a table in order to enable interaction and eye contact. All the sessions were conducted by a trained moderator and recorded on video and audio for further analysis. The total work time of each session was around 120 minutes and the all the sessions were developed following a common protocol.

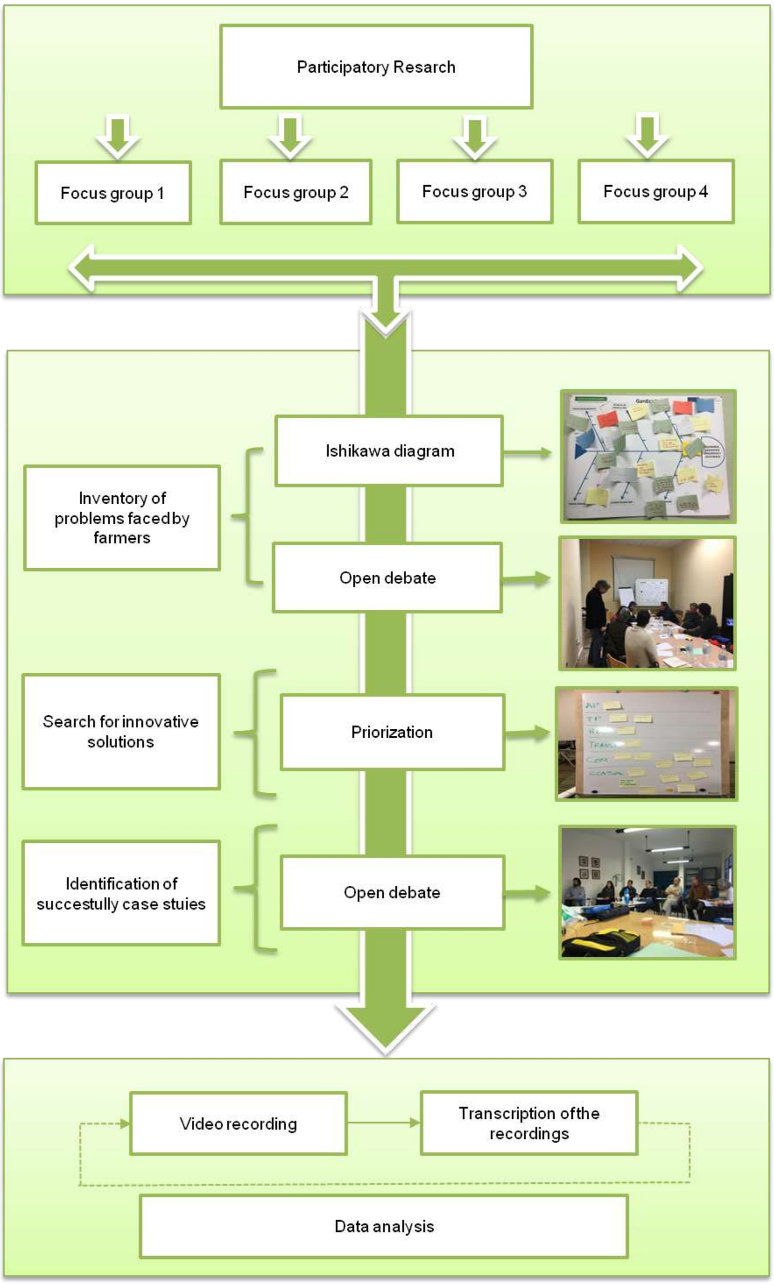


Figure 1: Methodological process.

Results

The first findings have identified a set of problems that are restricting livestock systems and prevent a conversion to an organic model of sustainable production. These problems have been grouped into eight categories which are described below.

1. Raw material availability: for participants one of the main problems found was related to high prices of organic raw materials that directly affect the economic viability of the small family farmers. Concerning this discussion, the participants with farmers´ profile mentioned that the regulations of the communal pastures use of organic farms that share territory with conventional farms does not allow farmers to use those pastures that are necessary for self-sufficiency.

2. Training: participants agreed upon the lack of knowledge of organic production techniques among farmers in the sector which is attributed to the lack of training, and also to the lack of initiatives such as, technical training aids for farmers and both public and private technical expertise.

3. Production techniques: participants concluded that due to the production techniques that legislation requires them to comply, such as the reduction in the stocking of their holdings, the farms' economic benefits has been reduced although it is only partially compensated by the agri-environmental aids currently valid in the region.

4. Regulation: In this section participants listed many problems which could be grouped into three subcategories, although all of them are directly linked to the regulations, they also have different interpretations.

Problems related to the regulation of the sector and examples of how participants expressed the problem appear in Table 1.

Table 1: Problems identified related to regulations: subcategories and examples given by participants.

Subcategory	Examples
Aids management	"Poorly focused production aid" "Lack of subsidies"
Excess of bureaucracy	"Strict and administrative complexity" "The administration as destroyer of the sector"
Animal health regulations	"Animal health, administration management against tuberculosis is controversial"

5. Processing: the participants have highlighted the absence of development in the processing industry in the region. Also the continuous decrease of slaughterhouses especially those who comply with the regulation for organic animals. In this sense, participants talked about the lack of initiative for the organic livestock sector, comparing this with other more developed in the Autonomous Community of Extremadura as it is the case of the fruit sector. For this reason participants argued that although quite much organic products are produced, they end up marketed as conventional.

6. Technical certification: participants with livestock profile commented on the lack of properly trained technical inspectors in organic farms, since sometimes it is observed that there are still many gaps in the interpretation or application of the organic standard at the time of certification.

7. Marketing: Participants do not find specified marketing chains in Extremadura where they can sell their organic products of animal origin, they also describe the sector as not properly united and they believe that a wider grouping is needed to get a more homogeneous product and ensure a continuous supply.

8. Consumption: According to the participants the consumer does not have sufficient information about the systems and techniques of organic livestock production due to the lack of public disclosure, so they confuse animal production systems without differentiating the sustainability thereof.

In the light of these preliminary results we can say that the problems identified are very diverse and that the search for solutions has to be adapted to respond to each one of them. The responsibility that is attributed to the administration in the application of rules and the lack of support for the sector is going to be one of the future research lines in order to establish collaboration between policy makers and farmers to make progress in the conversion of livestock production systems to organic and sustainable production models.

Acknowledgments

The authors would like to acknowledge the support and funding provided by the Junta de Extremadura and FEDER Funds within the V Plan Regional de I+D+i (2014-2017) through the Research Project GanEcoEx (Project reference IB16057) which made this research possible.

References

CAYMA (2003) Plan Forestal de Extremadura. Consejería de Agricultura y medio Ambiente de la Junta de Extremadura, Mérida, Spain.

den Herder M, Moreno G, Mosquera-Losada RM et al (2017) Current extent and stratification of agroforestry in the European Union. Agric Ecosyst Environ 241: 121–132.

Gaspar P, Mesías FJ, Escribano M et al (2007) Economic and management characterization of dehesa farms: Implications for their sustainability. Agrofort Syst 71: 151-162.

Horrillo A, Escribano M, Mesias FJ, Elghannam A, Gaspar P (2016) Is there a future for organic production in high ecological value ecosystems? Agric Syst 143: 114-125.

López-Sánchez A, Perea R, Dirzo R, Roig S (2016) Livestock vs. wild ungulate management in the conservation of Mediterranean dehesas: Implications for oak regeneration. For Ecol Manage 362: 99–106.

EXPLORING THE ECONOMIC POTENTIAL OF TWO FOOD FOREST FARMS IN THE NETHERLANDS

Oosterhof G[1]*, Masselink S[1], Van Dorp D[1], Van Dooren N[1], Eweg R[1], Stobbelaar DJ[1]

(1) Van Hall Larenstein University of Applied Sciences, Velp, The Netherlands

*Corresponding author: Geartsje.oosterhof@hvhl.nl

Abstract

The aim of our research was to search for viable business models for two business cases in The Netherlands: a commercial polyculture garden (Sprankenhof) and a Robinia forest with pigs (Boeren in het Bos). Our theoretical starting point is that small and medium-sized companies can adopt in general three sustainable development strategies: i) Intensification: cooperation to establish a base of public support for new intensive methods of production; ii) Valorisation: cooperation with new chain partners to open up existing markets; iii) Diversification: cooperation for new products and markets. In the companies surveyed, the diversification strategy is already being used at Sprankenhof and it appears to be a good choice, while the company Boeren in de Bos is trying to intensify sustainable pig farming, with the developing food forest supporting the pig farming. They focus on sustainable intensification by farming in a sustainable way to generate public acceptance and appreciation.

Keywords: valuable business models; development strategies; food forest; natural pig farming; polyculture garden

Introduction

It is generally assumed but not well documented that food forests have considerable positive ecological and social effects (Erisman et al. 2016). Moreover, not much is known about the economic viability of food forest enterprises. As of now, farmers who want to switch to (or include) a food forest in their enterprise cannot rely on reliable data and may hesitate to do so.

The aim of our research was to search for viable business models for two business cases in The Netherlands: a commercial polyculture garden (Sprankenhof) and a Robinia forest with pigs (Boeren in het Bos).

Materials and methods

Our theoretical starting point is that small and medium-sized companies can adopt in general three sustainable development strategies (Alvorst et al. 2011): i) Intensification: cooperation to establish a base of public support for new intensive methods of production; ii) Valorisation: cooperation with new chain partners to open up existing markets; iii) Diversification: cooperation for new products and markets

To be able to assess the feasibility of these development directions, the companies were analysed on the basis of canvas business model (Osterwalder 2010) and a client-based interview according to Aranya (2013).

The two companies studied are Boeren in het Bos (Farmers in the forest) (in Makkinga, province of Friesland) and the Sprankenhof (in Udenhout, province of Brabant). On the basis of these analyses, a number of scenarios have been set up and assessed and ultimately recommendations have been made for future development of the companies. A general discussion about what these results mean for the development food forests in The Netherlands concludes the article.

Description of the companies

Case Sprankenhof

The 4 ha plot Sprankenhof in Udenhout started in 2002 gradually evolved into a self-picking garden with fruit and vegetables (www.sprankenhof.com) (Figure 1). The picking garden is the main business of the company. In the design of the picking garden, wooded banks have been included, these are partially planted with edible species including nuts. In the garden there are also some 60 laying hens, in fenced areas protected from predators. Other activities offered by the farm include processing the vegetables into include jams and chutneys, offering cooking workshops, a shop, a guest house for meetings or private gatherings. Most of the income comes from the picking garden. Both entrepreneurs live and work on the property and their objective is to realize an income for both, whereby the current consultancy work for 3 days per week will be continued. They also want to make the wooded banks more edible.

Figure 1: Map of De Sprankenhof.

A number of business development options have been identified for the Sprankenhof, resulting in an increase in turnover. The described developments are examples of diversification.

1. Expanding the store and the product range with other sustainable products ('forgotten vegetables'), preferably from their own land but also from other producers (strategies: intensification and diversification).
2. Making better use of the premises on the property and investing in a break and breakfast. This will result in higher visitor numbers of the picking garden even in the low season and will increase the publicity of the company by the word-of-mouth. The investment for six rooms is an estimated € 250,000 (1000 euros / m^2, 250 m^2) which will result in revenues of an estimated € 50,000 - 80,000 per year gross income. This amount can be earned extra through the break and breakfast, without a lot of extra time to do (strategy: diversification).
3. Applying for a catering permit to serve beer, coffee and tea. This could attract families who would like to spend a few hours with their (grand) children while visiting the picking garden and shop (strategy: diversification).
4. Renting the cooking part of the company to chef entrepreneurs (strategy: diversification).

The combination of expanding the shop, both in terms of size and diversity, along with investing in a B & B in the existing, currently used premises, will strongly support the main objective of both entrepreneurs: to attract more visitors numbers to the Sprankenhof and the picking garden, even in the low season. In addition to this, both initiatives will have a direct positive effect on sales and profitability and the Sprankenhof is likely to provide a living for the family. For the long term the addition of a food forest will contribute to biodiversity, experience and marketing. For the short term it doesn't give financial advantage.

Case Boeren in het Bos (Farmers in the Forest)

The company Boeren in het Bos in Makkinga, use a total of 61 ha of forest for the Tamworth pigs divided over 3 locations: 7 ha of State Forestry Commission (SBB), 32 ha of a private owner and 22 ha Robinia forest of private owners (Figure 2). The operation includes 8 sows with their piglets and meat pigs (March 2018). In total there are approximately 150 animals. Farmers in the Forest have a closed pig farming system, which means that the meat pigs come from their own sows. The 8 sows annually produce 96 piglets (8 sows with 2 litters of 6 piglets each) and the following year 96 fattening pigs are available for sale. In 2017, 10 meat pigs were sold. The entrepreneurs plan to sell 25 meat pigs in 2018. In the case of unchanged operations, more meat pigs will be available than are currently sold. Holding the pigs too long increases the cost price, including the amount of labor.

If necessary, the entrepreneurs make use of alternate plots for fattening the sows and boars. The sows, piglets and meat pigs are kept outside all year round with shelters. In winter, the pigs are supplemented with whey and kitchen leftovers (swill) and water is brought to the pigs. The pigs are sold through shops, especially health food stores. A web store has also been set up (www.boereninhetbos.nl). The transition from the Robinia forest to the food forest is still in progress and no planting has yet taken place. The general aim is to generate an income for 2.5 fte (1.0 fte 35,000 euros).

Figure 2: Map of robinabos, Makkinga, Boeren in het Bos.

For Farmers in the Forest, three options have been identified that can significantly contribute to the growth in the turnover of the company and that can be earned back at an economically attractive instalment at acceptable costs. The described options are part of a sustainable intensification strategy.

1. Setting up a continuous crowd-farming initiative. This is a promising initiative for the company, which can have several positive effects on the operating result. Firstly, crowd farming will bring in the necessary work capital, which is pivotal to develop growth initiatives (investment in a pop up store, online distribution, investments in online marketing, etc). Secondly, it brings highly committed financiers who can also become regular customers and/or ambassadors and voluntary marketers of the company, the products and the online platform. Crowd farming and the accompanying digital portal, the underlying organization requires a somewhat larger investment in money (€ 300 - 1,000) and time (working hours). However, the research indicates that this initiative is both a solution for the financing of the business activities and will be an important

stimulus for further revenue growth, also outside the local target market in the rest of the country (strategy: intensification?).

2. Setting up a mobile popup outlet. This results in a relatively low investment (estimate: € 400, excluding the cost of labor or time) that gives the company the opportunity to increase brand awareness on local markets and to attract the niche target group more directly, e.g. the environmentally conscious consumer and sustainable investor. In this way the company will find the most dedicated consumers in the local market faster and vice versa (strategy: intensification?).

3. Increasing the revenues and reducing the costs. The company has indicated to seek an income for 1.5 fte from pig farming and 1 fte from cows. The sale of meat pigs requires at least a calculated number of 80 animals (15 euros / kg and 80% meat and correction for variable costs). In view of the entrepreneurs' objective, increasing the sales is paramount.

The three options are complementary to each other and as such "cross sells". The research shows that the initiatives of crowd farming and popup store combined with smart choices such as timely and sufficient sales of pigs can increase the turnover by an average of 10% (conservative estimate) to 20% (optimistic estimate) per year for the coming 5 years. A CAGR (cumulative aggregated growth ratio) of 10% in the period 2018 - 2023 would increase the turnover in 5 years by more than 60% in total. If this ratio would reach the 20% with the aid of the initiatives discussed, 5% of turnover would be able to achieve a growth of more than 140% in 5 years. Such sales growth figures in combination with a reduction of, for example, distribution costs could lead to economic economies of scale and improved profitability, which have not even been included in this study.

Discussion and conclusion

In the companies surveyed, the diversification strategy is already being used at Sprankenhof and it appears to be a good choice, while the company Boeren in het Bos is trying to intensify sustainable pig farming, with the developing food forest supporting the pig farming. They focus on sustainable intensification by farming in a sustainable way to generate public acceptance and appreciation (Altvorst et al. 2011).

For the Sprankenhof, the addition of a food forest to the business operations does not give a financial advantage in the short term. In the longer term it will give an addition in biodiversity, appearance, experience and marketing (Oosterhof et al. 2018). Further diversification with a store and Bed and Breakfast will generate an increase in income.

For Boeren in het Bos, the size of the pig stock is not in balance with the sales. Experience from other pig farmers shows that the market is limited for this luxury product, but is growing cautiously. Keeping the production and marketing balance in mind requires further research and monitoring.

In this way, food forests can contribute to a larger attraction of a company (Sprankenhof) where the 'real' money is earned mainly in B & B, etc. or to produce a recognizable niche product such as a pig in the forest, which can be sold as a luxury product.

References

Altvorst AC, Andeweg K, Eweg R, van Latesteijn H, Mager S, Spaans L (2011) Sustainable Agricultural Entrepreneurship: the urban area as engine for new economic activity: the six guises of the successful agricultural entrepreneur illustrated on the basis of nine projects. Transforum, Zoetermeer.

Aranya (2013) Permaculture Design: A Step by Step Guide. Huyden House Ltd.

Erisman JW, van Eekeren N, de Wit J, Koopmans C, Cuijpers W, Oerlemans N, Koks BJ (2016) Agriculture and biodiversity: a better balance benefits both. AIMS Agriculture and Food 1:157-174.

Osterwalder A and Y.Pigneur (2010) Business Model Generation: a handbook for visionaries, game changers and challengers. John Wiley and Sons, INc, Hoboken, New Yersey.

Session

Costs and revenues of agroforestry on the scale of the individual farm, a region and a state; proven practice and theoretical models

COMPARISON OF THE PROFITABILITY OF AN ARABLE ROTATION, A MONOCULTURE OLIVE SYSTEM AND A SILVOARABLE SYSTEM IN GREECE USING THE FARM-SAFE MODEL

Baron G[1*], Giannitsopoulos M[2], Pantera A[3], Graves A[2], Burgess PJ[2]

(1) Agrocampus Ouest, Rue de Saint-Brieuc, 35000, Rennes, France (2) Cranfield University, Cranfield, Bedfordshire, MK43 0AL, United Kingdom (3) TEI Stereas Elladas, Karpenissi, Greece

*Corresponding author: gildas.baron@yahoo.fr

Abstract

This study focused on the comparison of the profitability of three different production systems: an arable system, an intensive olive production and a silvoarable system which combine the two previous ones. For this, the Farm-SAFE model has been used, it considers many costs and incomes for each production and returns a simulated Net Margin and annual value. The silvoarable system appears to be the most efficient on a 60 year cycle. The olive production is an important source of incomes, but combining it with an arable production permits to cover and lower the investment costs and to vary the productions is safer.

Keywords: silvoarable; olive; arable; profitability; Farm-SAFE; economic modelisation

Introduction

Faced with climate variability and high fertiliser costs, there is increasing interest in developing sustainable agricultural systems in Greece. Pantera et al. (2017) in Molos, Greece has demonstrated that olive production in the area intercropped with nitrogen-fixing chickpeas was similar to where there was no intercrop. This paper compares three potential systems: i) an arable system with a five-year rotation of wheat/chickpeas/barley/grass-clover mixture/lentils, ii) an intensive olive production system with 280 irrigated trees/ha and a iii) silvoarable system with the same crop rotation and 100 olive trees/ha. The profitability of the three systems was determined using the Farm-SAFE economic model (Graves et al. 2011).

Materials and methods

Even if some studies proved some important co-benefits for trees and crops of being grown on the same plot, these benefits have not been much estimated on the economic point. The profitabilities of the three systems (arable/intensive olive/silvoarable combining the 2 first ones) were compared here in terms of the cumulative net margin (CNM), the net present value (NPV) and an equivalent annual value (EAV) for a 60 year simulation cycle. A discount rate of 4% was assumed to derive the NPV and the EAV, which is the discount rate typically assumed by the European Commission (European Commission 2014). There is an annex at the end of the article explaining what mean these economic concepts. The data for the arable and olive grove systems were collected from farmers, and the data for the agroforestry system was calculated on a pro-rata basis. For the agroforestry arable crops, the crop data were multiplied by the crop area of the virtual silvoarable field (85%); and the cost of the agroforestry olive trees was assumed to be related to ratio of the tree density (100/280). The two parameters where the data were assumed not be pro-rata were the olive yields, which were assumed to be 10% higher per tree, due to the lower tree density of trees, and the irrigation cost per tree which was assumed to be 50% lower per tree. The silvoarable yields were calculated for two scenarios: with the default olive and arable yields (Scenario 1) and with 75% of booth of those yields (Scenario 2).

Results

In the initial 13 years of the simulation, the greatest cumulative net margin was obtained from the arable system (as there were no establishment costs for the olive trees) (Figure 1). However after 13 years, the cumulative net margin of the silvoarable system (Scenario 1) was calculated to be greater than the olive-only and the crop-only systems (Figure 1). The silvoarable system with 75% yields (Scenario 2) was calculated to be more profitable than the arable system after 23 years. The olive-tree only system was assumed to have a negative cumulative net margin for the first 33 years due to the high establishment costs and the long time for the trees to produce high yields. The olive tree only system was calculated to become more profitable than the arable system after 41 years and more profitable than the 75% silvoarable system (Scenario 2) after 56 years.

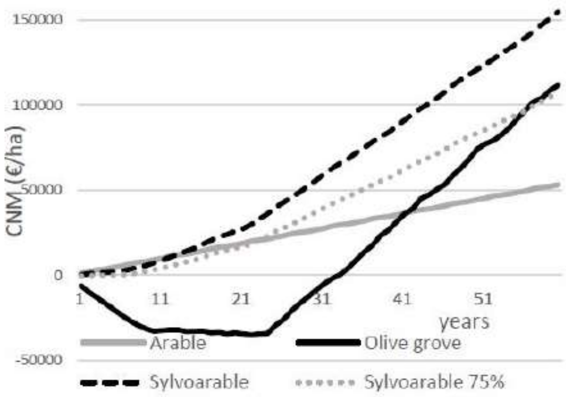


Figure 1: Comparison of simulated cumulative net margin of the arable system, the olive grove system and the silvoarable system with the default yields (Scenario 1), and with 75% of the default yields (Scenario 2).

A sensitivity analysis was used to examine the sensitivity of the cumulative net margin after 60 years. After 60 years, even with no crop production (-100% = 0% of the expected yield), the silvoarable system was calculated to be more profitable than the arable system (Figure 2a). The silvoarable system was also more profitable than the arable system, if the yields were only 25% of those expected (Figure 2a). The cumulative net margin of the silvoarable system after 60 years was more sensitive to changes in the olive yields (Figure 2b). The silvoarable system was more profitable than the arable system if olive yields were at least 25% of the default assumption, and was more profitable than the olive tree-only system if the olive yields were 60% of the expected yields (Figure 2b).

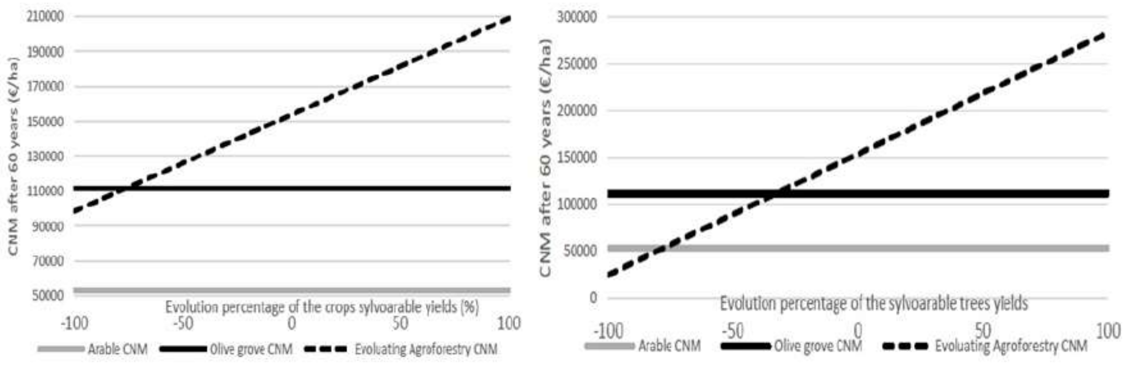


Figure 2: Sensitivity of the cumulative net margin of the arable, silvoarable (Scenario 1), and olive tree only systems after 60 years to a) arable crop yields, and b) olive yields.

The annual net present value (assuming a 4% discount rate) of each project varies during the 60 year simulation (Figure 3). The arable NPV per decade decreased steadily during the simulation. The intensive olive grove starts with a very negative NPV but it increases until the fourth decade so that it has the highest annual NPV during the three last decades. The mean net present value per decade of the silvoarable system was always positive and also relatively stable increasing up to the third decade before declining. The NPV in the first 10 years is below the arable system because of the high establishment costs of the trees and the very low productivity of the olives during the first seven years until it reaches a maximum at about 30 years.

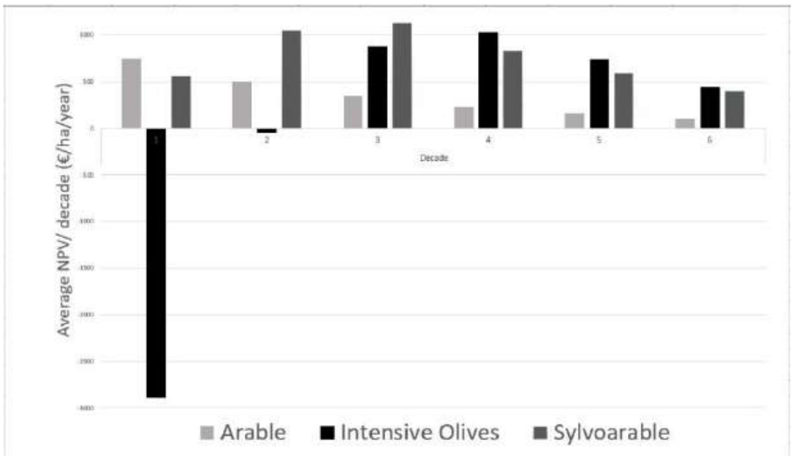


Figure 3: Mean annual net present value (assuming a 4% discount rate) for each decade for the arable, olive tree only and the default silvoarable system (Scenario 1).

The sensitivity of the equivalent annual value (over 60 years and assuming a discount rate of 4%) shows that the silvoarable system was the most profitable system under the default assumptions (Figure 4a) and assuming 75% of the default yields (Figure 4b). The olive tree-only system and the arable systems needed a 50% and a 75% increase in yield respectively to become more profitable than the default silvoarable system (Figure 4a). In Scenario 2, if the silvoarable system yields were only 75% of the default system, both the arable-only and the tree-only became more profitible if the yields of those systems were 35% higher than the expected levels.

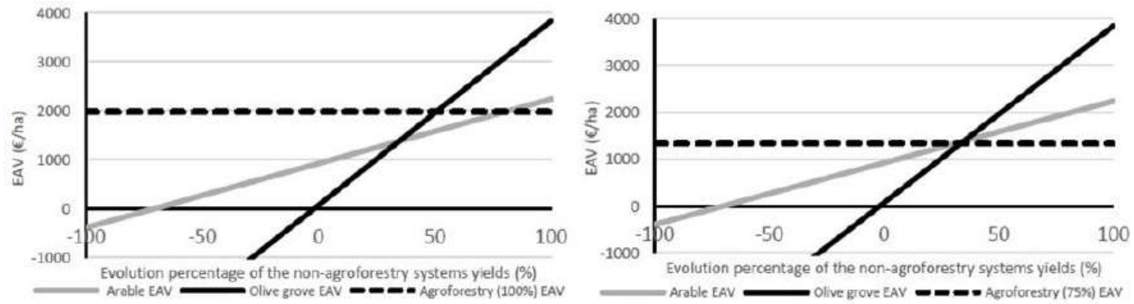


Figure 4: The sensitivity of the equivalent annual value of the arable-only and the olive tree-only to yields relative to the silvoarable system a) (Scenario 1) and b) (Scenario 2).

These results must be looked carefully. Indeed, we can regret that the data (costs & incomes) comes from different sources, which mean different agronomy contexts. Also, most of the machinery costs have not been consider, but the machinery costs of the silvoarable system are surely higher than the other systems. Most of the crops-trees interactions are not consider too, it probably leads to a bias.

Conclusion

It was possible to use the Farm-SAFE model to compare the profitability of an arable-only, an olive tree only, and two silvoarable systems in Greece. The arable rotation was chosen so that it would theoretically be possible to develop an efficient organic system of production. On the basis of the assumptions made (including a 4% discount rate and a 60 year time-frame), the silvoarable system was more profitable than the arable-only and the tree-only systems.

Annex

Description of the economic concepts:

The cumulative net margin (**CMN**) represents at the end of a year the total amount of the net margin since the beginning of the project.

The net present value (**NPV**) in capital budgeting as an indicator of the profitability of a project, it is calculated by the following formula:

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_o$$

Where C_t= net cash inflow during the period t; C_o = total initial investment costs; r = discount rate, and t = number of time periods (Investopedia, s.d.)

The INPV (Infinite Net Present Value) is the NPV if the estimation of what would be the NPV if the project ran forever. Farm-SAFE model has a maximum period of simulation of 60 years, so it is based on a 60 years cycle.

The Equivalent Annual Value (**EAV**) or Equivalent Annual Annuity is the calculation of the constant annual cash flow that a project generates over its lifespan. The following formula is used to have it:

$C = (r \times NPV) / (1 - (1 + r)^{-n})$

Where: C = EAV; NPV = net present value; r = interest rate per period, and n = number of periods (Investopedia, s.d.)

References

European Commission (2014) Guide to Cost-Benefit Analysis of Investment Projects: Economic appraisal tool for Cohesion Policy 2014-2020. http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf (accessed 22/04/2018).

Graves AR, Burgess PJ, Liagre F, Terreaux JP, Borrel T, Dupraz C, Palma J, Herzog F (2011) Farm-SAFE: the process of developing a plot- and farm-scale model of arable, forestry and silvoarable economics. Agrofor Syst 81: 93-108.

Pantera A, Papadopoulos A, Kitsikopoulos D, Mantzanas K, Papanastasis V, Fotiadis G (2017) Lessons learnt: Olive agroforestry in Molos, Central Greece, Contribution to Deliverable 3.8 in EU FP7 project AGFORWARD (613520). http://www.agforward.eu/index.php/en/intercropping-of-olive-groves-in-greece.html (accessed 22/04/2018).

Investopedia. (s.d.). Equivalent Annual Annuity (EAA) approach. from Investopedia: https://www.investopedia.com/terms/e/equivalent-annual-annuity-approach.asp#ixzz557Z8NlWn (accessed 22/04/2018).

Investopedia. (s.d.). Net Present Value - NPV. from https://www.investopedia.com/terms/n/npv.asp#ixzz557ZHZAD1 (accessed 22/04/2018).

LIFE REGENERATE PROJECT: REVITALIZING MULTIFUNCTIONAL MEDITERRANEAN AGROSILVOPASTORAL SYSTEMS USING DYNAMIC AND PROFITABLE OPERATIONAL PRACTICES (LIFE16 ENV/ES/000276)

Mesias FJ[1]*, Moreno G[1], Kallen S[2], Sonneveld E[2], López-Sotelo J[2]

(1) Forestry Research Group, Universidad de Extremadura, Extremadura, Spain; (2) Volterra Ecosystems SL, Spain

*Corresponding author: fjmesias@unex.es

Abstract

LIFE Regenerate is seeking to recover the land and the economies of the oak-based silvopastoral systems of the Mediterranean basin biome through integral land, livestock and biomass waste management. Measures to be applied in this project with the aim to contributing to a more healthy and balanced ecosystem include: incorporating the innovating Keyline water management design to decrease water stress and strengthen the system overall, making it less vulnerable to extreme climatic and weather conditions; implement well managed, holistic and rotational grazing which can effectively clear organic material that would otherwise be at risk of catching fire; harness biological control of pests combined with the planting of native and medicinal plant species, and natural fertilization from livestock rotation to increase floral and faunal biodiversity; find alternative uses for biomass after pruning; eliminate agro-chemical use; and finally inoculate the soil with beneficial funghi to improve the soils’ biological properties and quality.

Keywords: silvopastoral systems; mosaic landscape management; rotational grazing; improving soil quality; circular economy in agricultural production systems

Introduction

The oak-based silvopastoral systems of the Mediterranean basin biome (for example *dehesas*, *montados* and *meriagos* that cover up to 6 million ha in the EU) (den Herder et al. 2016) are in rapid decline (Plieninger et al. 2015). Estimates show that dehesas currently produce a deficit of 200€/ha. Prices for their products are similar to those 30 years ago, and land owners face losses of up to 500€/ha due to *phytophtora*-related diseases. It is estimated that these agro silvopastoral lands have lost up to 20% of their value and currently lose millions of euros in productivity each year (Oviedo et al. 2015; Limón 2016).

Simultaneously, agro-subsidies are steadily decreasing. In 2015, farmers in Andalucía reported up to 60% of cutbacks in CAP subsidies. Regional subsidies in this area now only cover about 8% of landowners (Donaire 2015). In Sardinia, rural abandonment has caused an increasing of the number of rented and leased farms and the loss of local typical micro-economies.

Many anthropogenic and environmental factors challenge the survival and sustainability of these valuable ecosystems. The younger generation inheriting these broken systems needs to transform current production models into cost-efficient operations that work with nature, not against it. They will have to lower input costs, find alternative sources of income, recycle resources, stimulate natural regeneration, improve soil health and increase forage productivity and quality, and farm productivity so that their land can become economically and environmentally sustainable.

Costs and revenues of agroforestry on the scale of the individual farm, a region and a state; proven practice and theoretical models

LIFE Regenerate's main objective is to demonstrate that these SMEs can become self-sufficient and profitable based on resource efficiency principles and incorporating added value products, both at a demonstration and a larger scale.

The project has the following specific objectives:

1. Combat the loss of natural regeneration and soil degradation in 100 ha of degraded silvopastoral areas by providing effective, mosaic landscape management procedures and improving soil quality

2. Recover the practice of multi-species rotational grazing, adapted to improve natural capital and optimize commercial advantages

3. Recycle biomass waste from undergrowth and pruning within the farm, reducing external input of fodder and creating alternative sources of income

4. Replicate the project's best practices to 5,000 ha in Spain, Italy and Portugal, proving it is a representative, effective model

5. Integrate new technologies and monitoring of project advances

6. Influence policy-making and involve external stakeholders to promote replication and long term sustainability

Materials and methods

The project will demonstrate the potential of soil and ecosystem regeneration through proper management of livestock, pastures, woodland and cropland and the reuse and recycling of waste within the exploitations. The management plan will put into practice and combine knowledge uptake from other areas/sectors especially concerning grassland, agroforestry and livestock rotation; test innovative methods such as production of livestock fodder from biomass waste from undergrowth and pruning; evaluate the results obtained, provide viable farm and waste management models, disseminate and raise awareness on the issues and results; and involve external stakeholders to promote long-term sustainability. The main innovation behind this business model scheme is to break away from the trade-offs typically assumed to these types of management plans; mainly the idea that to achieve multi-functionality and conservation of natural resources, productivity must be sacrificed and vice versa. The different technical innovations used in the management strategy are listed below:

- Technical innovations on land-use
    - Keyline and contour line water management
    - Diversify plant species (e.g. medicinal plants + pastures)
    - Detection and healing of fungal diseases (*La Seca*) through trial designs of treatments for early detection. Since soil ploughing is an important vector of dispersion and infection, staff will be instructed on how to restrict it as much as possible. Keylines will be designed to reduce waterlogging or swamping since this reinforces *Phytophtora* infections. ID Forest will also design the steps to prevent the spread of the infection such as inoculation with beneficial mycorrhizae and lime amendments to improve tree health.
    - Inoculation of soil with beneficial bacteria and truffles for production
- Technical innovations in livestock planning
    - Mosaic movement imitations in rotational grazing, thereby avoiding overgrazing while simultaneously stimulating pasture production and quality

Costs and revenues of agroforestry on the scale of the individual farm, a region and a state; proven practice and theoretical models

- Introduce multispecies to grazing cycle to optimize nutritional intake for animals and improve soil fertility
- Grazing, fencing and smart water points which will protect livestock from wild animals and the diseases they may carry
- Improving livestock health by introducing legumes into the fields

- Technical innovations in biomass waste management
    - Alternative sources of income by harvesting, chipping and fermenting biomass from undergrowth and pruning, converting it into a rich humus which can be used as biofertilizer, or for high value mushroom production
    - The humus can also be used to feed beetle larvae, serving as an alternative source of protein for pigs, horses and poultry

This project will involve two different phases: demonstration and replication. During the demonstration stage, the model will be tested over 100 ha in Salamanca (40 ha in Spain, CSIC) and Sardinia (60 ha in Italy, NRD-UNISS). During the replication action, the area size will be scaled 50 times, to a total of at least 5,000 ha. We calculate that 3 years after the closure of the project, the above results will have multiplied with at least the same factor due to consolidation at partners and spill-over effects to other farmers and landowners taking up the regenerative practices.

Figure 1 shows the farm of Salamanca and the new paddock division in red where the trials will be carried out.

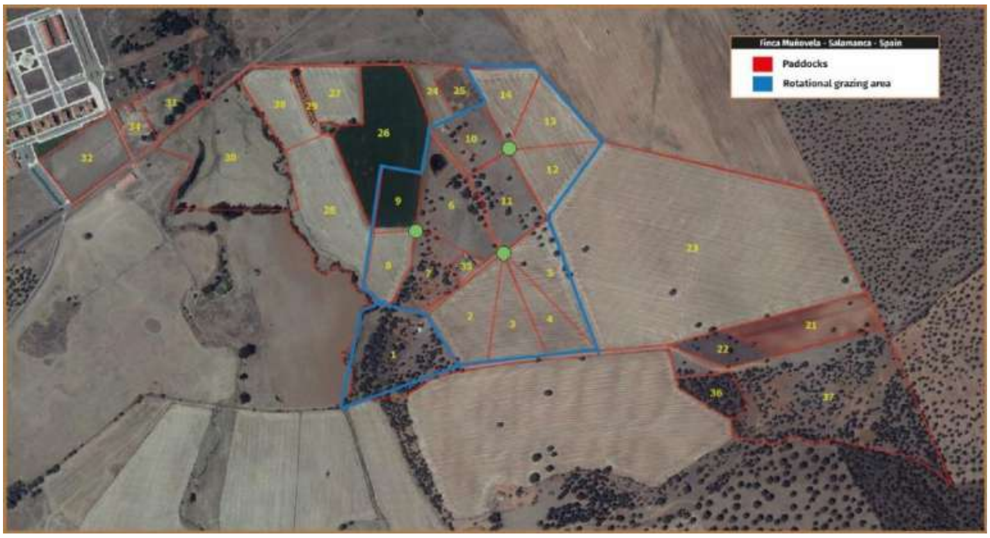


Figure 1: Farm “Muñovela” in Salamanca (Spain).

Expected results

The Regenerate project expects to achieve (summary of main principles in Figure 2):

1. Demonstration of an environmentally friendly, economically feasible and highly replicable business model for small and medium-sized farms in oak-based silvopastoral systems;
2. Economic benefits of €65,400 per year (€654 ha^{-1} $year^{-1}$), both from cost savings (less external feed and lower veterinary costs) and from additional income sources (free-range meat, mushrooms, truffle production, acorns, bedding for horses, and mulching), making the farms profitable and eliminating the need for subsidies;

Costs and revenues of agroforestry on the scale of the individual farm, a region and a state; proven practice and theoretical models

3. Total elimination of biomass waste, implementing a circular economy approach and recycling waste into value-added resources;
4. Improvement of soil quality (30-50%) by increasing the carbon sink, water retention capacity, soil nutrient availability, beneficial microorganisms, and prevention of erosion;
5. Improvement of pasture production and pasture quality (25-50% of agricultural land), leading to self-sufficiency in animal feed and higher profitability of livestock-raising practices;
6. Increase in plant diversity (15%) and overall biodiversity (20%). The project will plant 2,000 new multi-species trees during the demonstration phase;
7. Improvement of tree health and resilience in 50 ha of woodlands;
8. Overall increase in animal health and productivity, through reduction in mortality and decrease in calving intervals;
9. Active knowledge transfer and up-scaling through replication and training courses.

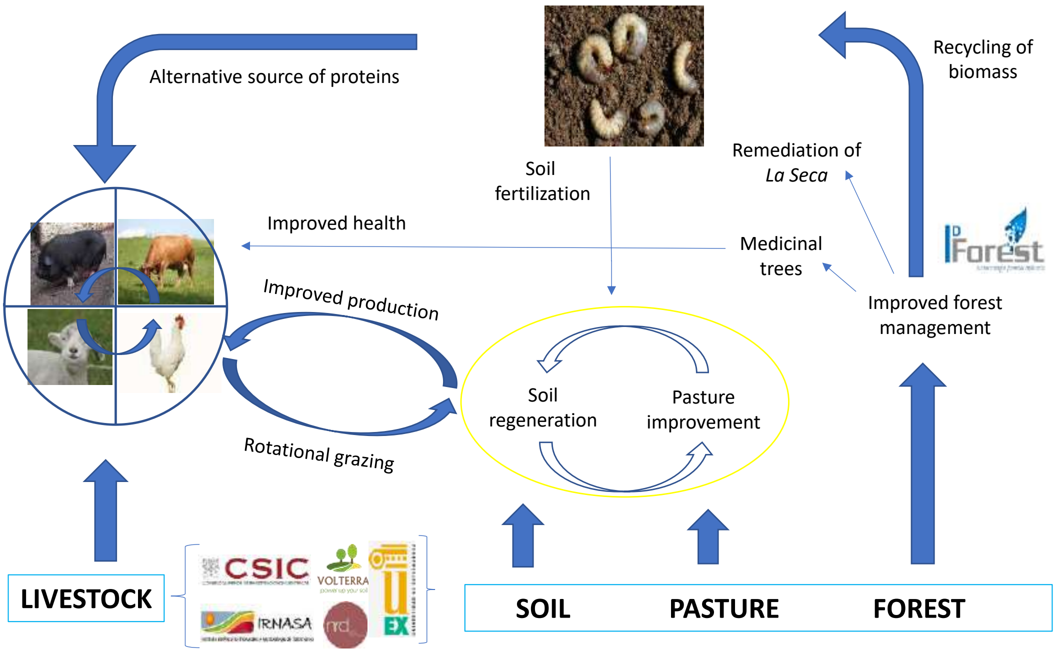


Figure 2: Circular economy principles put in practice in the LIFE Regenerate project.

Acknowledgements

This project is co-funded by the European Commission's LIFE programme.

References

den Herder M, Moreno G, Mosquera-Losada RM, Palma JH, Sidiropoulou A, Freijanes JJ, Papanastasis VP (2017) Current extent and stratification of agroforestry in the European Union. Agr Ecosyst Environ 241: 121-132.

Donaire G (2015) Los ganaderos advierten de la rebaja del 60% de las ayudas en la dehesa El País, 26 April 2015.

Limón R (2016) La falta de rentabilidad acelera el abandono de las dehesas El País, 16 August 2016

Oviedo JL, Huntsinger L, Campos P 2015 Landowner total income from oak woodland working landscapes in Spain and California. Proceedings of the Seventh California oak symposium: Managing oak woodlands in a dynamic world, pp. 3-6.

Plieninger T, Hartel T, Martín-López B, Beaufoy G, Bergmeier E, Kirby K, Montero MJ, Moreno G, Oteros-Rozas E, Van Uytvanck J (2015) Wood-pastures of Europe: Geographic coverage, social–ecological values, conservation management, and policy implications. Biol Conserv 190: 70-79.

EXPLORING THE POTENCIAL OF AGROFORESTRY INTEGRATION IN ARABLE AND DAIRY FARMS IN THE NETHERLANS – AN EX-ANTE ASSESSMENT AT FIELD AND FARM LEVEL

Prins E[1*], Groot J[2]

(1) Student, Farming Systems Ecology, Wageningen UR, Wageningen, The Netherlands (2) Farming Systems Ecology, Wageningen UR, Wageningen, The Netherlands

*Corresponding author: prinske86@hotmail.com

Abstract

Integration of well-designed agroforestry configurations is considered as a promising avenue to maintain farm productivity, while simultaneously strengthening ecological functioning of agroecosystems. The complexity of farming systems and the lack of knowledge on the performance of these agroecologically sound practices under Dutch economic, climatic and environmental conditions hamper farmers to implement agroforestry. In this study we performed a model-based ex-ante analysis of the impact of agroforestry implementation on the economic and environmental performance of two existing farms in The Netherlands. At the field level, we show that two out of three of the designed agroforestry configurations (AFCs) outperformed the monoculture crops (triticale and pasture), resulting in higher financial margin and organic matter balance. Furthermore, we show that these configurations could be successfully integrated at the farm level, reducing or eliminating the existing trade-off between ecological and economical objectives. Further research is needed to develop process-based estimations of technical coefficients.

Keywords: agroforestry; The Netherlands; arable; dairy; FarmDESIGN; restoration agriculture

Introduction

Farming systems in temperate regions are dominated by crop monocultures and large reliance on external inputs such as artificial fertilizers and concentrate animal feeds, which result in pressure on ecological processes. Integration of well-designed agroforestry configurations is considered as a promising avenue to maintain farm productivity, while simultaneously strengthening ecological functioning of agroecosystems. The complexity of farming systems and the lack of knowledge on the performance of these agroecologically sound practices under Dutch economic, climatic and environmental conditions hamper farmers to implement agroforestry.

In this study we performed a model-based ex-ante analysis of the impact of agroforestry implementation on the economic and environmental performance of two existing farms in The Netherlands.

Materials and methods

We selected an arable and a dairy farm to explore opportunities for integrating agroforestry practices. The arable farm is certified as biodynamic and is situated between the cities of Arnhem and Nijmegen, The Netherlands. On an area of 15.6 ha, the farmer cultivates a small area of pumpkins and various cereals. The dairy farmer owns 20 ha of permanent pasture and rents ca. 15 ha for pasture and cultivation of silage maize. The herd consists of 63 Holstein-Frisian dairy cows.

Model and objectives

The FarmDESIGN model was used to explore opportunities to integrate predefined agroforestry configurations (AFCs) and to evaluate farm performance before and after integration of the AFCs. FarmDESIGN is a multi-objective optimization and design tool for farming systems (Groot et al. 2012). The Pareto-based Differential Evolution algorithm is used to generate sets of solutions that contain alternative farming system configurations. Optimization of farming systems is executed based on the objectives to maximize the organic matter (OM) balance and operating profit.

Designing agroforestry configurations

In consultation with the farmers, three agroforestry configurations (AFCs) were designed. For the determination of the AFCs, the farmers' personal preferences for certain perennials and initial expectations about costs and benefits served as initial starting points. Both farmers formulated the preconditions that the AFCs can be managed as natural systems, with low labour requirements for establishment, fertilization and crop protection, being aware that yield is not being maximized. The AFCs are displayed in Figure 1. The biomass flows from fine root turnover were considered in effective organic matter calculations, but not included as a separate crop product.

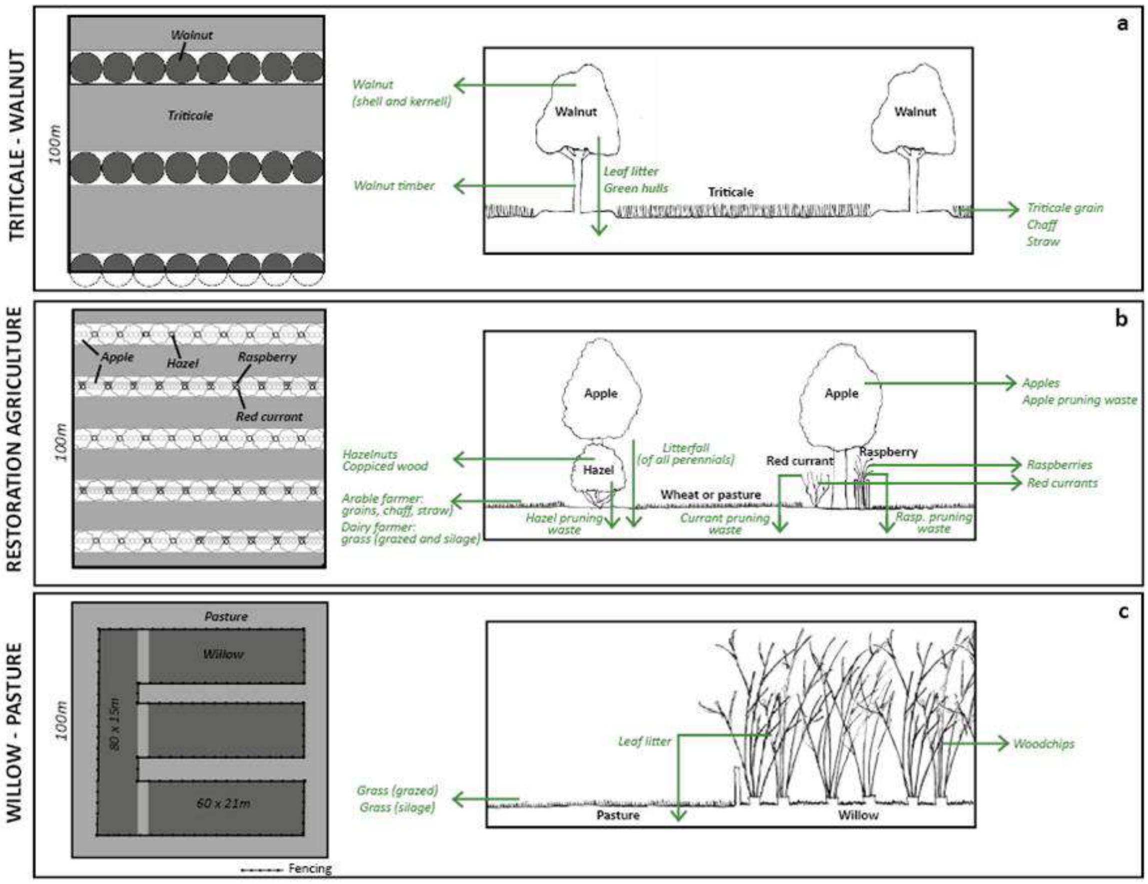


Figure 1: Schematic representation of the AFC triticale-walnut (arable farm; a), Restoration Agriculture (arable and dairy farm; b) and willow-pasture (dairy farm; c). Not true to scale. Left: one hectare of AFC at maturity, displayed from above. Right: a section of the crops (bold) and the flow of crop products (italic). Arrows pointing out of the box represent field outputs. Other biomass flows are circulated in the system. Fine root turnover is considered in EOM calculations.

Determining AFC parameters

All calculations, sources and considerations for determining AFCs parameters, together with the parameters of the AFCs, can be consulted in the supplementary materials 3-5. Crop experts were consulted to discuss the outcomes of the literature research to determine the final yield per AFC. FarmDESIGN summarizes outcomes throughout a year, while the yields are affected by dynamic processes that are affected by cultivation area per hectare AFC, interaction between components and yield formation per plant. To bypass this time dimension, the yields for different time periods were calculated and averaged. Prices of the crop products were kept equal to prices found at Dutch pick-your-own farms, in the literature and from the estimations by crop experts.

The majority of parameters on composition of food products were derived from the USDA Food Composition Database. Chemical constituents on pruning waste were determined by laboratory analyses of the biomass collected from a local pick-your-own farm.

To determine the costs per AFC, a list of all cultivation activities and investments was composed for each AFC. These lists included costs associated with the purchase of plants, plant support and fencing and the costs and labour associated with cultivation, such as planting, pruning, harvesting, mowing, shredding of pruning waste, and fertilization. Based on literature and estimations by the farmers and crop experts, labour demand of for all cultivation activities was estimated. Effective organic matter (EOM) at the field level was determined by multiplying biomass of shredded pruned materials, fine root turnover and litterfall by their humification coefficients, which were approximated based on literature. It was taken into account that the system increases its organic matter production as the system matures, by estimating organic matter production in different time periods. An average of the organic matter production over the entire rotation was used as a field parameter.

Figure 2 shows the margin and input on the organic matter balance of each crop. Restoration Agriculture is outperforming the other crops on both axis and triticale-walnut outperforms sole triticale. Willow-pasture considerably improves the organic matter balance but has a negative margin.

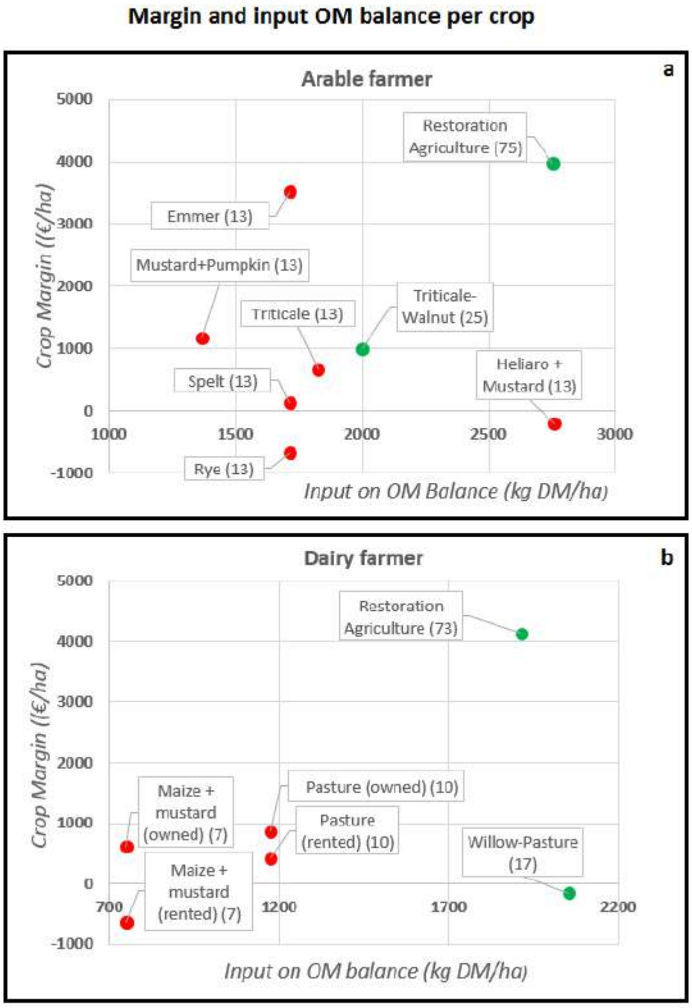


Figure 2: Performance of crop production activities in terms of contribution to soil organic matter and gross margin for current crops (red) and agroforestry fields (green) for the arable (a) and dairy farm (b). Regular labour (hours/ha) is displayed between parentheses, but is not included in the crop margin calculations on field level. The input on OM balance does not include OM inputs by imported manure and fertilizers.

Results

In this study, different explorations where executed. Due to the limited extent of this abstract, we only discuss the outcomes of integrating the AFC triticale-walnut at the arable farm and the AFC restoration agriculture at the dairy farm. Restoration agriculture performed similarly at the dairy and the arable farm.

Arable farmer: Exploration with triticale-walnut

With the inclusion of the triticale-walnut field, both higher operating profit and organic matter balance can be achieved. The exploration of the current farm (light) and the exploration of the farm with triticale-walnut configuration (dark) are combined in Figure 3a.

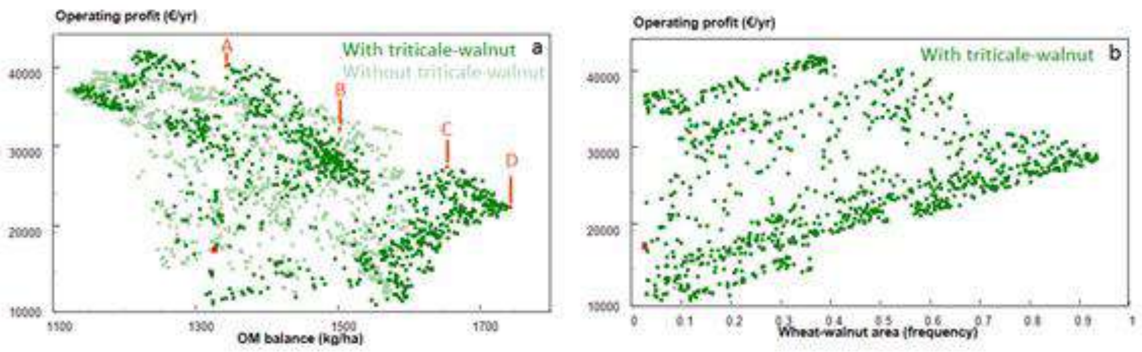


Figure 3: Outcomes of the exploration of the arable farmer with the triticale-walnut configuration along the objectives operating profit, OM balance, area of desired cereals and triticale-walnut area.

Along the trade-off front 4 non-dominated configurations were selected. Option A shows the best financial performance (€40,100) while still improving the OM balance. This is the result of a rotation with three crops with high margins (8.4 of triticale-walnut, 4.7 ha emmer and 1.7 hectare pumpkin). An higher OM balance could be achieved by option B (11.5 ha of triticale-walnut, 2.2 ha pumpkin and 1.2 ha heliaro) and option C (7.8 ha triticale walnut, 4.5 ha heliaro, 2 ha emmer) at the expense of a decrease in operating profit. Option D is the outcome of 10 ha of triticale-walnut and 5 ha of heliaro. Large areas of triticale-walnut were found in the configuration along the entire trade-off frontier, indicating triticale-walnut contributes to both operating profit and OM balance. The shape of the cloud point of Figure 3b shows a positive relation between operating profit and triticale-walnut cultivation. However, along the trade-off frontier an increase of triticale-walnut results in lower operating profits.

Dairy farmer: Exploration with Restoration Agriculture

For the integration of Restoration Agriculture at the dairy farm three explorations are executed, with 0, 5 and 10 ha of Restoration Agriculture as starting points (Figure 4). Without Restoration agriculture a maximal operating profit of €31,800/yr (A) was the result of increasing grass silage and maize import while decreasing purchase of concentrates. To obtain a higher OM balance, more maize silage, concentrates and bedding materials are imported, resulting in a lower financial performance (B and C). The implementation of 5 ha Restoration Agriculture AFC resulted in options to increase operating profit and OM balance (D, E and F in Figure 4). With 10 hectares Restoration Agriculture 7-11 ha of land is rented for pasture and 2.3 hectares for maize production. These results in an operating profit of €53,800 when all purchases are minimized (G). Increasing the import of DM again results in a higher OM balance and smaller operating profit (H and I).

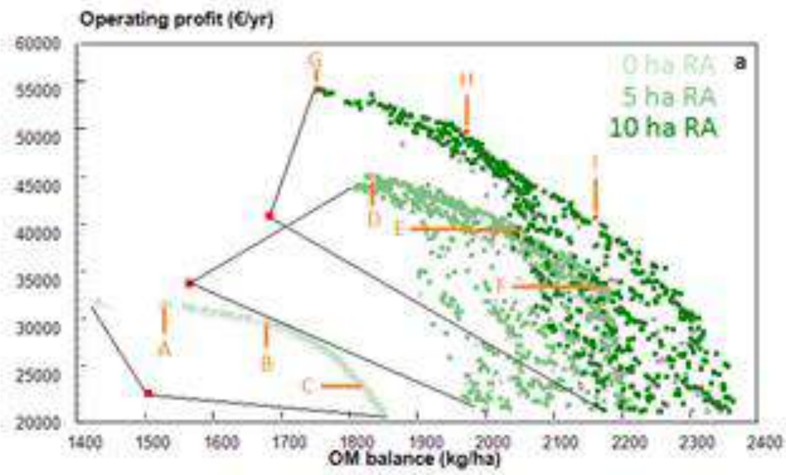


Figure 4: Exploration of integrating Restoration Agriculture (RA) at the dairy farm, with 0, 5 and 10 hectares of RA as starting points.

Discussion and conclusion

Our study demonstrates the triticale-walnut AFC and the Restoration Agriculture AFC outperform the current monoculture crops triticale and pasture in economical margin and OM balance. These AFCs were successfully integrated on farm level, with a better farm performance as a result. Without the AFCs, OM balance was increased by purchase of additional feed or bedding material, resulting in a lower operating profit. The AFCs improved OM balance by generating organic matter, diminishing this trade-off. For both farms, integration of Restoration Agriculture offered improved farm configurations with the best results. The willow-pasture AFC could not be integrated without a strong decrease in operating profit, making it unfeasible to produce all woodchips on farm. Further research is necessary in order to make more solid process-based estimations of technical coefficients of AFCs. For effective adoption of these promising systems, we also face challenges in non-productive related fields, such as policy issues and the setting up of new revenue models.

References

Groot JCJ, Oomen GJM, Rossing WAH (2012) Multi-objective optimization and design of farming systems. Agr Syst 110: 63–77.

FULL ARTICLE AVAILABLE AT: edepot.wur.nl/416387 (accessed 04/05/2018).

INTEGRATING A FINANCIAL MODULE IN THE WEB-ECOYIELD-SAFE MODEL FOR BIOECONOMIC ASSESSMENT OF AGROFORESTRY ECOSYSTEMS

Tomás A[1*], Palma JHN[1], Graves A[2], García de Jalón S[3], Burgess PJ[2]

(1) Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda, 1349-017 Lisbon, Portugal
(2) School of Energy, Environment and Agrifood, Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK (3) Basque Centre for Climate Change (BC3), Parque Científico de UPV/EHU, 48940 Leioa, Basque Country, Spain

*Corresponding author: anatomas@isa.ulisboa.pt

Abstract

When analysing different land uses, since they usually translate into different and not comparable goods and services, it is essential to evaluate their financial performance. Using the biophysical outputs already provided by the web application Web-EcoYield-SAFE, a new module was integrated in order to add financial outputs to the range of information already available to the user. To demonstrate its usage, the financial cumulative net margins (with and without grants) are shown for a case study based on silvoarable experiments in the UK.

Keywords: financial modelling; online platform; stakeholders; user-friendly; model; scenario comparison;

Introduction

Numerous studies have indicated that financial return is an important determinant of whether farmers implement agroforestry (Graves et al. 2009; García de Jalón et al. 2017a). Actually when considering the implementation of agroforestry systems, there's an evident need to evaluate its biophysical development as well as its socio-economic aspects. Since long-term experiments for these systems are still scarce, so are empirical datasets for entire tree rotations. This makes modelling an essential tool when implementing agroforestry systems, to evaluate their performance and feasibility.

A new financial module is here proposed to be included within Web-EcoYield-SAFE, a web-based decision support tool that allows farmers and advisors to estimate the long-term growth and environmental impact of agroforestry systems (relative to agriculture and forestry). This module is based on the Farm-SAFE model (Graves et al. 2007, 2011), and will allow users to compare the financial and economic performance of arable, forestry and agroforestry systems.

Materials and methods

Farm-SAFE adaptation and integration into Web-EcoYield-SAFE

The proposed financial module integrates Web-EcoYield-SAFE, a web implementation of EcoYield-SAFE (Palma et al. in preparation), a development of the agroforestry process-based model Yield-SAFE (van der Werf 2017).

This financial module was developed in Python, working as a web service directly accessed by the interface. It was based on the Farm-SAFE model, a Microsoft Excel-based spreadsheet model (Graves et al. 2007, 2011) developed during the SAFE project to initially assess the financial profitability of silvoarable systems (Dupraz et al. 2005).

The new module performs the financial assessment on the basis of the annual net margins. Following Graves et al. 2007, for the crop component, the revenues and costs were applied according to the proportion of the arable system. Revenues include grain, straw and grants. It was also assumed that cropping would only continue if the intercrop net margin was profitable, after which it was assumed the intercrop area would be fallowed. The financial data for the tree component comprised the revenue from timber, firewood and subsidies, and the costs of woodland establishment and management.

The financial net margin was calculated as revenues (R: € ha^{-1}) minus costs (variable VC and fixed FC: € ha^{-1}). Revenues and costs were discounted and converted into discounted net present values (NPV: € ha^{-1}), denoted using Eq. 1:

$$NPV_F = \sum_{t=0}^{n} \left(\frac{(R_t - VC_t - FC_t)}{(1+i)^t} \right) \quad (1)$$

where R_t , C_t were respectively revenue and costs in year t (€ ha^{-1}), i was the discount rate, and n was the time horizon for the analysis. The financial profits of the different systems were compared in terms of an equivalent annual value (EAV: € ha^{-1} $year^{-1}$) using Eq. 2:

$$EAV_F = NPV_F \left(\frac{(1+i)^n}{(1+i)^n - 1} \right) i \quad (2)$$

Case study

In order to demonstrate the usage of the financial module, a case study was chosen that compared three land use systems: 1) an arable system with four-year crop rotation (wheat, wheat, barley and oilseed); 2) a forestry system with a poplar plantation (156 trees ha^{-1}) and 3) a silvoarable system with poplar tree (156 trees ha^{-1}) with cropped alleys with the same rotation of the arable system. These were based on experimental silvoarable sites in Silsoe, United Kingdom, with a 20 year rotation period (Graves et al. 2010).

The analysis was performed for a 4% discount rate using prices and costs from García de Jalón et al. (2017b).

Results and discussion

The financial module

The new module is divided between system components (crop, livestock and tree), revenues (main and by-products prices), grants and cost types (variable, fixed and labour costs) (Figure 1).

To assess the profitability of a given system some steps need to be addressed: (1) identify the main characteristics of the site and system components; (2) define additional financial input values, such as the plot area, discount rate, management operations, labour, grants, costs and prices; and, finally, (3) run the established scenario, which will, in turn, run EcoYield-SAFE to generate the biophysical data needed and then the new financial module to generate the financial and economic outputs, which include economic indicators such as net present value, cash flow and equivalent annual value.

These outputs can be viewed on the web-app, in a graphical form, or downloaded as a CSV file for further examination.

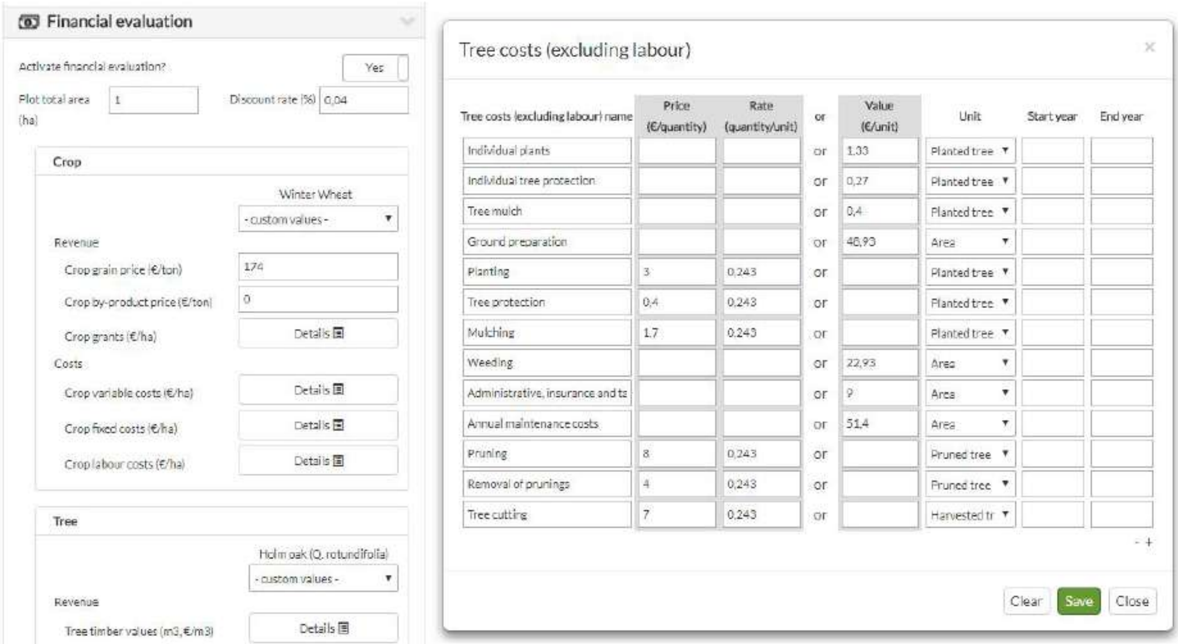


Figure 1: Financial module interface detail.

Case study

Figure 2 shows the financial cumulative net margins with and without grants for the presented arable, forestry and silvoarable systems. At the end of the rotation, for both analyses with and without grants, the arable system was the most profitable landuse, followed by the silvoarable and forestry system.

Only for the first 3 years does the forestry system presents a higher cumulative net margin then the silvoarable system, due to the fact that it was considered eligible for receiving planting and maintenance grants that are paid in the first 5 years (García de Jalón et al. 2017b). When excluding grants, forestry land use only reached positive net margin values at the end of the rotation (with the clearfell).

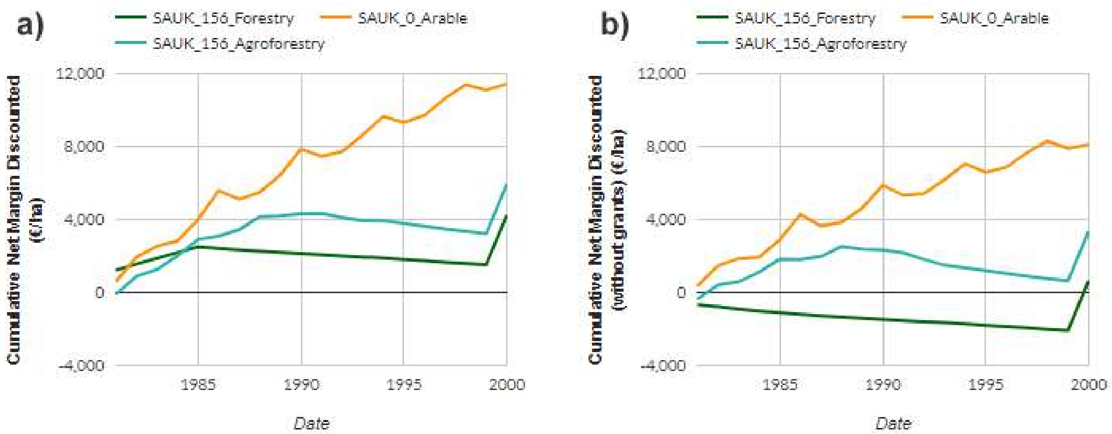


Figure 2: Financial cumulative net margin with (a) and without (b) grants.

Conclusion

The integration of the new financial module within the Web-EcoYield-SAFE model now provides users with a tool that can be used to undertake integrated biophysical and financial appraisals of agroforestry systems, thus improving assessments of the impact of different management decisions.

References

Dupraz C, Burgess P, Gavaland A, Graves A, Herzog F, Incoll L, Jackson N, Keesman K, Lawson G, Lecomte I, Liagre F, Mantzanas K, Mayus M, Moreno G, Palma J, Papanastasis V, Paris P, Pilbeam D, Reisner Y, Vincent G, Werf Van der W (2005) Synthesis of the Silvoarable Agroforestry For Europe project. INRA-UMR System Editions, Montpellier, pp.254. https://www1.montpellier.inra.fr/safe/english/results/final-report/SAFE%20Final%20Synthesis%20Report.pdf (accessed 24/04/2018).

García de Jalón S, Burgess PJ, Graves A, Moreno G, McAdam J, Pottier E, Novak S, Bondesan V, Mosquera-Losada MR, Crous-Durán J, Palma JHN, Paulo JA, Oliveira TS, Cirou E, Hannachi Y, Pantera A, Wartelle R, Kay S, Malignier N, Van Lerberghe P, Tsonkova P, Mirck J, Rois M, Grete Kongsted A, Thenail C, Luske B, Berg S, Gosme M, Vityi A (2017a) How is agroforestry perceived in Europe? An assessment of positive and negative aspects by stakeholders. Agroforst Syst https://doi.org/10.1007/s10457-017-0116-3

García de Jalón S, Graves A, Palma JHN, Williams A, Upson M, Burgess PL (2017b) Modelling and valuing the environmental impacts of arable, forestry and agroforestry systems: a case study. Agrofor Syst https://doi.org/10.1007/s10457-017-0128-z

Graves AR, Burgess PJ, Palma JHN, Herzog F, Moreno G, Bertomeu M, Dupraz C, Liagre F, Keesman K, van der Werf W, Koeffemande Nooy A, van den Briel JP (2007) Development and application of bio-economic modelling to compare silvoarable, arable, and forestry systems in three European countries. Ecol Eng 29: 434–449.

Graves AR, Burgess PJ, Liagre F, Pisanelli A, Paris P, Moreno G, Bellido M, Mayus M, Postma M, Schindler B, Mantzanas K, Papanastasis VP, Dupraz C (2009) Farmer Perceptions of Silvoarable Systems in Seven European Countries. In: Rigueiro-Rodríguez A, McAdam J, Mosquera-Losada MR (eds) Agroforestry in Europe. Advances in Agroforestry, vol 6. Springer, Dordrecht, pp. 67-86.

Graves AR, Burgess PJ, Liagre F, Terreaux JP, Borrel T, Dupraz C, Palma J, Herzog F (2011) Farm-SAFE: The process of developing a plot- and farm-scale model of arable, forestry, and silvoarable economics. Agroforst Syst 81: 93–108.

Palma JHN, Graves AR, Crous-Duran J, Garcia de Jalon S, Oliveira TS et al. (in preparation) EcoYield-SAFE: maintaining a parameter-sparse approach in modelling silvopastoral systems.

van der Werf W, Keesman K, Burgess P, Graves A, Pilbeam D, Incoll LD, Metselaar K, Mayus M, Stappers R, van Keulen H, Palma J, Dupraz C (2007) Yield-SAFE: A parameter-sparse, process-based dynamic model for predicting resource capture, growth.

HIGH-RESOLUTION ECONOMIC EVALUATION OF BLACK WALNUT ALLEY CROPPING AGAINST THE MAIZE-SOYBEAN ROTATION IN THE MIDWEST USA

Wolz KJ[1,2,3*], DeLucia EH[3,4]

(1) Program in Ecology, Evolution, and Conservation Biology, University of Illinois Urbana-Champaign, Urbana, IL, USA; (2) Savanna Institute, Madison, WI, USA; (3) Institute for Sustainability, Energy, and Environment, University of Illinois Urbana-Champaign, Urbana, IL, USA; (4) Department of Plant Biology, University of Illinois Urbana-Champaign, Urbana, IL, USA

*Corresponding author: kevin@savannainstitute.org

Abstract

The maize-soybean rotation (MSR) dominates the Midwest US and degrades many ecological functions. Black walnut alley cropping (AC) is an alternative land-use that can enhance productivity and restore ecosystem services. Given the lack of robust market mechanisms to monetize ecosystems services, we tested whether the profitability of AC could drive adoption in the Midwest. Publically available data on black walnut soil suitability, timber prices, crop productivity, and cash rents were combined in a high-resolution spatial analysis to identify target regions where these alternatives can outcompete MSR. We show that AC could be more profitable on 23.4% of cultivated land, assuming a 5% discount rate. The economic competitiveness of alternatives was not correlated with MSR productivity. Results reveal major opportunities for landowners and investors to increase profitability by investing in AC on both marginal and ideal MSR land.

Keywords: agroforestry; intercropping; silvoarable; discount rate; land-use; marginal land

Introduction

The maize-soybean rotation (MSR) is the dominant land-use in the Midwest US. Though extremely productive, MSR degrades many ecological functions (Foley 2005), is sensitive to future climate change (Mistry et al. 2017), and its profitability is volatile (Brandes et al. 2016). Alley cropping (AC), an agroforestry practice that grows crops in alleys between tree rows, is an alternative land-use that can enhance productivity and restore ecosystem services (Thevathasan and Gordon 2004; Jose 2009; Tsonkova et al. 2012). For example, AC can sequester substantial amounts of carbon (Udawatta and Jose 2012) and reduce nitrogen losses via nitrate leaching (Dougherty et al. 2009) and nitrous oxide emissions (Beaudette et al. 2010). While these environmental benefits can certainly increase landowners' interest in agroforestry (Winans et al. 2016), they have failed to drive adoption due to the lack of robust market mechanisms to monetize their value. Profit remains the central driver for adoption of sustainable agricultural strategies.

Alternative agricultural practices are typically targeted at so-called "marginal" lands, which have low MSR productivity and contribute disproportionally to negative externalities (Richards et al. 2014). However, there are strong economic opportunities for land-use alternatives across existing MSR land (Brandes et al. 2016). Here, we evaluate the economic competitiveness of one specific land-use alternatives: black walnut (*Juglans nigra*) AC. Merging high-resolution site suitability and profitability analyses enabled us to move beyond previous studies of coarse-scale profitability (Yemshanov et al. 2007; Frey et al. 2010) or basic site suitability at high resolution (Reisner et al. 2007; Wang and Shi 2015). Our dynamic black walnut growth model and high-resolution visualizations offer a novel, robust tool for landowners and investors.

Juglans is the most common tree genus in temperate AC, used in 34% of field experiments (Wolz and DeLucia 2018). Whether sold as veneer or less valuable sawlogs, black walnut commands higher prices than all other temperate timber species. Furthermore, black walnut is an ideal species for AC because of its short growing season, sparse canopy, large taproot, and deep rooting system. The economic competitiveness of AC depends on the productivity of black walnut relative to that of MSR. Land that is marginal to MSR may not necessarily be productive for a given land-use alternative.

Materials and methods

Publically available data on black walnut soil suitability (BWSI), timber prices, crop productivity (NCCPI), cash rents, and land cover were combined to identify target regions where AC can be a direct economic competitor of MSR without monetization of any environmental benefits or direct government assistance. Analyses were performed at a 10x10 m resolution and focused on existing MSR land ("cultivated land") in Missouri, Illinois, Indiana, and Ohio.

All analyses were performed at 10x10 m resolution using the National Soil Survey Geographic Database (gSSURGO). Cultivated land was identified using the 2016 Cropland Data Layer (CDL) created by the USDA NASS. Average cash rental rates of cropland for each county in 2008-2016 were obtained from USDA NASS. To estimate cash rental rate for each map unit in each county, we followed the method of Brandes et al. (2016) to scale county-level rent by an index of maize-soybean productivity.

To estimate the potential growth rate of black walnut on each soil map unit, we fitted a growth model to data from all publications measuring diameter at breast height (DBH) of field-grown black walnut. Growth curves were then scaled using BWSI (Wallace and Young 2008). Maize, soybean, and wheat yields for each county were obtained from USDA NASS. These three species are the most common species used in temperate AC experiments (Wolz and DeLucia 2018). To estimate the trajectory of alley crop yields following tree establishment, data from all temperate and subtropical AC studies that report relative yield of maize, soybean, or wheat were extracted from the catalog of AC literature developed by Wolz and DeLucia (2018).

Parameters supplied to the black walnut model in addition to the DBH trajectory were taken primarily from Godsey (2006), Yemshanov et al. (2007), and Schultz and DeLoach (2004). Initial stand spacing for AC was 3.4 x 9.8 m, which was the mean spacing of systems in the literature used to develop the alley crop yield trajectories.

The cropland rent ($R_{m,c}$) represents the average annual income received by a landowner from MSR operators for each map unit m in each county c. Black walnut AC is economically competitive with MSR when its profitability meets or exceeds the threshold of $R_{m,c}$. The long-term, heterogeneous cash flow of AC cannot be compared directly to $R_{m,c}$, but first must be converted into a homogeneous cash flow over the same period, or the annual equivalent value (AEV). For each map unit m in each county c, we solved for the threshold discount rate $TDR_{AC,m,c}$ such that $AEV_{AC,m,c}$ was equal to $R_{m,c}$.

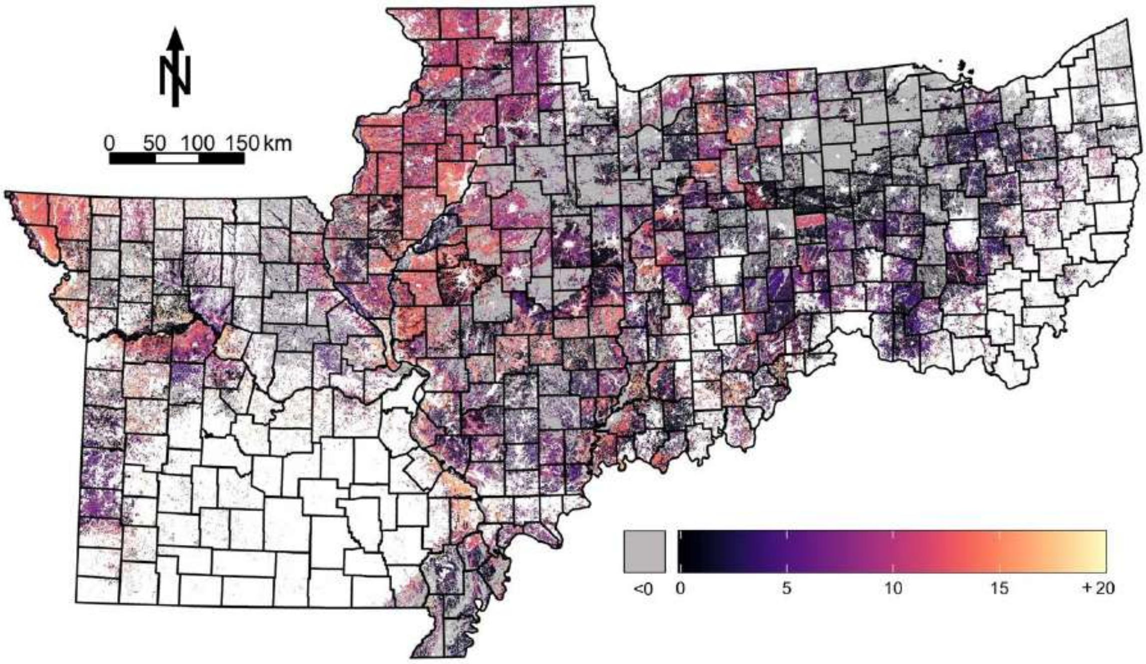


Figure 1: Distribution of the threshold discount rate (TDR_{AC}) at which the annual equivalent value (AEV) of AC and MSR are equal. Gray areas are cultivated land on which either BWSI = 0 or $TDR_{AC} < 0$. White areas are non-cultivated land.

Results and discussion

A total of 12 publications provided useable data on DBH of field-grown black walnut. Data spanned from one to 109 years after tree establishment, with DBH ranging from 0.5 to 58.3 cm. Mined literature provided relative yield data for a total of 93 site-crop-year combinations. Data spanned from 1 to 23 years after tree establishment, and relative yields ranged from 0.14 to 1.05. Maize, soybean, and wheat all exhibited significant declines in relative yield with tree age ($p < 0.01$). The largest yield declines were observed in maize, then soybean, and finally wheat with little yield reduction over time.

Black walnut AC (Figure 1) exhibited competitive TDRs in many regions across the four states studied. The higher the TDR, the more competitive AC is with MSR. Therefore, the percentage of cultivated land where AC outcompeted MSR (i.e. where AC has a higher AEV than MSR) increased with decreasing TDR (Figure 2a). The economic competitiveness of AC was not correlated with crop productivity (Figure 2b). Instead, cultivated land at the extremes of crop productivity contained the lowest proportion of land where AC was competitive.

Our results project strong economic competitiveness of black walnut AC with MSR. High TDRs were found on marginal and ideal MSR soils, confirming that the marginal land concept is inadequate in identifying target regions for AC. Instead, black walnut growth rate was the central driver of AC competitiveness. These results demonstrate that the soil suitability of alternatives is more important than MSR productivity in optimal land-use allocation. A shift away from the MSR-centric perspective in defining target regions for land-use alternatives is necessary.

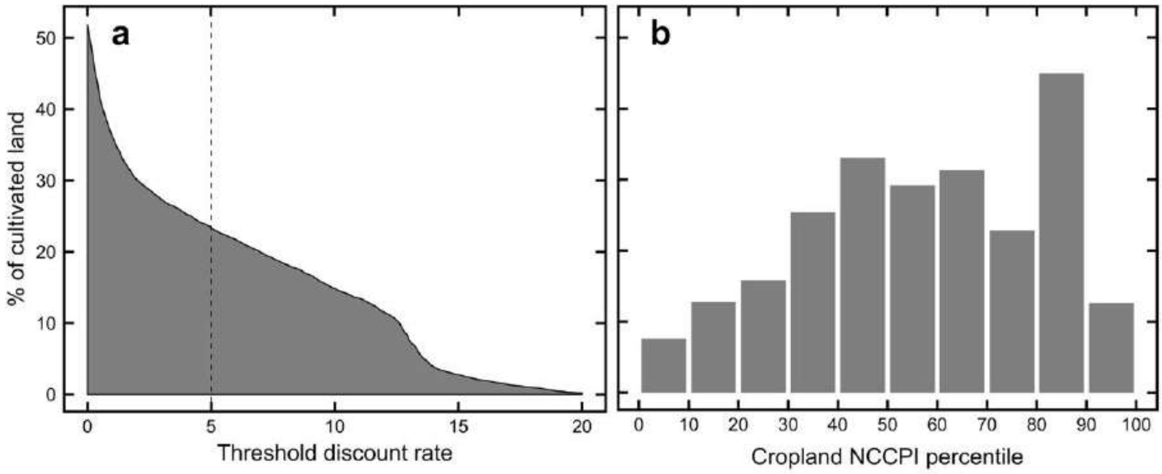


Figure 2: (a) Percentage of cultivated land as a function of TDR, on which black walnut AC has a higher AEV than MSR. The dashed line indicates a TDR of 5%. (b) Percentage of cultivated land in each NCCPI class on which black walnut AC has a higher AEV than MSR at a TDR of 5%. NCCPI classes are defined in terms of percentiles of NCCPI (e.g. the 0-10 NCCPI percentile includes the 10% of cultivated land with the lowest NCCPI).

References

Beaudette C, Bradley RL, Whalen JK, et al (2010) Tree-based intercropping does not compromise canola (*Brassica napus* L.) seed oil yield and reduces soil nitrous oxide emissions. Agr Ecosyst Environ 139: 33–39.

Brandes E, McNunn GS, Schulte LA, Bonner IJ, Muth DJ, Badcock BA, Sharma B, Heaton EA (2016) Subfield profitability analysis reveals an economic case for cropland diversification. Environ Res Lett 11:014009.

Dougherty MC, Thevathasan NV, Gordon AM, Lee H, Kort J (2009) Nitrate and *Escherichia coli* NAR analysis in tile drain effluent from a mixed tree intercrop and monocrop system. Agr Ecosyst Environ 131:77–84.

Foley JA (2005) Global Consequences of Land Use. Science 309: 570–574.

Frey GE, Mercer DE, Cubbage FW, Abt RC (2010) Economic potential of agroforestry and forestry in the lower Mississippi alluvial valley with incentive programs and carbon payments. South J Appl For 34: 176–185.

Godsey L (2006) Black Walnut Financial Model. University of Missouri Center for Agroforestry.

Jose S (2009) Agroforestry for ecosystem services and environmental benefits: an overview. Agrofor Syst 76: 1–10.

Mistry MN, Wing IS, De Cian E (2017) Simulated vs. empirical weather responsiveness of crop yields: US evidence and implications for the agricultural impacts of climate change. Environ Res Lett 12: 075007.

Reisner Y, de Filippi R, Herzog F, Palma J (2007) Target regions for silvoarable agroforestry in Europe. Ecol Eng 29: 401–418.

Richards BK, Stoof CR, Cary IJ, Woodbury PB (2014) Reporting on marginal lands for bioenergy feedstock production: a modest proposal. Bioenerg Res 7: 1060–1062.

Schultz EB, DeLoach WM III (2004) Site suitability and economic aspects of black walnut (*Juglans nigra* L.) in Mississippi. South J Appl For 28: 123–131.

Thevathasan NV, Gordon AM (2004) Ecology of tree intercropping systems in the north temperate region: Experiences from southern Ontario, Canada. Agrofor Syst 61: 257–268.

Tsonkova P, Böhm C, Quinkenstein A, Freese D (2012) Ecological benefits provided by alley cropping systems for production of woody biomass in the temperate region: a review. Agrofor Syst 85: 133–152.

Udawatta RP, Jose S (2012) Agroforestry strategies to sequester carbon in temperate North America. Agrofor Syst 86: 225–242.

Wallace DC, Young FJ (2008) Black walnut suitability index: a natural resources conservation service national soil information system based interpretive model.

Wang F, Shi X (2015) Geospatial analysis for utilizing the marginal land in regional biofuel industry: A case study in Guangdong Province, China. Biomass and Bioenergy 83: 302–310.

Winans KS, Whalen JK, Rivest D, Bradley RL (2016) Carbon sequestration and carbon markets for tree-based intercropping systems in Southern Quebec, Canada. Atmosphere 7: 1–13.

Wolz KJ, DeLucia EH (2018) Alley cropping: Global patterns of species composition and function. Agr Ecosyst Environ 252: 61–68.

Yemshanov D, McKenney D, Fraleigh S, D'Eon S (2007) An integrated spatial assessment of the investment potential of three species in southern Ontario, Canada inclusive of carbon benefits. Forest Policy and Economics 10: 48–59.

AGROFORESTRY NETWORK IN BRABANT, THE NETHERLANDS: HOW FARMERS DEVELOP A NEW SUSTAINABLE AND ECONOMICALLY RENTABLE FARMING SYSTEM AND HOW THEY CAN CONTRIBUTE TO REGIONAL ECOSYTEM FUNCTIONS

Rombouts P[1]*, LuskeB[2], Vonk M[3], van Veluw K[2]

(1) Rombouts Agroecologie, The Netherlands (2) Louis Bolk Institute, Kosterijland 3-5, 3981 AJ Bunnik, The Netherlands (3) Groen ing Consultancy, The Netherlands

*Corresponding author: piet@romboutsagroeco.nl

Abstract

Agroforestry Network Brabant is an initiative to guide farmers and estate owners in the reintroduction of trees in modern agricultural management (business approach). Within the agroforestry network Brabant, farmers are supported with information and calculations for cost and benefits. Within the network ten farm or estate owners were selected. With each of these land owners a customized business plan was developed, suitable for the present ecological circumstances. Farmers are very motivated to start trial and error experiments with agroforestry. Nevertheless understanding of practical, economic and technical features might be more important than a scientific approach. Advisors have to accompany farmers in a system way of thinking.

Keywords: business approach; agricultural landscape development; nature inclusive farming

Introduction

Agroforestry Network Brabant is the initiative in the south of the Netherlands to guide farmers and estate owners in the reintroduction of trees in modern agricultural management. This requires a new creative business approach and agricultural landscape development perspective. Within the agroforestry network Brabant, farmers and estate owners in their search for a resilient, cost effective and diverse business systems, are supported with information (meetings and excursions) and calculations for cost and benefits.

Why agroforestry gain a foothold in Brabant

Brabant is the province where intensification and up scaling of agricultural practices used to be common practice. At the moment however, the province is frontrunner in forcing back ecological functions and biodiversity levels on farmland. With the realization of the Nature Network Brabant (NNN Brabant) and founding of the "Green Development Fund Brabant" (Groen Ontwikkelfonds Brabant GOB) a financial campaign has started to stimulate nature inclusive farming (Erisman et al. 2016). In farm development GOB acknowledges agroforestry and organic as nature inclusive farming system approaches, which are considered to contribute to the development of nature values on farmland. Therefore the framework in Brabant is very suitable and more than 40 farmers were interested in joining the regional network.

Costs and revenues of agroforestry on the scale of the individual farm, a region and a state; proven practice and theoretical models

Business plans

Ten farm or estate owners within the agroforestry network were selected, each with a different idea on how to introduce trees into their farming systems. With each of these land owners a customized business plan was developed, suitable for the present ecological circumstances. On the basis of the literature, practical knowledge and experiences of (mono) cropping of nuts, fruits and timber, the costs and benefits for several types of agroforestry systems were calculated. Furthermore:

Results

Success of an agroforestry system is not automatically assured. We identified several crucial factors in designing potential successful business models:

- The relatively high labor in agroforestry systems compared to monocultures, require creativity for identifying business opportunities, like on farm processing and regional market opportunities
- To make agroforestry profitable and to make the right choices about the investment, it is important to calculate costs and benefits and make estimates of the financial break-even point.
- High land prices require that future agroforestry farmers need to gain access to different types of financial support. This also requires creativity.
- New kinds of collaboration between produces and consumers have to be developed (e.g. share forestry or co-financing of agroforestry systems)
- The financial support of the GOB is a very relevant regional policy measure, which also shortens the break-even point of agroforestry systems
- The break-even point of agroforestry systems can be shortened when crops that deliver products after several years (e.g. walnut) are combined with animals (poultry) or crops (berries) that deliver products on the short term.
- People plant trees mostly for the next generation and therefore, it is important to involve the successors in this decision.

Future prospects

Farmers are very motivated to start trial and error experiments with agroforestry. Nevertheless planting trees needs planning en advance because results will often be clear after a long period. To prepare farmers it’s important to talk in their own language. Understanding of practical, economic and technical features might be more important than a scientific approach. Advisors have to accompany these farmers in a system way of thinking.

References

Erisman JW, N van Eekeren, J de Wit, C Koopmans, W Cuijpers, N Oerlemans and BJ. Koks 2016 Perspective Agriculture and biodiversity: a better balance benefits both. AIMS Agriculture and Food 1: 157-174.

Session

Agroforestry policies

AGROFORESTRY IN SWITZERLAND – A NON-CAP EUROPEAN COUNTRY

Herzog F[1*], Szerencsits E[1], Kay S[1], Roces-Diaz JV[1,2], Jäger M[3]

(1) Agroecology and environment, Agroscope, CH-8046 Zürich, Switzerland (2) Department of Geography, Swansea University, Swansea SA2 8PP UK (3) Agridea, CH-8315 Lindau, Switzerland

*Corresponding author: felix.herzog@agroscope.admin.ch

Abstract

Agroforestry in Switzerland makes up approximately twelve per cent of the country's farmland, with forest pastures, hedgerows and traditional fruit orchards being the most widespread systems. Those traditional agroforestry systems receive policy support due to the ecosystem services they provide, notably for biodiversity and landscape scenery. Under the same subsidy guidelines, also novel agroforestry systems, e.g. combining fruit trees and arable crops, qualify for support. This has allowed a small community of agroforestry pioneer farmers to emerge. The rules for evaluating the ecological quality of agroforestry systems are summarized. Private initiatives are becoming increasingly important, also in relation to carbon sequestration.

Keywords: biodiversity; carbon sequestration; ecological quality; landscape scenery

Introduction

Switzerland is located in the center of Europe, but is not a member of the European Union. It develops its own agricultural policy, which has to fit into the broad framework related to its membership of OECD, WTO and to bi-lateral trade agreements – as does the Common Agricultural Policy (CAP) of the European Union. In this contribution we want to report on: (i) the status of agroforestry in Switzerland, (ii) the policies and market initiatives that support it and (iii)agroforestry innovation in particular for the purpose of carbon sequestration.

Materials and methods

The current extent of Swiss agroforestry systems was derived from a spatial analysis of the recent land-use statistics (BFS 2015). Forest pastures were selected from all pastures employing open forest involving single tree density derived from the topographic landscape model TLM3d (Swisstopo 2017). The information on policies, market initiatives and innovation stem from literature and internet research and from stakeholder interviews as indicated below.

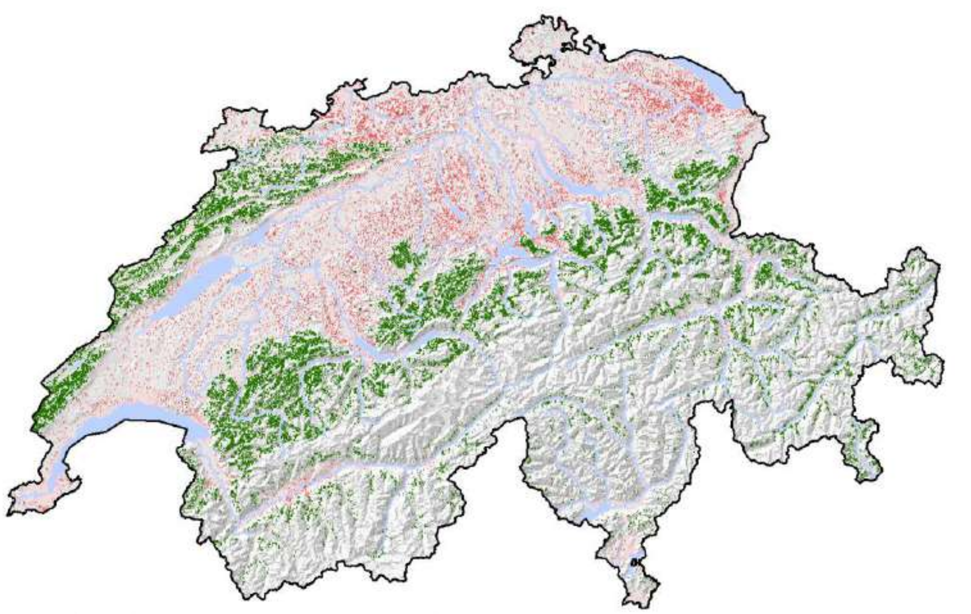
Results and discussion

Traditional agroforestry systems are still quite common in Switzerland (Riedel et al. 2012). In all, they make up twelve per cent of the 1.5 Million hectares of farmland (Table 1). Forest pastures are the most widespread agroforestry element. They occur in the Jura mountains, where they are a prominent landscape feature ("Wytweiden", "pâturage boisé", see Buttler et al. 2009) and in the northern pre-alps (Figure 1). Hedgerows as the second most relevant agroforestry type are quite evenly distributed across the farmland. Yet, there are only very few real "hedgerow landscapes" sensu "bocages" as in north-western France or "Knick" in northern Germany. Traditional fruit orchards are a still prominent agroforestry system in the lowlands. Chestnut selva, which formerly were a major source of food and income in south-alpine valleys, are the least widespread traditional agroforestry system today. Few isolated selva are also maintained in central Switzerland close to the inner-alpine lakes.

In addition, 15 per cent of the Swiss mountain forests are regularly grazed in early summer or in autumn, mostly with cattle (Mayer et al. 2003). This use is controversial and in some regions, the cantonal forest authorities attempt to adapt the forest laws to ban husbandry animals from forests.

Table 1: Extent of traditional agroforestry systems in Switzerland.

Agroforestry system	Description	Location	Area (sqkm)	References
Forest pastures	Pastures (mostly cattle, horses) with isolated trees	Pre-alps and Jura mountains	650	BFS (2015), swisstopo (2017)
Traditional fruit orchards ("Streuobst")	Fruit and nut trees on grassland, mown and/or pastured	Lowlands and hilly regions, often close to villages	222	BFS (2015), cat. 38
Hedgerows	Hedges and small forest islands on farmland	General, on farmland	307	BFS (2009), cat. 58
Chestnut selva	*Castanea sativa* on grassland, mown and/or pastured	Southern and central Switzerland	17	BAFU/WSL (2015)



Spatial distribution of traditional fruit orchards (red) and forest pastures (green), derived from Arealstatistik 2004 - 2009 (BFS 2015) and TLM3d (Swisstopo 2017)

Figure 1: Major traditional agroforestry systems in Switzerland: Forest pastures and traditional fruit orchards (hedgerows and chestnut selva not shown).

The main policies for supporting agroforestry in Switzerland are related to cross-compliance, agri-environmental schemes and landscape quality payments. In fact, since the late 1990ies, farmers have to manage seven per cent or more of their land as ecological focus areas (EFA) in order to qualify for direct payments (cross-compliance mechanism). They can choose amongst 15 EFA types comprising the four agroforestry systems listed in Table 1. For those systems, farmers can obtain additional payments if criteria for ecological quality are met and/or if they participate in regional projects for ecological networks and/or landscape quality. Regional policies of some cantons support those policies with additional programs to maintain characteristic agroforestry landscapes. Additional incentives come from label organizations and market initiatives (Table 2).

Ecological quality criteria have been introduced in 2001 with the main goal to promote farmland target species that have been specified for the different bio-geographical regions of Switzerland (BAFU and BLW 2008). The quality criteria were defined based on scientific ecological evidence in a dialogue with relevant stakeholders (representatives of nature protection NGOs, of farmers, of administrators, of control organisations). They are regularly revised and can be adapted to regional conditions. Landscape quality payments have been introduced only more recently (2014). They aim to overcome the administrative barriers posed by the strict legal separation between farm and forest land, which is particularly relevant for forest pastures. They allow for a more comprehensive promotion for the visual and cultural quality of the landscape.

About ten years ago, Swiss pioneer farmers began to experiment with novel agroforestry systems by combining trees with arable crops. Most of them actually plant fruit trees (Sereke et al. 2015) mostly because they are familiar with such trees (in contrast to forest trees) and because fruit and nut trees are promoted as EFA regardless of whether they are planted in a traditional silvo-pastoral or in a novel silvo-arable system. Farmers can apply for the same subsidies, including ecological quality and landscape payments. The crop rotation usually remains unchanged, which works well as long as the trees are still young. When trees get bigger, however, the combination between fruit trees and crops will become challenging and will need to account for the timing of crop and fruit harvest. In particular, the timing of pesticide applications on the individual components of the system (fruit tree, crop) is challenging, due to the legal restrictions that prescribe e.g. minimum time lags between the last application of a pesticide and the harvest. This will constrain the choice of crops in fruit tree agroforestry systems (Jäger 2016).

Table 2: Policies and market initiatives relating to agroforestry systems in Switzerland. Sources: BLW (2017) and internet sites as indicated.

Agroforestry system	National policies	Regional policies (examples)	Criteria for ecological quality	Private initiatives and market instruments (examples)
Traditional fruit orchards ("Streuobst")	Cross compliance and agri-environmental payments if <120 trees/ha (<100 for cherry, nut and chestnut); landscape quality payments	Additional incentives in cantons that want to maintain and promote the regionally characteristic agroforestry landscapes	≥0.2 ha with ≥10 trees, 30-100 trees/ha, combination with another EFA within 50 m distance	Label production: http://www.hochstamm-suisse.ch/, http://www.posamenter.ch/, http://www.zugerchriesi.ch/
Forest pastures			≥6 plant indicator species present on 20% of the area, ≥10% shrub/tree cover with ≥2.5% thorny or species rich shrubs	Regional nature parks promoting local, labeled products
Chestnut selva			As for fruit orchards	Foundations http://www.sl-fp.ch/, tourism related promotion http://www.bregaglia.ch/de/kastanienfestival
Hedgerows	Cross compliance and agri-environmental payments for hedges with 3 m grassland buffers on both sides	n.a.	≥2 m width (woody component) and 3 m grassland buffer at both sides. No invasive species, ≥ 5 shrub or tree species per 10 m length, ≥20% of thorny shrubs or one native tree every 30 m (stem perimeter ≥170 cm at 130 cm above ground)	n.a.

The Swiss Federal Office for Agriculture (BLW) and two private foundations support the national agroforestry community (www.agroforst.ch / www.agroforesterie.ch) by funding extension and monitoring activities. In addition to the above mentioned ecosystem services related to biodiversity and landscape, they want to learn more about the potential of agroforestry to sequester carbon for climate change mitigation. Regular measurements (Kuster et al. 2012) revealed that in 2017, an apple orchard planted with 100 trees per hectare in 2009 had sequestered 1.2 t of carbon per hectare in the tree biomass and another 0.9 to of carbon per hectare in accumulated soil organic matter (Seitz et al. 2017). Alig et al. (2015) compared the potential of 23 different mitigation measures that farmers can implement to reduce their emission of greenhouse-gas by means of life-cycle analysis. Whereas the potential reduction of those measures ranged between zero and thirty per cent, the planting of an apple agroforestry system (50 trees per hectare on 20 per cent of the arable land) would reduce greenhouse-gas emission by up to 110 per cent, accounting only for the carbon sequestered by the trees.

Conclusion

Traditional agroforestry systems are still relatively widespread in Switzerland and are supported by direct payments due to the ecosystem services they provide. The same payments are also available for novel agroforestry systems, as long as fruit and nut trees are planted. Agroforestry with other tree species potentially provide similar ecosystem services and extending the payments to forest trees might facilitate the uptake of novel agroforestry systems in Switzerland.

References

Alig M, Prechsl U, Schwitter K, Waldvogel T, Wolff V, Wunderlich A, Zorn A, Gaillard G (2015) Ökologische und ökonomische Bewertung von Klimaschutzmassnahmen zur Umsetzung auf landwirtschaftlichen Betrieben in der Schweiz. Berne, Agroscope Science 29. https://www.agroscope.admin.ch/agroscope/de/home/publikationen/suchen/agroscope-science.html (accessed 12/10/2017).

BAFU and BLW (2008) Umweltziele Landwirtschaft. Umwelt-Wissen 0820, Bundesamt für Umwelt, Bern. https://www.bafu.admin.ch/bafu/de/home/themen/biodiversitaet/publikationen-studien/publikationen/umweltziele-landwirtschaft.html (accessed 13/10/2017).

BAFU/WSL (2015) Waldbericht. Bundesamt für Umwelt / Eidg. Forschungsanstalt für Wald, Schnee und Landschaft, Bern und Birmensdorf. http://www.wsl.ch/medien/news/Waldbericht_2015/ (accessed 09/10/2017).

BFS (2015) Arealstatistik 2004 -2009. Bundesamt für Statistik, Neuchâtel. https://www.bfs.admin.ch/bfs/de/home/statistiken/raum-umwelt/erhebungen/area.html (accessed 02/10/2017).

BLW (2017) Direktzahlungsverordnung. Bundesamt für Landwirtschaft, Bern. https://www.admin.ch/opc/de/classified-compilation/20130216/index.html (accessed 09/10/2017).

Buttler F, Kohler F, Gillet F (2009) The Swiss mountain wooded pastures: Patterns and processes. In: Rigueiro-Rodriguez A, McAdam J, Mosquera-Losada R (eds.) Agroforestry in Europe. Springer, pp. 377–396.

Jäger M (2016) Agroforstsysteme. Lindau, Agridea. www.agroforst.ch (accessed 1/10/2017).

Kuster M, Herzog F, Rehnus M, Sorg J-P (2012) Innovative Agroforstsysteme - On farm monitoring von Chancen und Grenzen / Systèmes agroforestiers novateurs - monitoring des opportunités et limites. Agrarforschung Schweiz / Recherche Agronomique Suisse 3: 470–477.

Mayer AC, Stöckli V, Konold W, Kreuzer M (2003) Hat die Waldweide eine Zukunft? Ein interdisziplinäres Projekt in den Alpen. Schw Z für Forstwesen 154, 169 – 174. http://www.szf-jfs.org/doi/pdf/10.3188/szf.2003.0169?code=swis-site (accessed 09/10/2017).

Riedel S, Walter T, Herzog F (2012) Schweiz – Suisse – Svizzera. In: Oppermann R, Beaufoy G, Jones G (eds.) High Nature Value Farming in Europe. Ubstadt, Verlag Regionalkultur, pp. 420–433.

Seitz B, Carrand E, Burgos S, Tatti D, Herzog F, Jäger M, Sereke F (2017) Erhöhte Humusvorräte in einem siebenjährigen Agroforstsystem in der Zentralschweiz / Augmentation des stocks d'humus dans un systeme agroforestier de sept ans en Suisse centrale. Agrarforschung Schweiz / Recherche Agronomique Suisse 8: 318–323.

Sereke F, Graves A, Dux D, Palma J, Herzog F (2015) Innovative agroecosystem goods and services: key profitability drivers in Swiss agroforestry. Agron for Sust Dev 35: 759–770.

Swisstopo (2017) TLM3d. Bundesamt für Landestopographie, Bern.

ADOPTION OF AGROFORESTRY OPTIONS IN LAND USE POLICY MEASURES IN NORTHERN AND SOUTHERN IRELAND

McAdam J[1]*, Curran E[2]

(1) Agri-Food and Biosciences Institute, Newforge Lane, Belfast, United Kingdom, BT9 5PX (2) Forest Service, Department of Agriculture Food and the Marine Coronea, Skibbereen, Co. Cork, Ireland

*Corresponding author: jim.mcadam@afbini.gov.uk

Abstract

The research programme at AFBI Loughgall, Northern Ireland showed that silvopastoralism (wide spaced trees planted into grassland) can be a means of increasing tree cover and to facilitate sustainable intensification of grassland. Economic predictions and farmer surveys of agroforestry have been favourable but it is when agroforestry is accepted for state support that on-farm planting is likely to increase. In the current RDP (2014-2020) agroforestry was included as an option in forestry measures in Ireland and in 2017 as an option in the Environmental Farming Scheme (ie an Agricultural measure) in Northern Ireland. In both measures, the planting and management specification stipulated was largely based on the research findings from the AFBI research programme. Uptake has been encouraging and these farmers and land owners will form the nucleus of a group of examples in practice which hopefully will encourage other participants.

Keywords: farm policy; forestry policy; rural development; silvopastoralism

Background and rationale for agroforestry on the island of Ireland

Over the past 50 years production of livestock from grassland in Ireland has intensified substantially creating serious environmental problems such as reduced biodiversity and nutrient leakage into watercourses. It is EU policy to promote sustainable farming practices which attempt to address some of the damage caused by previous agricultural practices and go forward with land use policies which are sustainable. Such policies will focus on decreased levels of livestock output, tightened nutrient management on farms, increased tree cover to contribute to habitat heterogeneity, stabilisation of rural communities and enhancement of biodiversity through a more sustainable and lower input agriculture.

There is scientific evidence that the introduction of wide spaced trees in silvopastoral systems can make these grassland landscapes more sustainable, deliver a wide range of ecosystem services and align with a sustainable agriculture and forestry land management strategy. However tree cover in Northern Ireland (NI) (6%) is the lowest in Europe (mean 31%) and in Ireland is approximately 12%.

Silvopasture can be used to extend the grazing season to help higher grass utilisation and give resilience to grazing during extreme rainfall, while increasing biodiversity, carbon sequestration (Fornara et al. 2017), reducing water run-off and providing renewable fuel. Silvopasture might also be deemed to be more sustainable than farm woodland because of the intimate spatial integration of trees and agriculture and would include, for example, reduced wind and temperature stress and shelter for animals. There are additional benefits from root differentiation, a reduction in leaching losses of nutrients, faster nutrient cycling in the presence of grazing animals and reduced soil erosion (McAdam 2000). Additionally, silvopasture can make a positive impact on sustainable landscape and rural development, compared to conventional farm woodlands and forests, because of the diversity of employment opportunities created by multi-functional systems. Economic predictions are also encouraging. In Ireland, the

Department of Agriculture, Food and Marine sees agroforestry as making a contribution to producing veneer quality hardwoods, environmental protection, sheep and poultry welfare, to increasing carbon sequestration on a national level and sees future potential for principles of agroforestry being integrated into organic farming. This might be seen as a route to enabling eligibility of organic units within a forestry scenario.

Technical development of agroforestry

There has been an active research programme of agroforestry research in N I since 1989 (Sibbald et al. 2001; McAdam 2000). This programme was largely driven by the concept of improving grassland sustainability (ie from an agricultural perspective) and has shown that silvopastoral systems established in permanent pasture can deliver most of the ecosystem services referred to above. This was highlighted in the recent Sustainable Agricultural Land Management Strategy for NI (DAERA 2017). In Ireland, interest was shown in the NI trials from the perspective of increasing tree cover on farmland or previously afforested land ie from a forestry perspective). Both perspectives are equally valid and illustrate the potential for agroforestry to be a multifunctional land use option delivering a wide range of policy objectives.

Cooperation between the two jurisdictions was formalised and facilitated by the formation (in 2011) of an All-Ireland Agroforestry Initiative group with the objectives to:-

(a) Establish a network (ideally 4 at least) of agroforestry demonstration sites in N. Ireland and Ireland – at least one to include the use of wide spaced trees in conjunction with other agro- ecologically sustainable systems.

(b) Interact with both relevant authorities to promote the inclusion of agroforestry in Woodland Grant Schemes

(c) Promote knowledge transfer and awareness of agroforestry, either through 1 (above) or at other farm agroforestry events.

(d) Seek connectivity between agroforestry and e.g. IFA, Macra na Feirme, Community Groups, Woodland Trust. BIHIP.

Although the group only operated formally for a few years, it did bring the relevant parties in both jurisdictions together and the objectives have continued to be delivered.

Policy development

The success of the research programme at Loughgall and the realisation that it clearly presented the underpinning science for policy uptake has resulted in agroforestry being adopted into policy in both jurisdictions.

In *Northern Ireland*, an agroforestry establishment option was drawn up within the Rural Development Programme (RDP) under the Environmental Farming Scheme. The measure is justified under Priority 4 – "Restoring; preserving and Enhancing Ecosystems related to agriculture and forestry". The Option aims to "increase the area of agroforestry which will provide carbon sequestration benefits. The Option will also contribute to biodiversity, nutrient cycling and water quality. Agroforestry will integrate trees with crops and/or livestock on the same plot of land." The planting and management specification stipulated was based on the research findings from the trial reported above. Farmers/landowners accepted on the scheme still receive the Basic Payment and in Year 1: £1637.00 per ha; Years 2 – 5: £65.00 per ha each year. In the first call there have been 24 applications wishing to establish 32.5 ha of agroforestry, 64% of the target uptake. The applicants (all active farmers), cover a wide geographical spread.

In *Ireland*, in the previous RDP (2007 – 2013) there was an option to support an agroforestry initiative, however this did not materialise. The option was reintroduced in the current RDP

(2014 -2020) and this time there is an option to plant agroforestry. As a pilot project in 2012, 1.89 hectares were planted on a private livestock farm near Dunmanway, County Cork. The species used are mainly ash with some oak in the wetter areas. The design used was the basic design of single trees at 5 meter spacing with the plants protected by tree shelters.

All farmers/landowners accepted on the scheme will receive an establishment payment of €6220 per ha (in 2 tranches) and €645-660 per yr for 5 years. This was a substantial increase over the initial rates in tranche 1 of the scheme (€4450 per ha and €250 per yr for 5 years) and was awarded on the basis that a higher establishment specification was needed and the scheme was meeting EU objectives. In addition, agroforestry has great potential for planting in acid sensitive areas or in areas where the fresh water pearl mussel is in danger due to the low fertilizer, herbicide and cultivation inputs. There has been widespread support for the measure by NGOs and environmental lobbyists. Currently there are 46.95 hectares of agroforestry at various stages of grant approval.

Both these measures and options are based on the management prescriptions and system performance from the research site at AFBI Loughgall. Uptake has been encouraging and these farmers will form the nucleus of a group of examples in practice which hopefully will encourage other applicants.

Other developments

There have been other positive developments in Ireland. Some farmers and landowners have sought advice to introduce self-funded agroforestry projects on their land. One landowner cleared Sitka spruce from his land, reseeded it with grass and planted wide-spaced hardwood trees. He now grazes the area with sheep and in the summer will use the area for eco-tourism.

Another farmer is exploring the possibility of planting agroforestry in a plantation which had been recently cleared because of an infestation of ash die back.

The winners of a special award in the BT Young Scientist of the year competition in Ireland were a group of schoolchildren who submitted a project investigating “The relatively new land use, agroforestry, and its potential to offset carbon emissions from other agricultural sources” Curran et al (2017). Working with the farmer involved in the project referred to above in County Cork, they compared three different land uses for the sequestration of carbon: conventional pasture, agroforestry and conventional forestry for soil carbon. The students also looked at the amount of carbon stored in the biomass of the trees. They proposed that agroforestry is an attractive way for farmers to grow trees without tying up their land in forestry for long periods of time, as agricultural activity can continue beneath the trees. They found that 3.3% of farm emissions could be offset per year by the growth of agroforestry. They also found that agroforestry resulted in an increase in soil organic matter and therefore carbon. They concluded that agroforestry could be an attractive way for farmers to offset some of their greenhouse gas emissions by sequestering carbon, thus helping to reduce the levels of greenhouse gases.

Several major animal nutrition companies have expressed an interest in silvopastoralism as a system to enhance grassland utilisation on wet heavy soils.

Recommendations

Silvopastoralism can be succesfully supported either under agricultural or forestry measures. How the option is implemented will depend on the appropriate advice being given to the landowner.

Acknowledgements

Policy development support was carried out under the aegis of the AGFORWARD project (Grant Agreement N° 613520) is co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD, Theme 2 - Biotechnologies, Agriculture & Food.

References

Curran A, Collins T, Purcell,JR (2017) Agroforestry and Carbon Sequestration. Project No 2796, BT Young Scientist and Technology Exhibition. Schull Community College.

DAERA (2017) Delivering Our Future, Valuing Our Soils; A Sustainable Agricultural Land Management Strategy for Northern Ireland. Department of Agriculture, Environment and Rural Affairs; Expert Working Group on Sustainable Land Management. https://www.daera-ni.gov.uk/topics/land-and-landscape/soilsps (accessed 23/04/2018).

Fornara DA, Olave R, Burgess P, Delmer A, Upson M, McAdam J (2017) Land use change and soil carbon pools: evidence from a long-term silvopastoral experiment. Agroforest Syst DOI 10.1007/s10457-017-0124-3.

McAdam JH (2000) Environmental impact of agroforestry systems. In: Hislop M et al (eds) Agroforestry in the UK. Forestry Commission Research Bulletin No. 122, pp 82-89

Sibbald AR, Eason WR, McAdam JH, Hislop AM (2001) The establishment phase of a silvopastoral national network experiment in the UK. Agroforest Syst 53: 39-5.

THE POLITICAL CONSEQUENCES OF THE IMPLEMENTATION OF "GREENING". A CASE STUDY IN FRANCE

Magnin L*[1]

(1) LISIS, University Paris-Est Marne-la-Vallée – IHRIM, Ecole Normale Supérieure de Lyon, France

*Corresponding author: leo.magnin@ens-lyon.fr

Abstract

What do French breeders think about the "greening" of the CAP 2014-2020? To highlight the farmers' representations, a qualitative inquiry was carried out. In this presentation, we analyze ethnographic observations of paper work, in-depth sociological interviews, and grey literature. Two main results emerge. First, there is a gap between the policy and its implementation, and, second, most farmers have a negative representation of the CAP. We hypothesize that it is the implementation of the CAP that shapes French farmers' representations. We expose its complexity and argue that it engenders four political consequences: a lack of understanding, the perception of ecology as a way of saving on public spending, the rejection of a policy experienced as authoritarian, and political disaffection. To conclude, our principal recommendation is that in the preparation of the next CAP the technical feasibility of the measures should be an essential point in political negotiations.

Keywords: greening; ecologization; farming policy; qualitative methods; policy implementation

Introduction

How understand the relationships between farmers and agricultural policy? If quantitative methods are useful, they can also be usefully complemented by a qualitative methodology which allows us to reconstruct farmers' subjective representations. In this way, an ethnographic approach (Joly and Weller 2009) shows the chain of concrete actions between the administration and the farm. A recent study (Mesnel 2017) invites us to investigate how "red tape" has political consequences on agriculture. Farmers experiencing the complexity of the paper work they have to do might perceive policy constraints as very distant from their own agricultural reality. This perception, along with other professional factors such as economic hardship and demographic decline, co-produces farmers' political despondency. Thus, the main aim of this paper is to contribute to this research area by showing that it is the implementation of the new Common Agricultural Policy 2014-2020 that shapes French farmers' representations of it.

Materials and methods

To do so, we mobilize empirical materials obtained since 2015 through an ethnographic inquiry in the Rhône-Alpes region. This long-term study is still on-going and is part of a PhD thesis on the greening of agricultural policy. The anthropological method utilized is based on social immersion, which allows the researcher to go beyond respondents' public discourses and access their private language (De Sardan 2008). In this paper, we analyze three types of materials: ethnographic observations; in-depth sociological interviews; and grey literature. We observed the moment when the farmers filed their CAP forms. In general, they rely on diverse organizations such as the Chamber of Agricultural Agriculture, accountants specialized in agricultural matters, the largest union and the local breeders association. We then observed the state administration's treatment of the forms; we conducted interviews (n=20) with Puy-de-

Dôme crop-livestock farmers and we consulted various official texts, from the European regulation to French local administration memorandum.

Results

Two main results emerge. First, there is a gap between policy and its implementation, and, second, most farmers have a negative representation of the CAP 2014-2020. Our hypothesis is that farmers' representations result from the complexity of its implementation.

I- A complex implementation

A) The CAP 2014-2020 principles expressed in European regulation and the French legal framework: the new CAP as a text

In France, the CAP 2014-2020 really came into full effect in 2015. Greening has consisted in modification of first pillar direct payments: the single payment scheme has been replaced by a basic payment, a redistributive payment, and a green payment, each one representing approximately a third of the former single payment in France. The first two payments aim to distribute payments more fairly between farmers. The last one defines new environmental criteria, such as crop diversification, maintenance of permanent grassland, and the declaration of Ecological Focus Areas (EFA). The environmental cross compliance is reinforced by the seventh Good Agricultural and Environmental Condition (GAEC7). The GAEC7 protects hedges, ponds and copses. It is now forbidden to destroy these topographic elements without the authorities' approval (Balny et al. 2015) in France. Through the EFA and GAEC7, the CAP promotes non-contractual agroforestry because these two measures 1) are not limited to the second pillar, 2) are obligatory, and 3) promote large scale agroforestry practices, recognizing both intra-plot trees and the importance of hedges.

B) A complex French implementation: the new CAP as a digital challenge

How have these CAP modifications been implemented in France? Concretely, an exceptionally precise digital project has been carried out on a massive scale, digitizing ponds, copses, lines of trees, hedges, isolated trees, streams, etc. over half of the entire French area. The purpose of this work has been to identify elements of the EFA and elements protected by the GAEC7. In addition to this digitizing, in France, the implementation of the new CAP coincided with the EU's refusal of clearance of accounts for the years 2008 to 2012. The French state had therefore to pay out 1,078 billion euros. The problem laid with the Land Parcel Identification System (LPIS), that is, a national digital map. This map was considered to be too imprecise: the EU punished the French administration for having attributed payments to non-eligible areas such as roads. Consequently, the French LPIS was completely redone. To do so, a new administrative category was created: non-agricultural areas. These include the EFA, GAEC7, and non-eligible elements (Table 1).

Table 1: The creation of the “non-agricultural areas”.

From greening policy…		**…to its implementation**		
Regulatory section	Administrative category	Elements to digitize	Payment eligibility	Digital category
First pillar green payment	Ecological focus areas (EFA)	Ponds, isolated trees, aligned trees, hedges, buffer strips, copses, traditional walls.	Yes	**NON-AGRICULTURAL AREAS**
Cross-compliance	Good agricultural and environmental conditions (GAEC) n°7	Ponds, copses and hedges.	Yes	
Land Parcel Identification System remodeling		Roads, rocks, buildings, forests, streams, scrubs.	No	

In 2014, the identification of non-agricultural areas was delegated to the National Geographical Institute, which partly subcontracted this task to private companies. In 2015, French territorial administrations had to hire hundreds of temporary workers (Farvaques et al. 2017) to finish the job. In 2016, farmers had to verify and modify non-agricultural areas by themselves. The whole digital treatment took much more time than expected: though the new CAP has been running since 2015, it was still not finished at the end of 2017.

II- Four political consequences (PC) of the implementation of the CAP 2014-2020

PC n°1: Lack of understanding of the new CAP

The administrative consequence of this delay is simple: if all non-agricultural areas are not determined, then the farmers’ forms cannot be finished and payments cannot be delivered. To mitigate this situation, the state borrowed money to distribute repayable cash advances to the farmers, based on the payments distributed in 2014. De facto, for farmers, as they received in 2015 and 2016 the same payments as in 2014, the CAP 2015-2020 has no economic existence. Therefore, they do not understand the concrete modifications of the new CAP.

PC n°2: Ecology seen as a way of saving on public spending

When we asked about the changes brought by the new CAP (2014-2020), most farmers evoked the non-agricultural areas. Far from being a purely technical point, these areas have been the interface point between farmers and the new CAP. The single category, “non-agricultural areas”, refers to two types of areas, one of which is eligible, while the second is non-eligible (table 1). This complexity favored misunderstanding: many farmers then thought that the goal of the change in the CAP was to reduce their total payment. “Give less, annoy more”, as a breeder summed it up. This belief is furthermore reinforced by the evidence that their plots’ surfaces are diminished. The acreage is a very important indicator for the farmers. The fields’ surface on cadastral plan is a fixed reference for them that they can compare with the surface area eligible for the CAP payments. Year after year, they notice that their fields are getting smaller and smaller.

PC n°3: Rejection of a policy experienced as authoritarian

The new CAP promotes an up-down policy system. The GAEC7 is seen by farmers as an authoritarian mechanism forbidding the removal of hedges without approval. If agricultural red tape may engender resignation (Jacques-Jouvenot 2014) and despondency (Mesnel 2017), it may also engender anger as an outcome. Knowing that hedges are symbols of private property, forbidding their removal is perceived as emblematic of a vertical policy. This reinforces a discourse that points out the lack of farmers' autonomy, as the (frequently-heard?) sentence expression? "we are no longer masters in our home" expresses. In addition, the announcement of the rule stimulated infringement. Though this phenomenon is hard to quantify, massive hedge up-rooting was the response to hedge protection by the GAEC7.

PC n°4: Political disaffection produced by cumbersome "red tape"

Saying that the CAP is complicated and must be simplified is an often-heard statement. It is however important to give an example of the lack of transparency of the CAP greening. The software computation of the EFA was only available in 2017, which means that farmers had to file their CAP form without knowing if they had the necessary 5 % of EFA of arable land. During the on-line filing, accountants and technicians were trying to calculate estimations of the EFA. They were measuring hedges and counting trees and applying weighting factors with their manual calculators, but finally they could assert nothing certain. Confronted with this opacity, many farmers wanted to "protect" themselves and "to be in good standing" so they planted catch crops, whose EFA value is easy to compute. Implementation difficulties are not voluntary, neither exceptional because they reveal the high-level demands of the CAP 2014-2020. Digitizing tree after tree may seem incredible for some farmers, who see in these meticulous tasks the evidence that the agricultural administration lives in another world, far removed from the day-to-day reality of their productive work.

Discussion

Negative representations are still more flagrant in difficult times for farmers who cannot live from their production and sales. Most of the farmers we encountered were anxious about the "end of cattle breeding", and more generally about their professional situation within a global society. Coupled with severe difficulties in its implementation, the CAP 2014-2020 appears as a supplementary technical burden in a profession that is already deeply mired in economic and social difficulties.

Furthermore, the population studied is mostly composed of crop-livestock farmers living in a forested region, who do not understand why the same rules are applied to grain producers living on the plains and to them. It is now necessary to see if time will mend this attitude. However, if we cannot extend our results to the future, the compensation mechanisms for farmers who have up-rooted hedges may soon be the scene of new CAP rejection, because these farmers will have to pay to plant a new hedge or lose payment.

Our paper is a call to recognize the fact that the conventional farmer's hostility to agroforestry is not necessarily linked to inherited "traditional" attitudes against trees and hedges (Balny et al. 2015). Our results invite us to think that farmers' representations did not pre-exist the new policy measure, but that they are constructed ex post facto by its technical implementation.

Conclusion

To conclude, the principal recommendation derived from our observations is that, in preparing the next CAP, the technical feasibility of the new measures should be included as an essential point in political negotiations. Given that implementation of the CAP generates political consequences, it must not be treated as a purely technical and secondary matter, but rather as a primary and political one. To do so, implicating local administrations and organisms could be part of an efficient solution (Mormont 1996).

References

Balny P, Domallain D, de Galbert M (2015) Promotion des systèmes agroforestiers. Propositions pour un plan d'actions en faveur de l'arbre et de la haie associés aux productions agricoles, Conseil Général de l'Alimentation, de l'Agriculture et des Espaces Ruraux (CGAAER), rapport n°14094.

De Sardan OJP (2008) La rigueur du qualitatif: les contraintes empiriques de l'interprétation socio-anthropologique. Academia-Bruylant, Louvain-La-Neuve.

Farvaque N, Nouaf Z, Robilliard F (2017) Rapport d'expertise sur les conditions de travail dans les Services d'économie agricole (SEA), Orseu.

Jacques-Jouvenot D (2014) Une hypothèse inattendue à propos du suicide des éleveurs : leur rapport aux savoirs professionnels. Etudes rurales 193: 45 60.

Joly N, Weller JM (2009) En chair et en chiffres. TERRAIN 53: 140 153.

Mesnel B (2017) French farmers and red tape. Gouvernement et action publique 1: 33 60.

Mormont M (1996) Agriculture et environnement : pour une sociologie des dispositifs. Économie rurale 236: 28 36.

AGROFORESTRY WITHIN THE PILLAR I: INCLUDING WOODY PERENNIALS IN PILLAR I LANDS TO FOSTER SUSTAINABILITY

Mosquera-Losada MR[1*], Santiago-Freijanes JJ[1, 2], Aldrey JA[2], Ferreiro-Domínguez N[1, 3], Pantera A[4], Rigueiro-Rodríguez A[1]

(1) Crop Production and Project Engineering Department, Escuela Politécnica Superior de Lugo, University of Santiago de Compostela; Campus Universitario s/n, 27002 Lugo, Spain (2) Geography Department, Facultad de Geografía e Historia. Plaza de La Universidad, n8 1 15782, Santiago de Compostela, Spain (3) Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda s/n, 1349-017 Lisbon, Portugal (4) TEI Stereas Elladas, Dpt. of Forestry & Natural Environment, 36100, Karpenissi, Greece

*Corresponding author: mrosa.mosquera.losada@usc.es

Abstract

Agroforestry within the Pillar I can be established in arable lands, permanent grasslands and permanent crops, but the current Common Agricultural Policy (CAP) prevents from agroforestry practices extension. Some improvements have been carried out within the OMNIBUS regulation, mainly linked to avoid the reduction of loss of payments by the presence of woody perennials in the plots. Agroforestry adoption was also allowed by the greening. However, the inefficiency of the greening application and the complexity of the system linked to cross-compliance and Pillar II made difficult to implement agroforestry as part of the greening option. The future of the CAP will be based on the “payment for results” and the development of a set of indicators to justify the results that will definitively be an opportunity for fostering agroforestry across Europe.

Keywords: silvoarable; silvopasture; riparian buffer strips; arable land; permanent grassland; permanent crops

Agroforestry within the Pillar I

Pillar I is the part of the Common Agricultural Policy (CAP) completely funded by the European Union aiming at paying farmers to make plots and farms more profitable and sustainable but also trying to benefit the impact at landscape scale from an environmental point of view, but also foster Rural Development. Farmers can receive Pillar I payments if they have the “right” to get the money and/or have land that is eligible to get these funds, depending on the countries. Eligibility is linked to a specific type of land included as Arable land, Permanent grassland and Permanent Crops, meaning that for example forest lands are not able to receive Pillar I payments unless they are linked to some woody perennial species under short rotation coppice management producing bioenergy as a type of permanent crop or if established local practices are the selected for permanent grasslands. Besides these three types of lands, agroforestry is supported by the greening, which represents the 30% of the Pillar I payments.

Agroforestry on arable land: silvoarable and riparian buffer strips

Regulation 1307/2013 Article 4(f) defines "arable land" as “*land cultivated for crop production or areas available for crop production but lying fallow…*”. EU delegated regulation 640/2014 Article 9 explains that “*an agricultural parcel that contains scattered trees shall be considered as eligible area provided that the following conditions are fulfilled: (a) agricultural activities can be carried out in a similar way as on parcels without trees in the same area; and (b) the number of trees per hectare does not exceed a maximum density”.* It also states that this maximum density *“shall be defined by Member States and notified on the basis of traditional cropping practices,* *natural conditions and environmental reasons. It shall not exceed 100 trees per hectare. However, that limit shall not apply in relation to the measures referred to in Articles 28* [i.e. an agri-environment-climate measure] *and 30* [i.e. a Natura 2000 and Water Framework Directive measure] *of Regulation (EU) No 1305/2013*". However, the complexity of these rules when applied by Member States in real farms makes that many farmers do not establish and even destroy the woody component in the arable lands of their farms as they are afraid to have their payments reduced or even lost. This makes difficult to farmers adopt silvoarable practices (combination of a woody component (tree and/or shrub) in spite of the enormous advantages they have to increase profitability and ecosystem services delivery. Silvoarable agroforestry and riparian buffer strips should be promoted on arable land due to the advantages they provide. For example, the reduction of wind speeds and soil erosion can lead to substantial increases in arable crop productivity (up to 20% in windy areas with surrounding hedgerows) and improves resilience against extreme weather (adapting to climate change) including crop (lowering extreme temperatures) and livestock production (animal welfare). Agroforestry is a form of land use that allows ecointensification meaning that there is an increase of production because of the optimization based on the use of the resources but not on the increase of external inputs while reducing nitrate leaching (riparian buffer strips agroforestry practice). Agroforestry on arable land can also provide additional products (e.g. wood-fuel), improve soil structure, reduce nitrate leaching, and increase carbon sequestration (mitigating climate change).

Agroforestry on permanent grassland: silvopasture and riparian buffer strips

Regulation 1307/2013 Article 4(h) defines "permanent grassland" as "*land used to grow grasses or other herbaceous forage naturally (self-seeded) or through cultivation (sown) and that has not been included in the crop rotation of the holding for five years or more; it may include other species such as shrubs and/or trees which can be grazed provided that the grasses and other herbaceous forage remain predominant as well as, where Member States so decide, land which can be grazed and which forms part of established local practices where grasses and other herbaceous forage are traditionally not predominant in grazing areas*". One of the main problems of this definition was the associated concept of a "grazable trees" that made compulsory that the animal consumes the woody perennials by themselves and excluded good agroforestry systems like the dehesa because the animal fed acorns from the soil and not from the tree. This was solved by the current OMNIBUS regulation (EU 2017) that establishes "*Land which can be grazed, where grasses and other herbaceous forage are not predominant or are absent, and where the grazing practices are neither traditional in character nor important for the conservation of biotopes and habitats, may nevertheless have relevant grazing value in certain areas. Member States should be allowed to consider those areas as permanent grassland in the whole or in part of their territory*". Moreover, the option of having established local practices was implemented in most of the southern countries like Spain (13 out of 17 Spanish regions adopted it) to allow farmers to delivery animal products based on the available resources such as shrubs. The relevance of the shrubs is huge as they are one of the ecological traits, besides the selfsedeed species, able to provide feed for livestock during the summer drought, when no herbaceous vegetation is available at all (Figure 1).

Figure 1: Extending the grazing season. Tree shade allows herbaceous vegetation to survive to summer droughts for longer period of time (left). Shrublands (both herbaceous and shrubs) grazed in Galicia (NW Spain) during the summer time as legume shrub species allows herbaceous vegetation to be developed under the shrubs, that are also an excellent feed during the shortage summer (right).

Agroforestry on permanent grassland includes silvopasture and riparian buffer strips. Integrating woody vegetation on grassland can improve fodder production and provide additional feed sources (e.g. acorns, tree fodder) during periods of drought or cold, therefore leading to a reduced need for external farm inputs and reducing the need of feed transport and therefore the associated greenhouse gases emissions. For example *Morus alba* has a protein content over 20% (Mosquera-Losada et al. 2017a), but any of the trees cropped as shrubs or the shrubs are able to provide better fodder than herbaceous vegetation during the summer time in southern Europe. Integrating woody vegetation can also provide shade and shelter to animals during periods of extreme temperature improving animal welfare. The advantages of agroforestry practices for arable lands are strong enough to be fostered instead of penalized by the CAP. A good option will be the development of a management plan that dully justifies the existence of agroforestry practices within a multi-annual programme that allows farmers to receive funds from areas based on their productivity and the ecosystem services agroforestry practice deliver.

Agroforestry on permanent crops: silvopasture and silvoarable

Regulation 1307/2013 Article 4(g) defines "permanent crops" as ”*non-rotational crops other than permanent grassland and permanent pasture that occupy the land for five years or more and yield repeated harvests, including nurseries and short rotation coppice*”. Hence “permanent crops” include short rotation coppice and apple and olive trees, among others.

The promotion of agroforestry where permanent crops are established is essential to improve nutrient cycling but also reduce tree illnesses as happens with the combination of sheep and vineyards or chestnut trees, as animals consume leaves with fungus illness after grape harvesting and chestnut parasites in the different insect phases. Moreover, livestock intestine parasites are also reduced when woody perennials are part of the diet due to the higher tannin concentration they have compared with the herbaceous vegetation. However, agroforestry practices in permanent crop plots are not promoted in spite of the benefits they have and that they will be fully eligible for Pillar I payments independently of the tree density. Moreover there are also some crops such as medicinal plants (*Melissa* or *Mentha*) that can achieve higher active compounds when growing under shade and these could be promoted in permanent crop systems (Mosquera-Losada et al. 2017b) that should be further evaluated with other crops.

Greening payments

Regulation 1307/2013 paragraph 37 explains that Pillar I includes mandatory greening payments which “*support agricultural practices beneficial for the climate and the environment”*. These are effectively a release of 30% of the basic payment which is held back unless the farmer can demonstrate practices *“that go beyond cross-compliance and that are linked to* *agriculture, such as crop diversification, the maintenance of permanent grassland, including traditional orchards where fruit trees are grown in low density on grassland, and the establishment of ecological focus areas*." Organic farms receive this payment directly. Unfortunately, greening has not been as successful as expected as highlights the European Court of auditors (2017). With regard to agroforestry, it can be linked to permanent grassland preservation (already explained) but also to the existing agroforestry option for Ecological Focus areas (EFA). Greening can be fulfilled with agroforestry when this type of land was established Measures 222 and 8.2 of the previous and current CAP. Moreover, the presence of landscape features (that if woody vegetation is involved can be considered agroforestry) is also one of the options available to fulfill the Greening. The low adoption of agroforestry as part of the EFA can be explained by the link to 222 and 8.2. Moreover, the low adoption of landscape features to justify the greening can be explained by the complexity of controlling them and avoiding double funding as these features are also financed by the Rural Development measures (mainly related to the agro-environment measure) as highlights the European Court of Auditors (2009). Funds cannot be given to the same activity and choosing different options for the same land use activities is compulsory to avoid double funding; this generates a significant burden and makes difficult to control and evaluate the real impact of greening on farm activities. The fact that landscape features can be found elsewhere in the CAP linked to sustainability of agricultural systems makes their protection complicated and, above all, difficult to evaluate. To understand how policy drives the presence or enhancement of these landscape features is crucial for knowing if the policy is correct or not and to identify and propose future policy improvements.

Post 2020 CAP

The new CAP model based on payments linked to results within the Pillar I, makes agroforestry more prone to be adopted. It has also been said that the European Commission will not use tree density as a limit to avoid CAP direct payments, leaving this responsibility to Member States that will have to ensure agricultural production and activity. Some examples of agroforestry practices paid to farmers by the results they provide are available such as the Andalucian Firebreak Areas network (RAPCA 2015). This example has been highlighted several times by the European Commission as a good example to follow. Farmers are contracted to use animals for grazing firebreaks. The contract establishes the degree of grazing that should not be within over or under grazing, and it is seen as a good example of preventing forest fires by maintaining forest sections surrounded by tree less lands that will produce healthy animal products sold in local markets and serving for educational purposes for students, farmers and consumers.

The European Commission has explained that a set of EU common indicators will be developed to ensure that CAP payments are targeted to European society needs that are included in the sustainable development goals. One of these indicators should be related with the adequate inclusion of woody perennials to enhance land productivity, mitigate climate change while increasing agricultural systems resilience.

Acknowledgements

This work was funded through the AFINET (www.afinet.eu) project from the European Union´s H2020 Research and Innovation Programme under grant agreement no 727872 and the Xunta de Galicia (Consellería de Cultura, Educación e Ordenación Universitaria (''Programa de axudas a etapa posdoutoral DOG n8122, 29/06/2016 p.27443, exp: ED481B 2016/0710'')). The views and opinions expressed in this article are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

References

EU (2017) OMNIBUS Regulation http://www.consilium.europa.eu/media/32072/pe00056en17.pdf (accessed 06/05/2018).

European Court of Auditors (2017) Greening the CAP: income support more complex, and not yet environmentally effective. https://www.eca.europa.eu/en/Pages/ecadefault.aspx (accessed 06/05/2018).
Mosquera-Losada MR, Ferreiro-Domínguez N, Fernández-Lorenzo JL, González Hernández P, Rigueiro Rodríguez A (2017a) Fodder tree evaluaiton in Galicia. Spain. https://agforward.eu/index.php/en/agroforestry-with-pigs-in-galicia-spain.html?file=files/agforward/documents/LessonsLearnt/WP5_ES_Morus_lessons_learnt.pdf (accessed 06/05/2018).
Mosquera-Losada MR, Ferreiro-Domínguez N, Fernández-Lorenzo JL, González Hernández P, Rigueiro Rodríguez A (2017b) Medicinal plants in silvoarable systems in Galicia, Spain. https://www.agforward.eu/index.php/en/silvoarable-systems-in-spain.html?file=files/agforward/documents/LessonsLearnt/WP4_ES_Medicinal_plants_lessons-learnt.pdf (accessed 06/05/2018).
RAPCA (2015) Red de areas pasto-cortafuegos de Andalucía. http://www.juntadeandalucia.es/medioambiente/site/portalweb/menuitem.7e1cf46ddf59bb227a9ebe205510e1ca/?vgnextoid=522dbc3b5864b310VgnVCM2000000624e50aRCRD&vgnextchannel=e1d5a5f862fa5310VgnVCM1000001325e50aRCRD (accessed 06/05/2018).

AGROFORESTRY POLICY IN THE USA AND EUROPE

Ormsby Mori G[1], Mosquera-Losada MR[2*]

(1) Center for Agroforestry, University of Missouri, Columbia, Missouri, USA (2) Department of Crop Production and Engineering Projects, Escuela Politécnica Superior de Lugo, University of Santiago de Compostela, Campus Universitario s/n, 27002 Lugo, Spain

*Corresponding author: mrosa.mosquera.losada@usc.es

Abstract

Agroforestry is a sustainable land use that has been recently recognized in both the United States and Europe. A brief summary of the current status and extent of agroforestry in USA and Europe is described in this paper as well as the current policies and the role of the innovation working groups in both areas. We also provide insights for better development of agroforestry across the USA and Europe by indicating the main challenges that should be overcome.

Keywords: policy recommendations; challenges; opportunities; obstacles; working groups

Introduction

Agroforestry has been modernly practiced in Europe since the beginning of XXI century while in the United States since at least the 1930s when trees were planted by the Conservation Corps in both windbreaks and in mixed cropping practices in response to the environmental and economic crisis of the "dustbowl era." Agroforestry has likely been practiced in various forms and through intentional management by Native Americans and early European settlers since much earlier. Science-based agroforestry research and practice in the USA began gaining traction in the 1970s, when different research institutions in Europe started to focus on agroforestry (Rigueiro-Rodríguez et al. 2000; Papanastasis et al. 2009; Castro 2009). The Association for Temperate Agroforestry (AFTA) was established as a nonprofit organization by research scientists and university educators in the mid-1980s to promote and advance the science and practices of agroforestry in the temperate zone, while the European Agroforestry Federation (EURAF) was established in 2011 with the same aim but in Europe.

A few countries around the globe have developed and adopted a fully articulated national policy on Agroforestry (e.g. France, India, Nepal, México) while in many other countries there have been varying forms of support such as strategic frameworks for agroforestry, agroforestry centers established, research funded, incentive programs created etc. In the United States, a National Agroforestry Center was established in 1991 and a comprehensive National Agroforestry Strategic Framework was developed for the period 2011-2016. A formal agroforestry policy is still lacking in the USA and agroforestry development has been limited in scope and assisted to some degree through policies and supportive programs in a range of sectors - agricultural, forestry, conservation, rural development at different levels of government. In Europe, an agroforestry specific measure was included as part of the 2007-2013 Common Agrarian Policy (CAP) which allows European Union countries to open the measure and implement it at European level. However, and due to various reasons the implementation of this measure across Europe was not very successful (Santiago-Freijanes et al. 2018).

This presentation will provide an update and overview of policy development for agroforestry in the United States and Europe, including the current status, policy development, opportunities, working groups, obstacles and key policy recommendations.

Current status of agroforesrtry in the US and Europe

In the United States, little data exists on agroforestry adoption across the landscape. Forests, farmland and pasture in the US total around 716 million ha and the total land in agroforestry in any of these sectors does not exceed 1% (USDA 2013). The actual extent of all agroforestry practices, alley cropping, windbreaks, riparian forest buffers, managed silvopasture and forest farming, might amount to 3 million ha, or approximately 0.42% of productive landscapes suitable for agroforestry (Jose 2017). Formal data collection on agroforestry through the USDA agricultural census first began in 2012, with a single question asking whether alley cropping and silvopasture were practiced. Across the United States a total of 2725 farms responded affirmatively, but no information on total hectares was collected. Expanded data collection on agroforestry is planned for the 2018 agricultural census. Some information can be garnered from participation in federal cost share assistance programs of the Natural Resources Conservation Service. Between the period 2008–2012, assistance by USDA programs to implement windbreaks, riparian forest buffers, and alley cropping was provided for approximately on 336,000 acres, or less than 1% percent of suitable cropland with agroforestry potential.

In Europe, an inventory of main agroforestry practices, silvopasture, silvoarable or alley cropping, forest farming, homegardens and riparian buffer strips have been carried out by den Herder (2017) identifying the tree-based agroforestry areas and Mosquera-Losada et al. (2018) identifying the tree/shrub-based agroforestry areas. Close to 20 million of hectares in Europe can be allocated to different types of agroforestry mainly in the southern countries of Europe. Agroforestry has a huge potential depending on the CAP funded area we are considering, over 99% and 90% of the arable and permanent grassland lands can potentially include agroforestry practices and be used to increase sustainability and ecosystem services delivery.

Agroforestry policy development

Since interest in agroforestry research began to emerge in the 1970s, a number of supportive programs have emerged, such as the Conservation Reserve Program created in the 1985 Farm Bill and administered by the Farm Services Agency, responding to the farm crisis of the 1980's. Several other programs administered by the Natural Resources Conservation Services (NRCS) providing cost share or incentives for adoption of conservation measures and agroforestry practices have been created by successive farm bills. The USDA National Agroforestry Center (NAC), originally established as a center for semi-arid agroforestry under the 1990 Farm Bill, was expanded into a US Forest Service and NRCS partnership in 1995. The NAC, in coordination with a network of partners, seeks to advance agroforestry science and adoption, but has not been consistently fully funded or staffed, including key positions like the NRCS Lead Agroforester.

A comprehensive National Agroforestry Strategic Framework was developed for the period 2011-2016, under which an interagency agroforestry steering committee was convened. The stated intention to develop and release a formal agroforestry policy statement, as indicated in the framework, however, has not yet been realized. Efforts are currently ongoing to update and release a new agroforestry strategic framework. An AFTA led policy working group has recently been formed and work is proceeding on an analysis of current policies and regulations impacting agroforestry, and articulating a policy platform with specific recommendations and goals for creating a policy environment favorable to advancing agroforestry research, education and adoption.

Agroforestry policy measures in Europe have been included as part of the CAP by the European Commission in the periods 2007-2013 and the current 2014-2020. When in the first period only agroforestry establishment were able to be funded, nowadays and thanks to the recent 1307/2013 regulation both establishment and maintenance of the established plots for a period of 5 years are possible. Moreover, the recent CAP 2014-2020 modification in the so called OMNIBUS allows the agroforestry measure to improve already existing agroforestry systems.

Opportunities for advancing agroforestry through existing programs and policies

Despite the absence of a coherent agroforestry policy statement in the US, there are numerous policies and programs that have been favorable to or present opportunities for advancing agroforestry adoption. For example, the Natural Resource Conservation Service (NRCS) in addition to major programs (EQIP, WHIP, CREP, CSP) providing financial incentives and technical assistance, has also established several practice standards relevant to agroforestry, such as practice standard #381 for silvopasture establishment. These, along with other relevant Farm Bill programs that present opportunities for agroforestry development, from the Forest Stewardship Program, the Sustainable Agriculture Research and Education (SARE), Organic Agriculture Research and Extension Initiative (OREI), and the Specialty Crop Research Initiative (SCRI), will be discussed. In Europe, besides the "agroforestry measure" around 29 measures in the CAP 2007-2013 and 27 measures in the CAP 2014-2020 can be recognized that fosters agroforestry in different European countries. The so called agroforestry measure is more used to foster agroforestry than the proper agroforestry measure (measures 222 and 8.2 in CAP 2007-2013 and CAP 2014-2020, respectively). However, there is not a clear recognition of the agroforestry practices as such by both policy makers and farmers, but indeed a recognition of the positive role that the combination that woody perennials (trees or shrubs) with agricultural products delivery from the lower storey have for delivering ecosystem services.

Role of partnerships and agroforestry working groups

Multi-stakeholder partnerships have been important for advancing agroforestry, their role and contribution, as well as that of numerous regional Agroforestry Working Groups and Associations will be discussed. Several regional working groups (Northeast Mid-Atlantic Agroforestry Working Group, Mid-America AF working group, the 1890's consortium), networks and non-profit organizations (e.g. Green Lands Blue Waters, Chesapeake Bay initiative, Savanna Institute etc.) have been established and played important roles in outreach, coordination and advancing agroforestry adoption and policy development at various scales. Europe has also established agroforestry working group within the multi-actor innovation approach concept. One of the 17th thematic networks in Europe is about agroforestry, the so called Agroforestry Innovation Network (AFINET) which is based on 9 Regional Innovation networks (RAINs) placed in 9 different European Union countries. These RAINs are composed by farmers (at least 30%), that meet every six months to discuss about main challenges to be overcome to foster agroforestry as well as the main innovations and dissemination activities that should be carried out to increase agroforestry adoption across Europe (Villada et al. 2018).

Major policy obstacles to agroforestry adoption

There are a number of policies and programs in the US that present significant obstacles to agroforestry adoption. Several examples, such as Farm Services Agency (FSA) programs for counter-cyclical payments, crop insurance and others policies that present disincentives to farmers to invest in longer term perennial crops or mask the true costs and risks of unsustainable practices, along with opportunities for incentives to support more sustainable agricultural practices that could be addressed by policy measures are considered. From a policy point of view, the main obstacle for agroforestry adoption in Europe is linked to the maximum tree density allowed for permanent grasslands and arable lands to receive direct payments. The lack of ensuring Pillar I payments when establishing an agroforestry plot funded under Pillar II (measure 222 and 8.2) measure prevents a lot of farmers from agroforestry adoption. Also the lack of an adequate system of education that help farmers to better implement agroforestry should be fostered at European level.

Key policy recommendations

Some of the priorities and key policy recommendations for advancing agroforestry in the US include, funding the National Agroforestry Center, making changes in the CRP program to allow harvesting and providing incentives for “productive conservation” approaches, changes to crop insurance and counter cyclical payment programs and increased support for agroforestry research, education and capacity building for expanded technical service provision. In Europe recommendations will be linked to invest more in research dealing with the optimization of agroforestry components at spatial and time scale, fostering the use of native woody legumes to make the systems more sustainable, providing better added-value through certification, invest in education and innovation.

Acknowledgements

We are grateful to the European Commission through the AFINET project from the European Union´s H2020 Research and Innovation Programme under grant agreement no 727872. The views and opinions expressed in this article are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

References

Castro M (2009) Silvopastoral systems in Portugal: Current status and future prospects. In: Rigueiro-Rodríguez A, McAdam J, Mosquera-Losada MR (eds) Agroforestry in Europe: current status and future prospect, vol 6. Springer, Dordrecht, pp.111-126.

Den Herder M, Moreno G, Mosquera-Losada MR, Palma JHN, Sidiropoulou A, Santiago-Freijanes JJ, Crous-Duran J, Paulo JA, Tomé M, Pantera A, Papanastasis VP, Mantzanas K, Pachana P, Papadopoulos A, Plieninger T, Burgess PJ (2017) Current extent and stratification of agroforestry in the European Union. Agr Ecosyst Environ 241: 121-132.

Jose S (2017) Agroforestry for Farm Diversification and Ecosystem Services in Temperate North America. Presentation at the 2017 Tri-Societies Convention. Tampa, Florida.

Mosquera-Losada MR, Santiago-Freijanes JJ, Rois M, Moreno G, den Herder M, Aldrey JA, Ferreiro-Domínguez M, Pantera A, Pisanelli A, Rigueiro-Rodríguez A (2018) Agroforestry in Europe: a land management policy tool to combat climate change. Land Use Policy (in press).

Papanastasis VP, Matnzanas K, Dimi-Papanastasi O, Ispikouidis I (2009) Traditional agroforestry systems and their evolution in Greece. In: Rigueiro-Rodríguez A, McAdam J, Mosquera-Losada MR Agroforestry in Europe: current status and future prospects, vol 6. Springer, Dordrecht, pp.89-109.

Rigueiro A (2000) Sistemas silvopastorales en la Iberia Húmeda. Actas de la III Reunión Ibérica de Pastos y Forrajes. Sociedad Española para el Estudio de los Pastos y Sociedade Portuguesa para o estudio dos pastagens and forragens. A Coruña, Spain.

Santiago-Freijanes JJ, Pisanelly A, Rigueiro-Rodríguez A, Aldrey JA, Pantera A, Vityi A, Lojka B, Kachova V, Mosquera-Losada MR (2018) Agroforestry development in Europe: Policy issues. Land Use policy (in press).

USDA (2013) Agroforestry: USDA Reports to America, FY 2011–2012 (Comprehensive version). USDA, Washington, DC.

Villada A, Verdonckt P, Ferreiro-Domínguez N, Rodríguez-Rigueiro FJ, Arias-Martínez D, Rois-Díaz M, den Herder M, Paris P, Pisanelli A, Reubens B, Nelissen V, Paulo JA, Palma JHN, Vityi A, Szigeti N, Borek R, Galczynska M, Balaguer F, Smith J, Westaway S, Rigueiro-Rodríguez A, Mosquera-Losada MR (2018) AFINET: Agroforestry Innovation Thematic Network IV EURAF Conference (this volume).

AGRICULTURAL WOOD AS AN ECOLOGICAL FOCUS AREA: CONVENTIONAL GERMAN FARMERS' ATTITUDES

Drittler L[1*], Theuvsen L[1]

(1) Department of Agricultural Economics and Rural Development, University of Goettingen B, Goettingen, Germany

*Corresponding author: lara.drittler@uni-goettingen.de

Abstract

Cultivating agricultural wood is an option to comply with the greening-restrictions of the current Common Agricultural Policy. Agricultural wood is a bioenergy source well accepted by wider society. It is classified as ecologically important by various European studies and its growing could answer some of the public criticism directed towards industrialised agriculture. However, agricultural wood is only of minor relevance in most European countries. In order to identify characteristics that influence farmer's attitudes towards agricultural wood, a standardised online survey was conducted among farmers in Germany in the first quarter of 2017. The results indicate that farms with less favourable local conditions and arable farms as well as risk-averse farmers are more promising target groups.

Keywords: agricultural wood; ecological focus areas; farmers; attitudes; Germany

Introduction

In the current funding period 2014-2020 of the Common Agricultural Policy (CAP), direct payments are linked to three greening-restrictions: crop diversification, preservation of permanent grassland and land use for environmental interests. To comply with these requirements, farms with more than 15 hectares of arable land have to create at least five percent of their arable land as so-called Ecological Focus Areas (EFA). Cultivating agricultural wood (such as short-rotation-coppice (SRC) or agroforestry) is an option for the provision of these EFAs. Currently, agroforestry systems are not accepted as EFA in Germany. But SRC are permitted as EFA under the conditions of a minimum size of 0.3 hectares and the growing of specific tree species (BMEL 2015). Another option for the provision of agricultural wood as EFA is strip-type integrated agricultural wood. For this, a SRC is planted on parts of the farmland that are mechanically difficult to reach (Feldwisch 2011).

Agricultural wood is a bioenergy source that is well accepted by wider society (Henke and Theuvsen 2015; Herbes et al. 2014). Various European studies classify it as ecologically important (Burger 2010; Nahm and Morhart 2017) and growing agricultural wood could answer some of the public criticism directed towards industrialised agriculture (Nahm and Morhart 2017). Despite these advantages agricultural wood is only of minor relevance in most European countries. For example in Germany, only 2.474 hectares of agricultural wood has been planted as EFA (BMEL 2016).

However acceptance of agricultural wood is vital for the successful establishment of this EFA-measure. So far, only a few studies have dealt with the acceptance of agricultural wood in general, to which one can add that, reference to Greening as a core element of the CAP has been completely lacking in those studies (Glithero et al. 2013; Boll et al. 2015; Warren et al. 2016).

Against this background, the objective of this article is therefore to identify differing characteristics between farmers' attitudes towards agricultural wood as EFA, so that possible target groups could then be defined for an increase in acceptance.

Materials and methods

Conventional farmers throughout Germany were surveyed in the first quarter of 2017 by means of a standardized online survey. Different distribution channels such as mailing lists and advertisements in agricultural newsletters were used to recruit as many farmers as possible. All variables regarding farmers' attitudes towards agricultural wood, as well as their attitude towards risk, were measured using the five-point Likert scale from -2 = "totally disagree" to +2 = "totally agree". When enquiring into farm and sociodemographic characteristics, nominally scaled variables were used.

The data were evaluated using IBM SPSS Statistics 24. In order to obtain a brief overview, frequency distributions of sociodemographic and farm characteristics, as well as attitudes towards agricultural wood as EFA, were considered (Raab-Steiner and Benesch 2008). To reduce the large number of items that describe farmers' attitudes, an explorative factor analysis was carried out (Bühl 2010). In a further step, depending on scaling, correlation analysis and mean comparisons were conducted to discover in which characteristics farmers' attitudes differ (Raab-Steiner and Benesch 2008). Normal distribution was neglected due to the explorative character of the study.

Results

Two hundred and thirty eight farmers farming conventionally completed the survey. On average, they are rather prepared to take risks (μ=0.73). 78.6% of farmers have a medium to high risk tolerance. Most of the farms are located in southern Germany (30.7%), followed by northern (27.7%) and western Germany (24.8%). The lowest share of farmers surveyed is situated in eastern Germany (16.8%). This differs somewhat from the situation over the entire country, since nearly half of all farms are located in southern Germany and a quarter in western Germany (Destatis 2017). In the survey, the average farm size is 309.0 hectares, of which, on average, 259.7 hectares are arable land. These farms are therefore considerably larger than the German average (Destatis 2017). Among all participants, 89.1% work full time on their farms.

Frequencies shown in Figure 1 clearly illustrate that the farmers surveyed have a negative attitude to strip-type integrated agricultural wood as EFA. Only 10.9% of the participants already grow agricultural wood. On average participants neither intend (μ=-1.29) or plan concretely (μ=-1.61) to grow strip-type integrated agricultural wood as EFA. Furthermore, more than two thirds of the farmers are put off growing agricultural wood by the long term commitment of farm land (76.1%).

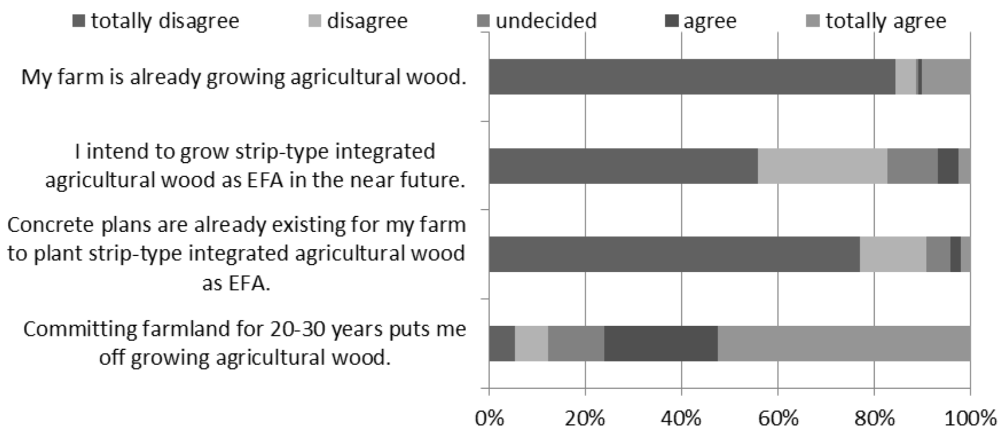


Figure 1: Frequency distributions of important statements. Source: Authors' calculation.

To identify important factors influencing conventional farmers' attitude towards strip-type integrated agricultural wood as EFA and to reduce complexity, an explorative factor analysis was conducted. The final factor solution contained four factors with 15 variables (Table 1). All quality tests indicated that all four factors meet the common requirements (Bühl 2010). The first factor, “Endorsement of agricultural wood as EFA”, describes the general attitude towards agricultural wood as EFA from the point of view of conventional farmers. It summarises items that relate to the farmers’ growing intentions and their assessment of benefits stemming from growing agricultural wood. The second factor, “Risks of growing agricultural wood”, combines four items concerning conventional farmers’ perception of growing risks. The third factor, “Image of agricultural wood”, aggregates two items that present the position of farmers towards an image increase through growing agricultural wood. The last factor, “Level of information about agricultural wood”, consists of two items enquiring whether farmers have obtained information.

Table 1: Result of the factor analysis.

Factors and underlying items	**FL**
Factor 1: Endorsement of agricultural wood as EFA (Cronbach’s Alpha=0.898)	
[1] If growing strip-type integrated agricultural wood is economic, I would plant agricultural wood.	0.860
[1] I believe that growing strip-type integrated agricultural wood as EFA is useful.	0.835
[1] I would grow strip-type integrated agricultural wood, if the weighting factor is correspondingly higher.	0.815
[1] Personally, the growing of strip-type integrated agricultural wood as EFA brings additional benefit.	0.795
[2] I intend to grow strip-type integrated agricultural wood as EFA in the near future.	0.671
[2] Agricultural wood is a useful option to meet the greening requirements of the CAP.	0.644
[2] The greening of CAP leads me to think about planting agricultural wood as EFA.	0.642
Factor 2: Risks of growing agricultural wood (Cronbach’s Alpha=0.724)	
[2] The irregular cash flow during the production process makes agricultural wood unattractive for me.	0.757
[2] Committing farmland for 20-30 years puts me off growing agricultural wood.	0.726
[2] The greening-premium could not compensate for higher costs during harvest between agricultural wood strips.	0.724
[2] High initial costs prevent me growing agricultural wood.	0.706
Factor 3: Image of agricultural wood (Cronbach’s Alpha=0.719)	
[2] Growing strip-type integrated agricultural wood increases my public reputation.	0.827
[2] Growing agricultural wood enhances my image among colleagues.	0.805
Factor 4: Level of information about agricultural wood (Cronbach’s Alpha=0.764)	
[1] I have exchanged information about agricultural wood with colleagues.	0.878
[1] I have informed myself about growing agricultural wood (internet, journals, lecture, fair etc.).	0.853
KMO (Kaiser-Meyer-Olkin measure) = 0.862; explained variance = 66.64 %; [1] Scale from -2=not correct at all to +2=fully correct; [2] Scale from -2=totally disagree to +2=totally agree; FL=Factor Loading; n=238 Source: Authors’ calculation	

Farmers’ attitudes towards agricultural wood as EFA differs with regard to personality traits, type of farming, as well as location characteristics. Correlation analysis shows a significant connection between risk tolerance and the perception of the “image of agricultural wood” ($r=0.139$; $p=0.032$). The more risk-averse the farmer is, the higher is the perception of an image increase by growing agricultural wood. Furthermore, it was possible to detect differences with regard to various farming characteristics with the help of mean comparisons. Farmers’ “level of information about agricultural wood” differs significantly in mean values between full-time ($\mu=-0.06$) and part-time farmers ($\mu=0.47$) ($p=0.011$). In addition, the “level of information about agricultural wood” is significantly different between farmers who keep livestock ($\mu=-0.14$) and farmers who do not ($\mu=0.22$) ($p=0.007$). Moreover, the “level of information about agricultural wood” varies significantly between farmers who cultivate permanent crops ($\mu=0.86$) and farmers who do not ($\mu=-0.15$) ($p=0.000$). This finding is validated by a significant positive correlation between the area under permanent crops and “level of information about agricultural wood” ($r=0.182$; $p=0.005$). Part-time farmers, farmers without livestock, as well as farmers who cultivate permanent crops, are rather better informed about agricultural wood. Farmers who cultivate permanent crops also differ from other farmers in their “endorsement of agricultural wood as EFA” ($\mu_{\text{permanent crops}}=0.49$; $\mu_{\text{no permanent crops}}=0.08$) as well as in their perception of “risks of growing agricultural wood” ($\mu_{\text{permanent crops}}=-0.34$; $\mu_{\text{no permanent crops}}=0.06$). If farmers already cultivate permanent crops, they stronger support the growing of agricultural wood and estimate the risks as lower than other farmers.

Moreover, it was possible to detect differences and connections between attitude and location characteristics. It could be found that significant differences in mean values exist between the level of information and the relief of the farm location (p=0.001). Farmers who cultivate areas on plateaus (μ=0.92) are better informed about agricultural wood than farmers in low mountain ranges (μ=0.01) and lowlands (μ=-0.10). This finding is validated by a significant positive correlation between the level of information and the location altitude (r=0.130; p=0.045). Furthermore, the level of information and the perception of the "image of agricultural wood" vary between the different levels of erosion risks ($p_{\text{Factor 4}}$=0.003; $p_{\text{Factor 3}}$=0.039). Farmers who cultivate areas without risks of wind erosion (μ=-0.17) are rather less informed about agricultural wood than other farmers (μ=0.21). Farmers who cultivate areas without any water erosion risks (μ=-0.11) perceive the image of agricultural wood less favorably than other farmers (μ=0.16). Additionally, significant negative correlations could be found between annual rainfall and "Endorsement of agricultural wood as EFA" (r=-0.261; p=0.000). The less the annual rainfall, the higher is the endorsement of agricultural wood.

Discussion

The descriptive results showed that, in general, farmers tend to be against growing strip-type integrated agricultural wood as EFA. This result is in line with other studies concerning the acceptance of agricultural wood in other regions, for instance in England (Glithero et al. 2013; Warren et al. 2016). In Germany, farmers are also rather sceptical due to their lack of knowledge and experience with regard to agricultural wood as well as due to the long-term capital and area commitment (Skodawessely et al. 2008). However, German farmers are still willing to grow agricultural wood (Boll et al. 2015).

The aim of this article was to analyse characteristics that influence the attitudes of German farmers towards agricultural wood as EFA. The acceptance of agricultural wood is important for successful establishment of this EFA-measure. This analysis also contributed to closing the existing gap in research by highlighting the role of personality traits, type of farming, and location characteristics.

However, high standard deviations indicated that farmers cannot be regarded as one homogeneous group. They differ in various characteristics with regard to their attitudes towards agricultural wood as EFA. Due to the general low acceptance of agriculture wood as EFA in Germany, all farmers should be seen as a target group. In particular the results indicate that farms with less favourable local conditions (risk of erosion, low rainfall precipitation) and arable farms are more promising target groups, and risk-averse farmer can be considered as another.

Further research, the identified characteristics can help in classifying different groups (clusters) of farmers that vary with regard to their willingness to cultivate agricultural wood as EFA. On the basis of this further specification of target groups, recommendations for action could be derived in order to contribute to an increase in the acceptance of agricultural wood in Germany.

Acknowledgements

This work is supported by the Deutsche Bundesstiftung Umwelt (DBU). The authors express their gratitude to the DBU for the financial support.

References

BMEL (2015) Umsetzung der EU-Agrarreform in Deutschland. BMEL, Bonn, Germany.
BMEL (2016) Antwort der Bundesregierung auf die Kleine Anfrage der Abgeordneten Dr. Kirsten Tackmann, Caren Lay, Karin Binder, weiterer Abgeordneter und der Fraktion Die Linke. Bundestags Drucksache 18/10569. Deutscher Bundestag, Berlin, Germany.

Boll T, Neubert F, Zimmermann K, Bergfeld A (2015) Decision Criteria and Implementation Strategies for Short Rotation Coppice in Germany from the Perspective of Stakeholders. In: Manning DB, Bemmann A, Bredemeier M, Lamersdorf N, Ammer C (ed) Bioenergy from Dendromass for the Sustainable Development of Rural Areas. Wiley, Weinheim, pp 331-346.

Bühl A (2010) SPSS 18 – Einführung in die moderne Datenanalyse. Pearson, Munich, Germany.

Burger FJ (2010) Bewirtschaftung und Ökobilanzierung von Kurzumtriebsplantagen. Dissertation, Technical University of Munich, Germany.

Destatis (2017) Landwirtschaftliche Betriebe. https://www.destatis.de/DE/ZahlenFakten/Wirtschaftsbereiche/LandForstwirtschaftFischerei/LandwirtschaftlicheBetriebe/LandwirtschaftlicheBetriebe.html (accessed 31/05/2017).

Feldwisch N (2011) Rahmenbedingungen und Strategien für einen an Umweltaspekten ausgerichteten Anbau der für Sachsen relevanten Energiepflanzen. In: LfULG (ed) Umweltgerechter Anbau von Energiepflanzen. https://www.deutsche-digitale-bibliothek.de/item/DRE6H5WTGCSBGGGEB6FOMSAF3BWTNNUA. (accessed 22/09/2017).

Glithero NJ, Wilson P, Ramsden SJ (2013) Prospects for arable farm uptake of Short Rotation Coppice willow and miscanthus in England. Appl Energ 107: 209-218.

Henke S, Theuvsen L (2014) SLCA: Regional differenzierte Bewertung von Biogasanlagen und Kurzumtriebsplantagen. In: Eder M, Sinabell F, Stern T (ed) Jahrbuch der Österreichischen Gesellschaft für Agrarökonomie 23. Vienna, pp 81-90

Herbes C, Jirka E, Braun JP, Pukall K (2014) Der gesellschaftliche Diskurs um den „Maisdeckel“ vor und nach der Novelle des Erneuerbare-Energien-Gesetzes (EEG) 2012. GAIA 23: 100-108

Nahm M, Morhart C (2017) Multifunktionalität und Vielfalt von Agroforstwirtschaft. In: Böhm C. (ed) Bäume in der Land(wirt)schaft – von der Theorie in die Praxis. Tagungsband mit Beiträgen des 5. Forums Agroforstsysteme 30.11. to 01.12.2016 in Senftenberg, pp 17-24

Raab-Steiner E, Benesch M (2008) Der Fragebogen – von der Forschungsidee zur SPSS/PASW Auswertung. UTB, Stuttgart, Germany.

Skodawessely C, Glaser T, Pretzsch J, Schmidt PA (2008) Attitudes of farmers and nature conservation associations to short-rotation coppice (in German). Swiss Forestry Journal 159: 158- 164.

Warren CR, Burton R, Buchanan O, Birnie RV (2016) Limited adoption of short rotation coppice: The role of farmers' socio-cultural identity in influencing practice. J Rural Stud 45: 175-183

Agroforestry can mitigate environmental problems in European agricultural deficit areas

Kay S[1*], Roces-Díaz J[1], Crous-Duran J[2], Giannitsopoulos M[3], Graves A[3], den Herder M[4], Moreno G[5], Mosquera-Losada MR[6], Pantera A[7], Palma J[2], Szerencsits E[1], Herzog F[1]

(1) Department of Agroecology and Environment, Agroscope, Zurich, Switzerland (2) Forest Research Centre, University of Lisbon, Lisbon, Portugal (3) Cranfield University, Cranfield, Bedfordshire, United Kingdom (4) European Forest Institute, Helsinki, Finland (5) Forestry Research Group, Universidad de Extremadura, Plasencia, Spain (6) Crop Production and Project Engineering Department, Escuela Politécnica Superior de Lugo, University of Santiago de Compostela; Campus Universitario s/n, 27002 Lugo, Spain (7) Forestry and Natural Environment Management, TEI Stereas Elladas, Greece

*Corresponding author: sonja.kay@agroscope.admin.ch

Abstract

Agricultural production is one of the main causes for pressure on natural resources and environment in Europe. Agroforestry is known to provide food, fodder and material while enhancing ecosystem services and environment. In this context, this study evaluates how agroforestry can help to reduce environmental pressure in Europe. In the first step, we localised environmental deficit regions in European farmland areas based on a literature review and existing digital spatial information. For the second step local agroforestry experts were consulted to propose agroforestry systems, which they recommend to farmers of those regions to mitigate the environmental deficits.

Keywords: ecosystem services; deficit regions; carbon storage; biodiversity

Introduction

In Europe, environmental pressures such as water pollution or impacts of climate change have been increasing over the last decades. With the Nitrate Directive (91/676/CEE) in 1991, the Water Framework Directive (Directive 2000/60/EC) in 2000, and the Biodiversity Strategy in 2010, the European Commission showed awareness to environmental problems and tried to mitigate undesirable effects. Nonetheless, these problems persist and are linked to or caused by (intensive) agricultural production.

In this context, agroforestry (AF) can play an important role in future agricultural policy to mitigate critical emissions: agroforestry systems are known to simultaneously provide food, fodder and material whilst generating ecosystem services such as soil protection, water regulation, landscape diversity and (functional) biodiversity (Torralba et al. 2016). Additionally they have a great potential for climate mitigation and adaption (Hart et al. 2017).

Against this background, the European AGFORWARD project (www.agforward.eu) tried to answer the question, what agroforestry can do to help reaching the above-mentioned environmental targets. The study presented here was conducted as part of this project and is organized in two steps: First, based on a literature review and existing digital spatial information, farmland areas with potential (overlapping) environmental deficits in Europe were localised. Secondly, local agroforestry experts were consulted to propose agroforestry systems, which they recommend to farmers of those regions to mitigate the environmental deficits.

Materials and methods

In this study, the focus was on agricultural land in Europe, both arable land and grassland (Tóth et al. 2013; BFS 2015) without the Natura 2000 areas (EEA 2015), existing Agroforestry areas (den Herder et al. 2017) and the High Nature Value Farmland (EEA 2015). We proceeded in two steps:

1. Based on literature and existing information, we identified areas with potential environmental deficits in i) soils (soil erosion by wind and water, soil organic carbon), ii) water (water pollution by nitrates, water use efficiency in irrigated land), iii) affected by climate change (e.g. rising temperature) and iv) deficits in ecological functions (pollination and pest control deficits, threats to soil biodiversity). These analyses resulted in nine continental scale maps of ecosystem service deficits. By combining the maps, we created a heat map for environmental deficits to identify priority regions for the implementation of AF.

2. Based on participatory research and development (R&D) in 40 AGFORWARD working groups across Europe, we propose specific agroforestry systems that can mitigate the above-mentioned deficits and reduce the critical loads. Those systems are tailored to the respective deficit regions and based on advice from local agroforestry specialists. This resulted in a matrix of agroforestry systems divided into arable and grassland.

Results

In total, more than half of European agricultural was in good condition and grasslands were less harmed than croplands. While e.g. climate change (temperature increase > 2°C until 2050) affected more than 80% of arable and grasslands; soil erosion by wind was almost not relevant. The worst 10 % of the area with accumulated deficits were defined as priority regions, where the implementation of AF can be particularly effective. Regional hotspot areas for environmental deficits are the north-western part of France, Denmark, the centre of Spain, the North (Po region) and the south-west (Sicily) of Italy and the eastern part of Romania.

Regional experts suggested suitable agroforestry systems for affected cropland and grassland per biogeographical region. Table 1 gives an extract of the recommended systems, the potential tree species, number of trees per hectare, tree products and suitable crops.

Table 1: Extract of expert recommendation summary of suitable agroforestry systems

Region	Type	Species	Trees ha^{-1}	System	Crops	Tree Products
Mediterranean lowlands	Silvopastural single trees	Poplar; Peduncolate oak	57	lines	grass	fodder tree, timber
Mediterranean hills	Silvoarable single trees	Fruit trees	417	lines	fodder crops	fruits
Atlantic	Silvopastural single trees	Poplar	25	boundary	grazing, hay, silage	timber
Atlantic	Silvopastural single trees	Ash and Oak	400	single tree scattered	grazing, hay, silage	fodder tree, timber

Discussion

The analysis addressed nine deficits indicators and their occurrence in European agricultural land. The best available data were used, being aware that differences in scales (100 – 1000 m), time periods (2006 - 2017) and objectives (e.g. modelled nitrate losses in EU vs. nitrate losses in Switzerland) exist and might result in spatial inaccuracies (Schulp et al. 2014).

Additionally, our results provided ideas for suitable tree and crop species and a possible composition of agroforestry systems. Nonetheless, we are aware that the systems are highly dependent on soil, water and climate conditions of a specific plot or location. The underlying hypothesis that agroforestry can mitigate the environmental deficits was verified in various studies at plot and landscape scale (e.g. Nair et al. 2007; Reisner et al. 2007; McIvor et al. 2014).

Conclusion

The study provided an indication on where and which kind of agroforestry can mitigate the environmental problems in Europe and help to reach the ambitious European policy targets.

References

BFS (2015) Arealstatistik 2004 -2009. Bundesamt für Statistik, Neuchâtel. https://www.bfs.admin.ch/bfs/de/home/statistiken/raum-umwelt/erhebungen/area.html (accessed 18/04/2018).

den Herder M, Moreno G, Mosquera-Losada RM, Palma jhn, Sidiropoulou A, Santiago-Freijanes JJ, Crous-Durán J, Paulo JA, Tomás M, Pantera A, Papanastasis VP, Mantzanas K, Pachana P, Papadopoulos A, Plieninger T, Burgess PJ (2017) Current extent and stratification of agroforestry in the European Union. Agric Ecosyst Environ 241:121–132.

EEA (2015) Natura 2000 data - the European network of protected sites.

Hart K, Allen B, Keenleyside C, et al (2017) Research for Agri Committee - the Consequences of Climate Change for Eu Agriculture. Follow-Up To the Cop21 - Un Paris Climate Change Conference.

McIvor I, Youjun H, Daoping L, et al (2014) Agroforestry: Conservation trees and erosion prevention. Encycl Agric Food Syst 1: 208–221.

Nair VD, Nair PKR, Kalmbacher RS, Ezenwa I V (2007) Reducing nutrient loss from farms through silvopastoral practices in coarse-textured soils of Florida, (USA). Ecol Eng 29: 192–199.

Reisner Y, de Filippi R, Herzog F, Palma J (2007) Target regions for silvoarable agroforestry in Europe. Ecol Eng 29:401–418.

Schulp JEC, Burkhard B, Maes J, Van Vliet J, Verburg PH (2014) Uncertainties in ecosystem service maps: A comparison on the European scale. PLoS One. doi: 10.1371/journal.pone.0109643

Torralba M, Fagerholm N, Burgess PJ, Moreno G, Plieninger T (2016) Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. Agric Ecosyst Environ 230: 150–161.

Tóth G, Gardi C, Bódis K, Ivits E, Aksoy E, Jones A, Jeffrey S, Petursdottir T, Montanarella L (2013) Continental-scale assessment of provisioning soil functions in Europe. Ecol Process 2: 32.

AGROFORESTRY DEFINITION AND PRACTICES FOR POLICY MAKERS

Mosquera-Losada MR[1*], Santiago-Freijanes JJ[1, 2], Moreno G[3], den Herder M[4], Aldrey JA[2], Rois-Díaz M[1, 4], Ferreiro-Domínguez N[1, 5], Pantera A[6], Rigueiro-Rodríguez A[1]

(1) Crop Production and Project Engineering Department, Escuela Politécnica Superior de Lugo, University of Santiago de Compostela; Campus Universitario s/n, 27002 Lugo, Spain (2) Geography Department, Facultad de Geografía e Historia. Plaza de La Universidad, n8 1 15782, Santiago de Compostela, Spain (3) Forestry School, University of Extremadura, Plasencia, Spain (4) European Forest Institute, Yliopistokatu 6, 80100 Joensuu, Finland (5) Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda s/n, 1349-017 Lisbon, Portugal (6) TEI Stereas Elladas, Dpt. of Forestry & Natural Environment, 36100, Karpenissi, Greece

*Corresponding author: mrosa.mosquera.losadasc.es

Abstract

Agroforestry definitions and practices are difficult to understand mainly because of both time and spatial scale understanding is needed to fully be aware of the concept. The definition of agroforestry to facilitate the identification by policy makers could be "*the deliberate integration of woody vegetation (trees and/or shrubs) as an upper storey on land with pasture (consumed by animals) or an agricultural crop in the lower storey. The woody species can be evenly or unevenly distributed or occur on the border of plots. The woody species can deliver forestry or agricultural products and other ecosystem services (i.e. provisioning, regulating or cultural".* In this paper, five agroforestry practices are identified (silvopasture, silvoarable, riparian buffer strips, forest farming and homegardens or kitchengardens) that can be linked to agricultural lands, forest lands and urban, rural and periurban areas.

Keywords: silvopasture, silvoarable, riparian buffer strips, forest farming; homegardens

Agroforestry: policy definition and practices

Agroforestry is not always fully understood as it integrates both spatial and time scale and many concepts at the same time. However, this is essential for policy makers to promote agroforestry. Policy bodies such as FAO (2015) define agroforestry as "*a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals"*, definition also supported by the ICRAF (2017). In Mosquera-Losada et al. (2016), the following definition (with some minor changes) was proposed: agroforestry is "*the deliberate integration of woody vegetation in at least two vertical layers on land, with the bottom layer providing an agricultural product such as crops or forage/pasture which is consumed by animals".* For the European Union, a list of agricultural products including forage, annual and perennial crops is provided by Annex 1 of the EU Directive 1308/2013 CAP. The European Agroforestry Federation (EURAF 2017) defines agroforestry as "*the integration of woody vegetation, crops and/or livestock in the same area of land. Woody vegetation can be inside parcels or on the boundaries (hedges)*". Each of these definitions includes "woody perennials" which is also identified by the agroforestry policy strategies of USA (USDA 2011), AFTA (2016) and India (Government of India 2014) and in the development of the Measure 8.2 of the current CAP. This allows the inclusion of systems such as hedgerows (e.g. bocage in France) and the combined grazing of shrubs or trees besides grass as a mechanism to adapt farming systems to shortage periods and climate change.

Woody perennials are also considered by the European Commission in the sub-measure fiche (EU 2014) describing Measure 8.2 (as a deployment of the Regulation 1305/2013) on the establishment of agroforestry, where agroforestry on agricultural land is defined as "*land-use systems and practices where woody perennials are deliberately integrated with crops and/or animals on the same parcel of land management unit without the intention to establish a* *remaining forest stand. The trees may be arranged as single stems, in rows or in groups, while grazing may also take place inside parcels (silvoarable agroforestry, silvopastoralism, grazed or intercropped orchards) or on the limits between parcels (hedges, tree lines)*". Moreover, whilst the EU definition adequately describes agroforestry for agricultural lands two additional contributions could be proposed. Firstly agroforestry can occur on urban, periurban, agricultural and forest land. Secondly, it should be considered that fruit trees that integrate the woody component and the agricultural production in the tree is not agroforestry because at least two layers in the same unit of land is needed. So, a proposal for defining agroforestry is "*the deliberate integration of woody vegetation (trees and/or shrubs) as an upper storey on land with pasture (consumed by animals) or an agricultural crop in the lower storey. The woody species can be evenly or unevenly distributed or occur on the border of plots. The woody species can deliver forestry or agricultural products and other ecosystem services (i.e. provisioning, regulating or cultural)*" (Mosquera-Losada et al. 2017).

Agroforestry practices

Besides the definition of agroforestry, it is useful to identify agroforestry practices that are used at plot level. Mosquera-Losada et al. (2016), describes five main types of agroforestry practices (Table 1). Silvopasture and silvoarable are the main subjacent practices of agroforestry. However, some global agroforestry practices can also be identified in order to facilitate the identification of such practices by policy makers in different types of lands which are "riparian buffer strip" when besides silvopasture or silvoarable a water body involved, "forest farming" linked to forest lands and "homegardens" linked to households.

Table 1: Spatial agroforestry practices in Europe (Mosquera-Losada et al. 2018)

Agroforestry practice	Description	
Silvopasture		Combining woody with forage and animal production. It comprises forest or woodland grazing and pastoral land with hedgerows, copses, isolated/scattered trees or trees in lines or belts.
Silvoarable		Widely spaced woody vegetation inter-cropped with annual or perennial crops. Also known as alley cropping. Trees/shrubs can be distributed following an alley cropping, copses, isolated/scattered trees, hedges and line belts design.
Riparian buffer strips		Lines of natural or planted perennial vegetation (trees/shrubs) bordering croplands/pastures to protect livestock, crops, and/or soil and water quality. They can be combined with arable lands (silvoarable) or grasslands (silvopasture).
Forest farming		Forested areas used for production or harvest of natural standing speciality crops for medicinal, ornamental or culinary uses, including those integrating forest and agricultural lands.
Homegardens or kitchengardens		Combining trees/shrubs with vegetable production in urban areas

Agroforestry practices and land use

EU and international policies are usually linked to “agricultural land”, “forestry land”, and “other rural areas”, which makes important to link agroforestry practices to land use as shown in Table 2. Silvopasture can be found in both agriculture and forest lands, while riparian buffers strips can only be found in agricultural lands. There are some examples of silvopasture linked to wood pasture and meadow orchards or isolated trees in arable lands. Silvoarable can be a synonymous of alley cropping. Specially interested are the hedgerows that can be linked to silvopasture and silvoarable when they are not connected to water bodies or riparian buffer strips when they are close to inland water bodies. Two types of agroforestry practices can be found in forest lands which are silvopasture (when animals are present) and forest farming usually linked to the extraction of agricultural products from the understorey. Finally, rural, periurban and urban areas are linked to homegardens or kitchengardens practices.

Table 2: Agroforestry practices can be linked to dominant land use categories (agriculture, forest or peri-urban) (Mosquera-Losada et al. 2018).

<table>
<tr><th colspan="2">Land use and agroforestry practice</th><th>Examples</th><th>Brief description</th></tr>
<tr><td rowspan="6">AGRICULTURE</td><td rowspan="3">Silvopasture</td><td>Wood pasture and parkland</td><td>Typically areas used for forage and animal production that includes widely-spaced non-agricultural trees and shrubs.</td></tr>
<tr><td>Meadow orchards</td><td>Typically areas of widely-spaced agricultural trees and shrubs (e.g. fruit orchards, olive groves, vineyards) which are grazed.</td></tr>
<tr><td rowspan="3">Hedgerows, windbreaks and riparian buffer strips, forest strips</td><td rowspan="3">Here the woody components are planted to provide shelter, shade, or parcel demarcation to a crop and/or livestock production system. Riparian buffer strips are typically created to protect water quality and can be linked to silvopasture or silvoarable.</td></tr>
<tr><td>Riparian buffer strips</td></tr>
<tr><td rowspan="2">Silvoarable</td></tr>
<tr><td>Alley-cropping systems, isolated trees in arable lands</td><td>Widely spaced woody perennials inter-cropped with annual or perennial crops. As the tree canopy develops, the crops may be replaced with a grass understorey.</td></tr>
<tr><td rowspan="2">FOREST</td><td>Silvopasture</td><td>Forest grazing, mountain pastoralism, isolated trees in grasslands</td><td>Although the land cover is described as forest, the understory is grazed</td></tr>
<tr><td>Forest farming</td><td>Forest farming</td><td>Forested areas used for production or harvest of naturally standing specialty crops for medicinal, ornamental or culinary uses but also apiculture</td></tr>
<tr><td>RURAL, URBAN AND PERIURBAN</td><td>Homegardens</td><td>Homegardens</td><td>Combining trees/shrubs with vegetable production usually associated with peri-urban or urban areas</td></tr>
</table>

Acknowledgements

This work was funded through the AFINET (www.afinet.eu) project from the European Union´s H2020 Research and Innovation Programme under grant agreement no 727872 and the Xunta de Galicia (Consellería de Cultura, Educación e Ordenación Universitaria (‘’Programa de axudas a etapa posdoutoral DOG n8122, 29/06/2016 p.27443, exp: ED481B 2016/0710’’)). The views and opinions expressed in this article are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

References

AFTA (Association for Temperate Agroforestry) (2016) What is Agroforestry?Accessed 31 August 2016.http://www.aftaweb.org/about/what-is-agroforestry.html (accessed 06/05/2018).

EU (2014) Sub-measure fiche (annex II to the measure fiche "forestry") Establishment of agroforestry systems Measure 8.2.http://www.ead.gr/images/pdf/articles/%CE%A7%CE%A1%CE%97%CE%A3%CE%99%CE%9C%CE%95%CE%A3_%CE%A0%CE%9B%CE%97%CE%A1%CE%9F%CE%A6%CE%9F%CE%A1%CE%99%CE%95%CE%A3/08_Measure_Fiche_Art_23_agroforesty__NOV_14.pdf (accessed 06/05/2018).

EURAF (2017) Agroforestry in Europe. Accessed 1 May 2017.http://www.agroforestry.eu/ (accessed 06/05/2018).

FAO (2015) Agroforestry. http://www.fao.org/forestry/agroforestry/80338/en/ (accessed 06/05/2018).

Government of India (2014). National Agroforestry Policy 2014. Department of Agriculture and Cooperation, Ministry of Agriculture, New Delhi, India. http://www.indiaenvironmentportal.org.in/files/file/Agroforestry%20policy%202014.pdf (accessed 06/05/2018).

ICRAF (2017) Corporate Strategy 2017-2026. Transforming lives and landscapes with trees. https://www.worldagroforestry.org/sites/default/files/users/admin/Strategy%20Report_2017.pdf (accessed 06/05/2018).

Mosquera-Losada MR, Santiago Freijanes JJ, Pisanelli A, Rois M, Smith J, den Herder M, Moreno G, Malignier N, Mirazo JR, Lamersdorf N, Ferreiro Domínguez N, Balaguer F, Pantera A, Rigueiro-Rodríguez A, Gonzalez-Hernández P, Fernández-Lorenzo JL, Romero-Franco R, Chalmin A, Garcia de Jalon S, Garnett K, Graves A, Burgess PJ (2016) Extent and success of current policy measures to promote agroforestry across Europe. Deliverable 8.23 for EU FP7 Research Project: AGFORWARD 613520. (8 December 2016). http://www.agforward.eu/index.php/en/extent-and-success-of-current-policy-measures-to-promote-agroforestry-across-europe.html (accessed 06/05/2018).

Mosquera-Losada MR, Santiago Freijanes JJ, Pisanelli A, Rois M, Smith J, den Herder M, Moreno G, Lamersdorf N, Ferreiro Domínguez N, Balaguer F, Pantera A, Papanastasis V, Rigueiro-Rodríguez A, Aldrey JA, Gonzalez-Hernández P, Fernández-Lorenzo JL, Romero-Franco R, Lampkin N, Burgess PJ (2017) Deliverable 8.24: How can policy support the appropriate development and uptake of agroforestry in Europe? 7 September 2017. https://www.agforward.eu/index.php/es/how-can-policy-support-the-uptake-of-agroforestry-in-europe.html (accessed 06/05/2018).

Mosquera-Losada MR, Santiago-Freijanes JJ, Rois M, Moreno G, den Herder M, Aldrey JA, Ferreiro-Domínguez M, Pantera A, Pisanelli A, Rigueiro-Rodríguez A (2018) Agroforestry in Europe: a land management policy tool to combat climate change. Land Use Policy (in press).

USDA (2011) USDA Agroforestry Strategic Framework, Fiscal Year 2011–2016. https://www.usda.gov/sites/default/files/documents/AFStratFrame_FINAL-lr_6-3-11.pdf (accessed 06/05/2018).

AGROFORESTRY AND THE ENVIRONMENT IN THE FUTURE EUROPEAN CAP

Mosquera-Losada MR[1*], Santiago-Freijanes JJ[1, 2], Aldrey JA[2], Rois-Díaz M[1, 3], Ferreiro-Domínguez N[1, 4], Pantera A[5], Rigueiro-Rodríguez A[1]

(1) Crop Production and Project Engineering Department, Escuela Politécnica Superior de Lugo, University of Santiago de Compostela; Campus Universitario s/n, 27002 Lugo, Spain (2) Geography Department, Facultad de Geografía e Historia. Plaza de La Universidad, n8 1 15782, Santiago de Compostela, Spain (3) European Forest Institute, Yliopistokatu 6, 80100 Joensuu, Finland (4) Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda s/n, 1349-017 Lisbon, Portugal (5) TEI Stereas Elladas, Dpt. of Forestry & Natural Environment, 36100, Karpenissi, Greece

*Corresponding author: mrosa.mosquera.losada@usc.es

Abstract

Agroforestry has to play a key role in the next Common Agricultural Policy (CAP) with regard to the environment. Cross-compliance, Pillar I and Pillar II intend to protect the woody component in agricultural lands. However, the implementation is rather complex and usually inefficient as highlights the court of auditors. This paper summarizes the main points that will make agroforestry implementation more feasible for European farmers after 2020 CAP.

Keywords: cross-compliance; greening; Pillar I; Pillar II

Introduction

The Common Agrarian Policy (CAP) is one of the star and most important policies that Member States of the European Union develop together. It is implemented in periods of seven years, being the current one from 2014 to 2020 (Mosquera-Losada et al. 2016). The post 2020 CAP is intended to be more sustainable in Europe than the previous one, which means that production increase should be encompassed with environment and social improvements and respect, as highlights the European Commission communication on the Common Agricultural Policy post-2020 entitled “The future of food and farming”. This communication establishes the main objectives of the CAP (Figure 1) to which agroforestry can definitively contribute. Environment is usually promoted and protected in specific parts of the CAP such as cross-compliance, greening in the Pillar I and in Pillar II. This paper examines how agroforestry is considered by the CAP trying to provide suggestions for the post 2020 CAP.

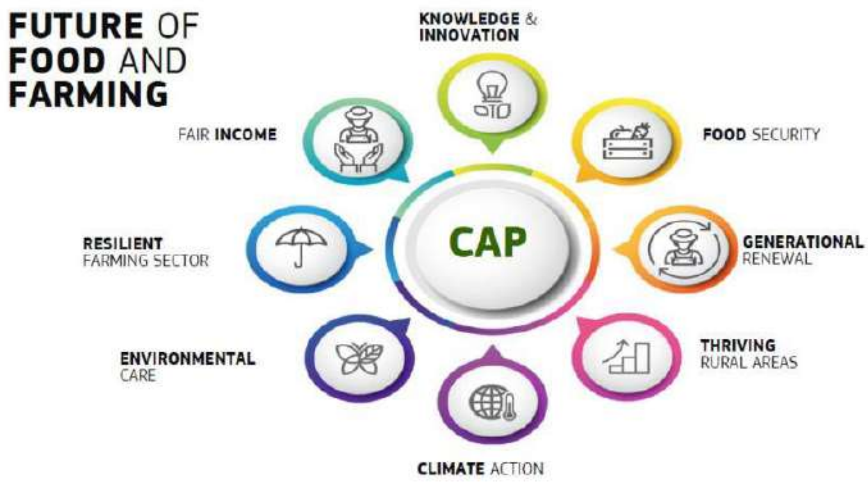


Figure 1: Main of objectives of the future of food and farming (EU 2017).

Agroforestry and cross-compliance

Between 2014 and 2020, the CAP is being administered in two big sections: Pillar I, which is completely funded by the European Commission and Pillar II, the Rural Development Programs, which is co-funded between European Commission and the Member States and is more related to environment. Farmers intending to receive direct payments should fulfil cross-compliance rules.

Farmers receiving direct payments through Pillar I and Pillar II have to comply with 13 Statutory Management Requirements (SMR) and standards for maintaining the land in Good Agricultural and Environmental Condition (GAEC) known as cross-compliance or conditionality. The SMRs are associated to issues such as water, biodiversity, food and feed laws, plant health, food safety, and animal welfare. The GAEC rules in 2014-2020 (Annex 2, Regulation 1306/2013) are focused on water, soil and carbon stocks, and landscape features. GAEC condition number 7 deals with "*the retention of landscape features, including where appropriate, hedges, ponds, ditches, trees in line, in group or isolated, field margins and terraces, and including a ban on cutting hedges and trees during the bird breeding and rearing season and, as an option, measures for avoiding invasive plant species*" (Annex 11 in regulation 1306/2013), which is highly relevant for agroforestry. Therefore, within cross-compliance, there is clear recognition that integrating woody vegetation can make agriculture more sustainable. However, the promotion and protection of this woody component in agricultural lands appear in a horizontal way through the cross-compliance, greening and different rural development measures (up to 27 measures protect or promote agroforestry practices across different countries), usually linked to landscape features. However, agroforestry is not recognized as such, in spite of the emphasis on woody vegetation preservation in the CAP. Landscape features preservation (linked to GAEC condition 7 described above) aims to protect, amongst other features, scarce woody vegetation in some European agricultural landscapes. However, the administrative burden for administrators in identifying and monitoring these features has made landscape features control difficult. The EU Court of Auditors (2009) has highlighted the lack of effectiveness of cross-compliance in regard to the protection of landscape features (associated with isolated trees, and trees and woody vegetation with different organizational frames in the landscape). Moreover, the current activities only focus on the preservation of landscape features but not on their promotion.

There are three main categories of agricultural land use when determining direct payments: arable, permanent pasture or permanent grassland (including herbaceous species other than grass, also browsable shrubs and trees), and permanent crops (i.e. nurseries, multi-annual crops and short rotation coppice) on which agroforestry practices linked to this specific type of land use can be used (Mosquera-Losada et al. 2018).

Agroforestry and Pillar I

When tree species are not designated as permanent crops by Annex 1 of Regulation 1308/2013 farmers loose the direct payments unless they are identified as landscape features with a maximum of 100 trees per hectare if arable land or permanent grassland is the main land cover (Regulation 640/2014). Moreover, member states can also select the pro-rata system on which the woody component of permanent grassland is discounted in spite of the ecosystem services they deliver (Mosquera-Losada et al. 2016). However, grazed and intercropped permanent crops areas that deliver Annex 1 (Regulation 1308/2013) products are eligible for Pillar I payments. Moreover, the integration of permanent crops on arable and permanent grassland (at any density) are also eligible for Pillar I payments (Mosquera-Losada et al. 2017).

In addition to the burden linked to identifying landscape features that has been recognized as a major problem by the EU Court of Auditors (2009), farmers have two main concerns regarding the eligibility of agroforestry:

a) the limitation to 100 trees per hectare in the current CAP, without identifying these trees as mature trees, prevents farmers from establishing, promoting and using agroforestry practices. Moreover, those trees with less than 4 m of width are not protected and discounted from farmers' direct payments.

b) the introduction of agroforestry with less than 100 trees per hectare is not clearly linked to the final tree density. This could be considered against basic silvicultural principles that link plantations with initial higher densities (low canopy cover) to select better trees when they become mature (interpretation of the 100 mature tree/ha rule in Article 9 of Regulation 640/2014). The argument to limit the tree density is to guarantee agricultural production, but, significant agricultural production can be obtained under different trees combinations with different densities when trees are young (low tree canopy cover) or old. There should be mechanisms for farmers to establish, maintain, and improve agroforestry practices on their land whilst retaining full direct payments of Pillar I. One way to achieve this is for farmers to identify "agroforestry practices" and secure Pillar I payments through the development of an agroforestry management plan.

Therefore CAP should propose agroforestry practices on arable and permanent grassland should be fully eligible if developed with i) a "management plan" including a minimum tree density (to be selected by member states), an initial tree density, and the pursuit of a final maximum tree density that should be less than 100 mature trees per hectare (if no Established Local Practices are declared) or ii) through Measure 222 (CAP 2007-2013) and 8.2 (CAP 2014-2020). In order to simplify eligibility rules for direct payments for agroforestry practices, we propose that an 'agroforestry option' should be implemented in all three categories of land use (i.e. arable land, permanent grassland and permanent crops) that, on one hand will make farmers aware of this sustainable land use, and on the other hand will make policy makers aware of the lands that are using these techniques. This would be self-declared by the farmer and supported/evidenced by the submission of a management plan. Agroforestry practices established with permanent crops should be promoted as it does not cause CAP eligibility problems.

Agroforestry and Pillar II

Pillar II promotes the establishment of agroforestry through 27 measures. There is one measure, measure 8.2 that aims at establishing agroforestry practices and 27 measures that both promotes agricultural products delivery in areas with a woody component or the establishment of a woody component (trees and/or shrubs) in agricultural lands that mostly not recognizes agroforestry as such. Main associated problems with this type of measures are that they did not allow to improve already existing agroforestry practices. OMNIBUS regulation have helped to overcome some of the problems of 8.2 measures as they have included the improvement of already existing agroforestry practices and systems like the dehesa and the montado besides the establishment of agroforestry practices.

Acknowledgements

This work was funded through the AFINET (www.afinet.eu) project from the European Union´s H2020 Research and Innovation Programme under grant agreement no 727872 and the Xunta de Galicia (Consellería de Cultura, Educación e Ordenación Universitaria (''Programa de axudas a etapa posdoutoral DOG n8122, 29/06/2016 p.27443, exp: ED481B 2016/0710'')). The views and opinions expressed in this article are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

References

European Court of Auditors (2009). European Court of Auditors Special report 8/2008: "Is Cross compliance an effective policy? http://www.eca.europa.eu/Lists/ECADocuments/SR08_08/SR08_08_EN.PDF (accessed 06/05/2018).

EU (2017) Communication from the Commission to the Europan Parliament, the council, the European economic and social committee ant the committee of the regions. The future of food and farming. https://ec.europa.eu/agriculture/sites/agriculture/files/future-of-cap/future_of_food_and_farming_communication_en.pdf (accessed 06/05/2018).

Mosquera-Losada MR, Santiago Freijanes JJ, Pisanelli A, Rois M, Smith J, den Herder M, Moreno G, Malignier N, Mirazo JR, Lamersdorf N, Ferreiro Domínguez N, Balaguer F, Pantera A, Rigueiro-Rodríguez A, Gonzalez-Hernández P, Fernández-Lorenzo JL, Romero-Franco R, Chalmin A, Garcia de Jalon S, Garnett K, Graves A, Burgess PJ (2016) Extent and success of current policy measures to promote agroforestry across Europe. Deliverable 8.23 for EU FP7 Research Project: AGFORWARD 613520. (8 December 2016). http://www.agforward.eu/index.php/en/extent-and-success-of-current-policy-measures-to-promote-agroforestry-across-europe.html (accessed 06/05/2018).

Mosquera-Losada MR, Santiago Freijanes JJ, Pisanelli A, Rois M, Smith J, den Herder M, Moreno G, Lamersdorf N, Ferreiro Domínguez N, Balaguer F, Pantera A, Papanastasis V, Rigueiro-Rodríguez A, Aldrey JA, Gonzalez-Hernández P, Fernández-Lorenzo JL, Romero-Franco R, Lampkin N, Burgess PJ (2017) Deliverable 8.24: How can policy support the appropriate development and uptake of agroforestry in Europe? 7 September 2017. https://www.agforward.eu/index.php/es/how-can-policy-support-the-uptake-of-agroforestry-in-europe.html (accessed 06/05/2018).

Mosquera-Losada MR, Santiago-Freijanes JJ, Moreno G, Herder M, Aldrey JA[4], Rois M, Ferreiro-Dominguez N, Pantera A, Rigueiro-Rodríguez A (2018) Agroforestry definition and practices for policy makers. IV EURAF Conference (this volume).

RURAL DEVELOPMENT AS PILLAR II TO FOSTER AGROFORESTRY

Mosquera-Losada MR[1*], Santiago-Freijanes JJ[1, 2], Aldrey JA[2], Rois-Díaz M[1, 3], Ferreiro-Domínguez N[1, 4], Rigueiro-Rodríguez A[1]

(1) Crop Production and Project Engineering Department, Escuela Politécnica Superior de Lugo, University of Santiago de Compostela; Campus Universitario s/n, 27002 Lugo, Spain (2) Geography Department, Facultad de Geografía e Historia. Plaza de La Universidad, n8 1 15782, Santiago de Compostela, Spain (3) European Forest Institute, Yliopistokatu 6, 80100 Joensuu, Finland (4) Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda s/n, 1349-017 Lisbon, Portugal

*Corresponding author: mrosa.mosquera.losada@usc.es

Abstract

Agroforestry practices and systems are sustainable use land management that should be fostered by the global and European Union policies. Within the Common Agrarian Policy (CAP) there are opportunities to foster agroforestry practices and systems that are not fully recognized as agroforestry but that should be improved. Main challenges of agroforestry are linked to a better technical and economic knowledge of these practices including recognition of added value through the value chain, as well as to the increase of agroforestry as sustainable land use among the students, public and farmers and better policy design.

Keywords: Common Agricultural Policy; measure 8.2; agricultural lands; forest lands

Introduction

The Common Agricultural Policy (CAP) is structured in two main Pillars: Pillar I that is fully funded by the European Union and Pillar II that is co-funded between the EU and the European member states. Rural Development is organized by official measures provided by the EU that are mainly designed by the Member states in agreement with the European Union. These measures are based on the Regulation 1305/2013, in the delegated acts and in the specific orientative measures provided by the European Commission. The aim of this paper is to evaluate the current stage of the Rural Development Programmes and agroforestry practices in the different European Union countries considering aspects related to agroforestry practices and systems, agroforestry at landscape level and supporting education and innovation.

Agroforestry practices in the Rural Development Programmes

Mosquera-Losada et al. (2016) identified 27 measures within the 2014-2020 Rural Development Regulations (Pillar II), including Measure 8.2, that could support the deliberate integration of woody vegetation with agricultural product delivery from the lower storey (Mosquera-Losada et al 2016; Santiago-Freijanes et al. 2018a). However this high number of measures tackling agroforestry makes difficult to evaluate the impact–including the spent money-of Pillar II on the agroforestry practices promotion. A summary of the main agroforestry activities (silvopasture/silvoarable/forest farming) can be seen in Table 1. The measure with the highest number of agroforestry practices implementation associated is the agri-environment measure (10.1) as happened before (214 in the CAP 2007-2013 period), mainly linked to meadow orchards (Santiago-Freijanes et al. 2018b). In total close to 467 measures are somehow promoting agroforestry from which hedgerows, followed by forest strips, and forest farming and meadow orchards are the most important.

Table 1: Number of regional programs that supported different agroforestry measure activities within the CAP 2014-2020 on which woody perennial vegetation is linked to agricultural activity such as Meadow orchards associated to silvopasture agroforestry practice, forest strips, hedgerows and isolated trees linked to silvoarable/silvopasture agroforestry practice on agricultural land and forest grazing and mountain pastoralism (silvopasture practice) and forest farming in forest lands (Mosquera-Losada et al. 2018c).

Agroforestry measure/activity		1.1	1.2	2.1	2.3	4.1	4.2	4.3	4.4	5.1	6.1	6.3	7.4	7.6	8.1	8.2	8.3	8.4	8.5	8.6	9.1	10.1	11.1	11.2	12.1	13.2	15.1	16.5	Total
AGRICULTURAL LAND	Meadow orchards					3		2	6					3								52	1						67
	Forest strips								20				1	7		1			5	1		34			1	1	2	1	74
	Hedgerows	1	1	1	1			1	42	1			1	7		2	1		3			53	1	1	3	1		1	122
	Isolated trees								16					5					1			33			4	1		1	61
FOREST LAND	Forest grazing							2							1	3		1	2			14							23
	Forest farming (apiculture)		1	1		6	2				2	1			1					5		34	8	6					67
	Forest farming (not apiculture)		1	1		1	1		1											12	1								18
	Mountain pastoralism					3		6	4					4								17	1						35
	Total	1	3	3	1	10	3	9	83	1	2	1	2	23	2	6	1	1	11	18	1	185	10	7	8	3	2	3	467

Agroforestry measure 8.2 linked to agroforestry practices in agricultural lands

Agroforestry measure was established thinking of the potential that silvoarable practices have to mitigate climate change, protect waters and promote biodiversity. However, in the 2007-2013 CAP, the uptake of the agroforestry measure was really low compared with the afforestation measure (Mosquera-Losada et al. 2016; Santiago-Freijanes et al. 2018a), being silvopasture more promoted (mostly in Hungary) than silvoarable agroforestry practices (mostly in France). There are at least three main reasons explaining the lack of success of agroforestry measure in the past that were partially solved in the current CAP. Firstly, the agroforestry measure in the CAP 2007-2013 should be compared with the other two measures aiming at introducing a woody component (measures 221 and 223). A maintenance period was supported in both measures that did not exist in measure 222, that could lead to a loss of Pillar I payments. When farmers established woody perennials under 221 or 222 measures they could implement also agroforestry as they could have some crops and usually animals to maintain the land in good conditions but keeping the payment for maintenance. This situation was partially solved in the current CAP as measure (8.1) supporting afforestation and the other (8.2) supporting agroforestry can be funded for both the establishment and maintenance of the established afforested and agroforestry land. However, the maintenance period was half for the measure 8.2 (5 years) compared with 8.1 (10 years) that could move farmers from 8.2 to 8.1 selection. A second important aspect that prevents from measure 8.2 adoption is that it only supported new establishment of agroforestry practices (Mosquera-Losada et al. 2018c) but not improvement or recovery of already existing agroforestry systems. However, this was modified with the OMNIBUS regulation that allows payment to improve already existing agroforestry lands. As a third aspect to make agroforestry measure more successful for the post-2020 we recommend that eligibility and therefore Pillar I payments should be ensured and that a clear recognition of the deliveries of agroforestry that is recognized by the FAO as one of the best forms for agricultural systems to mitigate and adapt to climate change.

Agroforestry measure 8.2 linked to agroforestry practices in forest lands

Agroforestry practices such as forest farming and silvopasture specifically linked to forest lands are not funded by Pillar I. Forest farming consist in the combination of an agricultural activity delivering an agricultural product described in Annex 1 in a forest land. These agricultural products could be medicinal plants, mushrooms but also small fruit tree production growing as a lower story. Forest farming activity is not clearly quantified across Europe. The knowledge of this activity is linked to the economic value it provides (Mosquera-Losada et al. 2018c), which can damage these activities due to the uncontrolled and over-extraction. Honey is another product that is usually linked to woody perennials placed in agricultural and forest lands. Herbaceous vegetation has a shorter period of flowering than woody perennials that could also be complementary in the flowering time therefore extending the period of honey production.

Silvopasture is a key agroforestry practice linked to forest lands to prevent from forest fires. In many places, forest grazing provides environmental benefits, for example besides the reduction of forest fire risk in some areas, it can be expected an increase of biodiversity through the creation of micro-environment heterogeneity from faeces, selective consumption and trampling mimicking the presence of wild large mammals in nature (Mosquera-Losada et al. 2016). Moreover, the use of biomass from those areas should also be promoted to maintain the forest health (by extracting the excess of dead wood whilst respecting biodiversity purposes) and to enhance the circular economy (fuel substitution by biomass).

Agroforestry at farm and landscape level

In addition to the Pillar II measures to promote agroforestry at plot level, there should be opportunities to encourage farmers to increase sustainability at farm and landscape level. These levels should be linked to a better distribution of the on-farm resources when feeding animals (i.e. extending the grazing season in forestlands) or providing feed during the summer (branches) and autumn (fruit) periods. The integration of woody perennials at landscape levels by cooperation among farms should be promoted to be linked to the payment for results concept linked to initiatives such as the Results-Based agri-environment schemes linked to the provision of ecosystem services linked to beter biodiversity, and soil, water and air quality to pursue climate change adaptation and mitigation.

Innovation and agroforestry: the AFINET project

The Agroforestry Innovation Network European Union Project aims at fostering agroforestry innovation in Europe. As a thematic network, it is in between Rural Development and Research European Union Programmes. From this network, a set of challenges have been described (Villada et al. 2018) that could provide some insights to foster agroforestry implementation in Europe linked to technical issues, economic, communication and policy improvements.

a) Technical issues: more knowledge about the best combinations among woody perennials and lower storey agricultural production is needed and should be dispersed this links with more research and adequate dissemination pathways linked to education activities. A wood example of this is the Focus Group of Agroforestry: Agroforestry: "Introducing woody vegetation into specialised crop and livestock systems. How to develop agroforestry as a sustainable farming system which can boost agricultural productivity and profitability?" carried out by the EIP-Agri (2017)

b) Economic issues: Agroforestry products are based on the better use of the in-farm resources (light, soil fertility…) and therefore these systems need fewer outputs to deliver agricultural products. Moreover, the combination of woody perennials and lower story production should be linked to a better profit by obtaining money from both products but also by enhancing the quality of the products and a better added-value return to farmers through the value chain.

c) Communication: linked to education in primary and high schools but also linked to a better improvement of farmers education strategies.

d) Policy: better policies have been highlighted as a main drawback by farmers when they speak about agroforestry expansion that can be solved through different initiatives that can be seen in Mosquera-Losada et al. (2018a, b, c, d).

Acknowledgements

This work was funded through the AFINET (www.afinet.eu) project from the European Union´s H2020 Research and Innovation Programme under grant agreement no 727872 and the Xunta de Galicia (Consellería de Cultura, Educación e Ordenación Universitaria ("Programa de axudas a etapa posdoutoral DOG n8122, 29/06/2016 p.27443, exp: ED481B 2016/0710'')). The views and opinions expressed in this article are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

References

EIP-Agri (2017) Agroforestry: introducing woody vegetation into specialised crop and livestock systems. How to develop agroforestry as a sustainable farming system which can boost agricultural productivity and profitability? https://ec.europa.eu/eip/agriculture/en/focus-groups/agroforestry-introducing-woody-vegetation (accessed 07/05/2018).

Mosquera-Losada MR, Santiago Freijanes JJ, Pisanelli A, Rois M, Smith J, den Herder M, Moreno G, Malignier N, Mirazo JR, Lamersdorf N, Ferreiro Domínguez N, Balaguer F, Pantera A, Rigueiro-Rodríguez A, Gonzalez-Hernández P, Fernández-Lorenzo JL, Romero-Franco R, Chalmin A, Garcia de Jalon S, Garnett K, Graves A, Burgess PJ (2016) Extent and success of current policy measures to promote agroforestry across Europe. Deliverable 8.23 for EU FP7 Research Project: AGFORWARD 613520. (8 December 2016). http://www.agforward.eu/index.php/en/extent-and-success-of-current-policy-measures-to-promote-agroforestry-across-europe.html (accessed 06/05/2018).

Mosquera-Losada MR, Santiago-Freijanes JJ, Aldrey JA, Ferreiro-Domínguez N, Pantera A, Rigueiro-Rodríguez A (2018a) Agroforestry within the Pillar I: including woody perennials in Pillar I lands to foster sustainability. IV EURAF Conference (this volume).

Mosquera-Losada MR, Santiago-Freijanes JJ, Aldrey JA, Rois-Díaz M, Ferreiro-Dominguez N, Pantera A, Rigueiro-Rodríguez A (2018b) Agroforestry and the environment in the future European CAP. IV EURAF Conference (this volume).

Mosquera-Losada MR, Santiago-Freijanes JJ, Rois M, Moreno G, den Herder M, Aldrey JA, Ferreiro-Domínguez M, Pantera A, Pisanelli A, Rigueiro-Rodríguez A (2018c) Agroforestry in Europe: a land management policy tool to combat climate change. Land Use Policy (in press).

Mosquera-Losada MR, Santiago-Freijanes JJ, Moreno G, Herder M, Aldrey JA, Rois-Díaz M, Ferreiro-Dominguez N, Pantera A, Rigueiro-Rodríguez A (2018d) Agroforestry definition and practices for policy makers. IV EURAF Conference (this volume).

Santiago-Freijanes JJ, Pisanelly A, Rois-Díaz M, Aldrey-Vázquez JA, Rigueiro-Rodríguez A, Pantera A, Vityi A, Lojka B, Ferreiro-Domínguez N, Mosquera-Losada MR (2018a) Agroforestry development in Europe: Policy issues. Land Use policy (in press).

Santiago-Freijanes JJ, Rigueiro-Rodríguez A, Aldrey JA, Moreno G, den Herder M, Burgess P, Mosquera-Losada MR (2018b) Understanding agroforestry practices in Europe through landscape features policy promotion. Agroforest Syst. https://doi.org/10.1007/s10457-018-0212-z.

Villada A, Verdonckt P, Ferreiro-Domínguez N, Rodríguez-Rigueiro FJ, Arias-Martínez D, Rois-Díaz M, den Herder M, Paris P, Pisanelli A, Reubens B, Nelissen V, Paulo JA, Palma JHN, Vityi A, Szigeti N, Borek R, Galczynska M, Balaguer F, Smith J, Westaway S, Rigueiro-Rodríguez A, Mosquera-Losada MR (2018) AFINET: Agroforestry Innovation Thematic Network IV EURAF Conference (this volume).

LINEAR WOODY FEATURES ON HOMEGARDENS IN EUROPEAN UNION

Santiago-Freijanes JJ[1, 2]*, Aldrey-Vázquez JA[1], Rigueiro-Rodríguez A[2], Mosquera-Losada MR[2]

(1) Geography Department, Universidade de Santiago de Compostela, Santiago de Compostela, Spain (2) Crop Production and Projects Enginery Departmen, Universidade de Santiago de Compostela, Lugo, Spain

*Corresponding author: josejavier.santiago@usc.es

Abstract

Homegardens are probably the most difficult agroforestry practice to map because of their size and presence in non-agricultural outlines. The combination of the fields of "homegardens" and "woody component" at LUCAS point level revealed that around 60% of the homegardens in Europe can be considered agroforestry. However, agroforestry could also be identified in the rest (40%) if we the transects besides the points of the LUCAS database are considered. The objective of this paper is to map and quantify the agroforestry homegardens in Europe by using the LUCAS database based on the transects to fine tune the amount of the homegarden agroforestry practice in Europe. The paper shows that Europe has 14,461.04 km^2 of homegardens, 41.26 of which aren´t permanent cover homegardens, but 42.34% of them have linear woody features and they can be considered agroforestry as they have a woody component integrated with an agricultural product in the understory.

Keywords: LUCAS database; hedgerow; isolated tree, landscape features

Introduction

The Land Use and Land Cover Survey (LUCAS) defines homegardens as "gardens, where the crops are planted heterogeneously and mainly for own consumption. These areas are mostly fenced (by metal fences or hedges) and mostly situated in residential areas or as allotment gardens" (Eurostat 2015). These land use type is key to provide local and more sustainable healthy food within a smart cities concept linking urban and rural areas as described the EIP-Smart cities and Communities (2017).

When a woody component, usually a fruit tree, is combined with vegetable production in the understory, homegardens are considered an agroforestry practice (Mosquera-Losada et al. 2016). Agroforestry homegardens (AFh) are difficult to map because linear woody features are not registered directly in the cover databases and homegarden areas are presumably identified as a residential area due to the small size of these plots around the house.

In Santiago-Freijanes et al. (2018), the extent of AFh in EU based on maps developed from the LUCAS classification with two covers and two uses and integrating fruit trees were developed. But, AFh could also have woody component that is not a permanent crop. The inventory of those no fruit based AFh can be carried out thanks to the survey of LUCAS carried out with transects of 250 meters longer from points previously localized across the European Union (EU).

This paper aims to identify homegarden agroforestry practices not linked to permanent crops, but linear woody features and to evaluate the extent of this type of agroforestry practice across EU.

Material and methods

EU homegardens were mapped by using LUCAS survey carried out in 2015. Surveyors filled established forms including two questions related with the two land covers and two land uses found in each point. Surveyors also took four photos from each point in the direction of the four cardinal points (North, West, East and South) and another photo of the point itself ten meters away from the point. Data are included in a database free available from Eurostat, LUCAS data are taken during the visit of the surveyors to previously defined points. In each point a transect of 250 meters long taken from the point itself to the East, is delineated and each defined woody feature recorded.

To examine the LUCAS data, we use free software LibreOffice-Calc and QGIS 2.18. We select the points that they presented as primary or secondary use (fields LU1 and LU2 of the database) the value U113, called “Kitchen garden”, which refers to homegardens. From those points we select the no woody covers in the primary or secondary covers fields (LC1 and LC2 in the database). We exclude woody covers, identified as the cover fields of the database named as forestry (coded as Cxx and being “xx” of the code a number that identifies types of forests species), permanent crops (coded as B7x and being the “x” of the code a number that identifies specific species) and other permanent crops (coded as B8x and being the “x” of the code a number that identifies specific species), and grassland with sparse trees or shrubs (coded as E10), and shrubland with sparse trees (coded as D10). In addition to the two covers and to uses and other fields characteristics LUCAS have a transect 250 meters long from the point itself to the East. This transect record all the features localized with the LUCAS cover codes, but also, to refer features typically linear or punctual add specific codes, these codes appear when the feature is narrower than 3 metres (Eurostat 2015). To the propose of this work the codes are: 10. Single bushes/trees; 11. Avenue trees or other lines of trees; 12. Conifer hedges; 13. Managed bush or tree hedges or coppices; 14. Not managed bush or tree hedges; 15. Grove/Woodland margins (if no hedgerow).

To our purpose we consider the feature coded with number 10 as the category “isolated trees” and the rest of the before mentioned codes (11, 12, 13, 14 and 15) as linear features or hedgerows.

Results

In the AFh without permanent crops as woody vegetation cover, both Luxembourg and Malta are not included in the study, because they have no homegardens registered in LUCAS (2015) and Finland and Ireland because 100% of their homegardens have permanent crops. Afh without permanent crops as woody vegetation cover represents the 41.26% of homegardens in EU (Table 1).

Table 1: Extension and percentage of homegardens by countries.

Countries	Area	Homegardens		No permanent cover homegardens	
	km^2	km^2	%	km^2	%
Austria	83944	304.08	0.36	76.02	25.00
Belgium	30666	63.51	0.21	63.51	100.00
Bulgaria	110995	621.62	0.56	260.21	41.86
Croatia	56539	561.22	0.99	240.52	42.86
Cyprus	9249	48.34	0.52	5.37	11.11
Czech Rep.	78874	1270.38	1.61	124.28	9.78
Denmark	43162	35.44	0.08	11.81	33.32
Estonia	45347	86.24	0.19	17.25	20.00
France	549059	1436.22	0.26	672.52	46.83
Germany	357745	1372.58	0.38	363.33	26.47
Greece	131912	402.78	0.31	84.80	21.05
Hungary	93013	648.05	0.70	360.03	55.56
Italy	300576	1541.36	0.51	618.64	40.14
Latvia	65519	390.14	0.60	134.11	34.37
Lithuania	65412	493.79	0.75	261.42	52.94
Netherlands	37824	60.47	0.16	45.35	75.00
Poland	313851	1502.46	0.48	710.26	47.27
Portugal	88847	355.19	0.40	276.26	77.78
Romania	239068	1287.39	0.54	915.48	71.11
Slovakia	49026	837.29	1.71	231.59	27.66
Slovenia	20277	84.27	0.42	21.07	25.00
Spain	498502	793.40	0.16	337.19	42.50
Sweden	449896	84.62	0.02	16.92	20.00
U.K.	165152	138.09	0.08	118.36	85.71
EU-28	4295513	14461.04	0.34	5966.29	41.26

In Figure 1 and Table 1 we can see that Romania, Poland, France and Italy have the largest extensions of AFh without permanent crops as woody vegetation cover while Cyprus, Denmark, Sweden and Estonia have less than 20 km2. Belgium (with 100%), United Kingdom, Portugal, Netherlands and Romania have the largest proportions of AFh without permanent crops as woody vegetation cover, while Czech Republic, Cyprus, Estonia and Sweden only have AFh without permanent crops as woody vegetation cover proportions lower than 20%. As we can see in Figure 2, there is a clear trend from the South and West countries with a 50% or more of their AFh without permanent crops as woody vegetation cover that have any type of the woody linear features involved. On the other hand, those countries placed in the northern and central part of EU do not have linear feature in their AFh without permanent crops as woody vegetation cover.

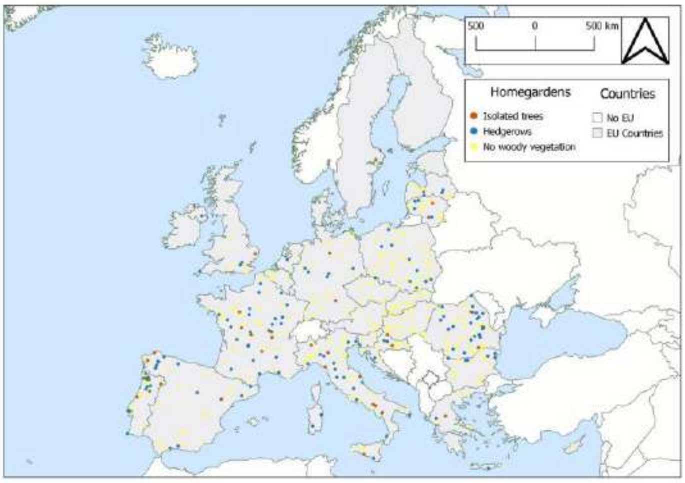


Figure 1: Agroforestry homegardens without permanent crops as woody vegetation cover in eu countries.

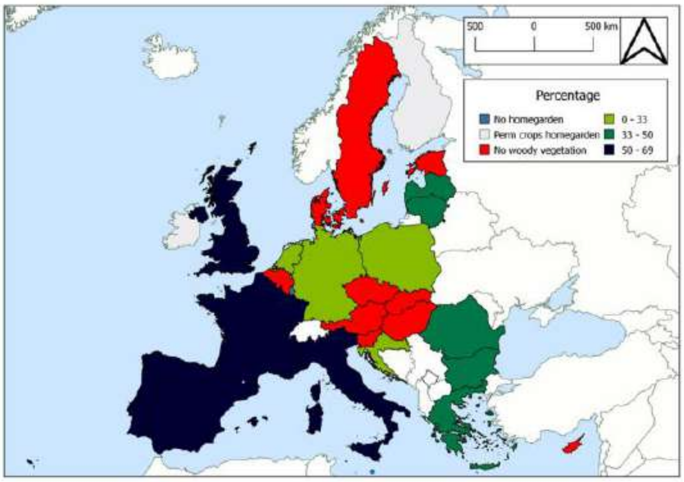


Figure 2: Agroforestry homegardens without permanent crops as woody vegetation cover with all types of woody linear feature in EU by countries.

In the AFh without permanent crops as woody vegetation cover, both Luxembourg and Malta are not included in the study, because they have no homegardens registered in LUCAS (2015) and Finland and Ireland because 100% of their homegardens have permanent crops. Afh without permanent crops as woody vegetation cover represents the 41.26% of homegardens in EU (Table 1).

In Figure 1 and Table 1 we can see that Romania, Poland, France and Italy have the largest extensions of AFh without permanent crops as woody vegetation cover while Cyprus, Denmark, Sweden and Estonia have less than 20 km2. Belgium (with 100%), United Kingdom, Portugal, Netherlands and Romania have the largest proportions of AFh without permanent crops as woody vegetation cover, while Czech Republic, Cyprus, Estonia and Sweden only have AFh without permanent crops as woody vegetation cover proportions lower than 20%. As we can see in Figure 2 and Table 2, there is a clear trend from the South and West countries with a 50% or more of their AFh without permanent crops as woody vegetation cover that have any type of the woody linear features involved. On the other hand, those countries placed in the northern and central part of EU do not have linear feature in their AFh without permanent crops as woody vegetation cover.

Discussion

AFh without permanent crops as woody vegetation cover is the 41.26%, and its 42.34% have linear features. That's means that only 23.79% of homegardens in EU have AFh without permanent crops or linear features as woody vegetation cover, according LUCAS. Excluding the countries that have not registered any homegarden (Luxembourg and Malta) and those that have not their AFh without permanent crops as woody vegetation cover (Finland and Ireland), we have 24 countries that we can split into two blocks, the 14 that have some type of woody linear feature in their homegrowns and 10 who do not register any of these elements. There is a clear trend South West on one side and North on the other probably due to the highest presence of woody component as part of the landscape due to the role they play as protectors of wind erosion such as UK and France and droughts and erosion as happen in the south of EU (Mosquera-Losada et al. 2016) Compared with the regression between the homegardens presence with a woody component as a permanent crop, the AFh without permanent crops as woody vegetation cover have a lower relationship with the presence of homegardens, probably, due to the low presence of AFh without permanent crops as woody vegetation cover in the states where these elements are not recorded (Santiago-Freijanes et al. 2018).

The fact that transects only take the elements present in the 250 m to the East from the point itself avoids that some woody linear elements found in the plot are registered. In the case of isolated trees, it is more than likely the undervalue because, since they are punctual elements, their presence in the transect line is difficult to be recorded.

Table 2. Extension and percentage of homegardens by countries.

Countries	With isolated trees		With hedgerows		With woody features	
	km^2	%	km^2	%	km^2	%
Austria	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.00	0.00	0.00	0.00	0.00	0.00
Bulgaria	0.00	0.00	115.65	44.44	115.65	44.44
Croatia	32.07	13.33	48.10	20.00	80.17	33.33
Cyprus	0.00	0.00	0.00	0.00	0.00	0.00
Czech Rep.	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.00	0.00	0.00
France	68.39	10.17	398.95	59.32	467.34	69.49
Germany	26.91	7.41	94.20	25.93	121.11	33.33
Greece	10.60	12.50	31.80	37.50	42.40	50.00
Hungary	0.00	0.00	0.00	0.00	0.00	0.00
Italy	83.88	13.56	272.62	44.07	356.51	57.63
Latvia	12.19	9.09	48.77	36.36	60.96	45.45
Lithuania	29.05	11.11	72.62	27.78	101.66	38.89
Netherlands	0.00	0.00	15.12	33.33	15.12	33.33
Poland	0.00	0.00	150.25	21.15	150.25	21.15
Portugal	39.47	14.29	128.26	46.43	167.73	60.71
Romania	28.61	3.13	414.83	45.31	443.43	48.44
Slovakia	0.00	0.00	0.00	0.00	0.00	0.00
Slovenia	0.00	0.00	0.00	0.00	0.00	0.00
Spain	29.75	8.82	158.68	47.06	188.43	55.88
Sweden	0.00	0.00	0.00	0.00	0.00	0.00
UK	9.86	8.33	59.18	50.00	69.04	58.33
EU-28	406.22	6.81	2119.94	35.53	2526.15	42.34

Conclusion

LUCAS database, and specifically the transects, is a useful tool to evaluate the current extent and the evolution of Agroforestry homegardens. This tool could be used in the future by the European Commission to evaluate the impact of homegardens promotion on agroforestry policies.

Acknowledgements

This work is part of AFINET PROJECT. Grant Agreement 727872. Call H2020-RUR-2016-2017 (Rural Renaissance - Fostering innovation and business opportunities). EU7).

References

EIP-Smart Cities and Communities (2017) Operational Implementation Plan: First Public Draft.
Eurostat (2015) LUCAS 2015. Technical Reference Document C1 Instructions for Surveyors.
LUCAS (2015) http://ec.europa.eu/eurostat/web/lucas/data/primary-data/2015 (accessed 06/04/2018).
Mosquera-Losada et al. (2016) Extent and success of current policy measures to promote agroforestry across Europe. Deliverable 8.23 for EU FP7. Research Project: AGFORWARD 613520. https://www.agforward.eu/index.php/en/extent-and-success-of-current-policy-measures-to-promote-agroforestry-across-europe.html (accessed 06/04/2018).
Santiago-Freijanes et al. (2018) Homegardens. Agriculture in the city as an agroforestry practice. 4th European Agroforestry Conference. Agroforestry as sustainable land use. Montpellier, France.

HOMEGARDENS: AGRICULTURE IN THE CITY AS AN AGROFORESTRY PRACTICE

Santiago-Freijanes JJ[1, 2]*, Mosquera-Losada MR[2], Aldrey-Vázquez JA[1], Rigueiro-Rodríguez A[2]

(1) Geography Department, Universidade de Santiago de Compostela, Santiago de Compostela, Spain (2) Vegetal Production and Projects Enginery Departmen, Universidade de Santiago de Compostela, Lugo, Spain

*Corresponding author: josejavier.santiago@usc.es

Abstract

Homegardens are probably the most difficult agroforestry practice to map because of their size and presence in non-agricultural areas. The LUCAS database allows to combine the “orchards” field with the “woody” component, needed to identify this agroforestry practice. The objective of this paper is to map and quantify the agroforestry homegardens in Europe by using the LUCAS database. The paper shows that Europe has 14461.04 km^2 of homegardens, 58.74% of which can be considered agroforestry as they have a woody component integrated with an agricultural product in the understory.

Keywords: LUCAS database; fruit trees homegardens; vineyards and olive homegardens; landscape features

Introduction

Homegardens identified with multi story combinations of trees and crops are usually linked to subsistence or self-consumption agriculture that are generally more complex in tropical than in temperate areas.

The Land-Cover and Land-Use Survey (LUCAS) defines kitchen gardens as “gardens, where the crops are planted heterogeneously and mainly for own consumption. These areas are mostly fenced (by metal fences or hedges) and mostly situated in residential areas or as allotment gardens” (Eurostat 2015). Homegardens are key to providing local and more sustainable healthy food while reducing the impact of agricultural activities on climate change. Homegardens can be in both rural and urban areas and are treated differently by EU policies (Mosquera-Losada et al. 2016).

When a woody component, usually fruit tree, is combined with vegetable production in the understory, homegardens are considered an agroforestry practice (Mosquera-Losada et al. 2016). Agroforestry homegardens are difficult to map because linear woody features are not registered directly in the cover databases and homegarden areas are presumably identified as a residential area due to the small size of these plots around the house.

Quantifying the extent of homegardens as an agroforestry practice at European scale is a difficult task because two layers or components are mixed: the woody component as an upperstorey and the agriculture production as a lowerstorey. For this purpose, a single database named LUCAS (LUCAS 2015), developed by Eurostat, combines coverage and use may be very useful (der Herder et al. 2016). This database is based on the visit of 340,000 points by surveyors (Eurostat 2015). LUCAS is carried out by Eurostat every three years since 2009. The last survey was run in 2015 on the mainland of European Union (EU). There are other sources such as the Corine Land Cover (CLC) that only describes coverage but not land use, therefore it is not useful to estimate the extent of agroforestry at EU level. This paper aims to quantify the presence of woody vegetation within the points classified as homegardens to provide and map this type of agroforestry practice all over EU.

Materials and methods

EU homegardens were mapped by using LUCAS survey carried out in 2015 (Eurostat 2015). LUCAS data are taken during visits by the surveyors to previously defined points in EU. Surveyors filled established forms including two questions related with the two land cover and two land uses found in each point. Data are included in a database freely available from Eurostat.

As den Herder et al. (2017) explained, by combining two covers of LUCAS, we can identify those areas of territory that have two crops at two heights. For example, while the CLC must assign a special category to the Iberian montado/dehesa without distinguishing if the lower crop is annual or pasture, LUCAS presents as a primary cover the woody element and as the secondary the lower crop. But the combination can also be made between cover and use. Thus, we can verify that a cultivation of tomatoes for example has a commercial destination or is destined for self-consumption in a home garden.

To examine the LUCAS data, we used the free software LibreOffice-Calc and QGIS 2.18. We selected the LUCAS points that were presented as primary or secondary use the value U113, identified as “Kitchen garden”, which refers to homegardens. From those points, we selected the woody covers in the primary and secondary covers fields. Woody covers were identified as the cover fields of the database named as forestry, permanent crops and other permanent crops, grassland with sparse trees or shrubs, and shrubland with sparse trees.

Based on the results of the previous exercise combining land cover and land use with the LUCAS database we mapped the whole extent of homegardens in EU (Table 1) that has a woody component, which were divided in fruit and those based on olive groves and vineyards (Table 2). The proportion of homegardens land use was estimated by dividing the total number of points identified as homegardens by the total number of points in each EU country. An estimation of the extent of homegardens per country was done by multiplying the before obtained percentage per the extension of each state (km^2).

Results

Most of homegardens are concentrated in Central and Eastern EU countries (Table 1), but also in the coastal areas of South EU Countries. Czech Republic, Slovakia and Croatia have around 1% of their land cover allocated to homegardens while France, Poland, Czech Republic, Germany, Italy and Romania have the largest area of homegardens in EU (over 1200 km^2). Few homegarden densities are found in Denmark, Finland, Ireland, Luxemburg, Malta, Sweden and United Kingdom with less than 0.1% of their total area and Cyprus, Ireland, Luxemburg and Malta with less than 15 km^2.

Table 1: Total area (km^2) and percentage of total area of homegardens and those with presence of agricultural woody cover (percentage of total homegardens) by EU member states.

Countries	Area	Homegardens		Woody cover homegardens/total homegardens	
	km^2	%	km^2	%	km^2
Austria	83944	0.36%	304.08	75.00%	228.06
Belgium	30666	0.21%	63.51	0.00%	0.00
Bulgaria	110995	0.56%	621.62	58.14%	361.41
Croatia	56539	0.99%	561.22	57.14%	320.70
Cyprus	9249	0.52%	48.34	88.89%	42.97
Czech Rep.	78874	1.61%	1270.38	90.22%	1146.1
Denmark	43162	0.08%	35.44	66.67%	23.62
Estonia	45347	0.19%	86.24	80.00%	69.00
Finland	337547	0.02%	83.97	100.00%	83.97
France	549059	0.26%	1436.22	53.17%	763.71
Germany	357745	0.38%	1372.58	73.53%	1009.25
Greece	131912	0.31%	402.78	78.95%	317.99
Hungary	93013	0.70%	648.05	44.44%	288.02
Ireland	70601	0.02%	14.43	100.00%	14.43
Italy	300576	0.51%	1541.36	59.86%	922.72
Latvia	65519	0.60%	390.14	65.63%	256.03
Lithuania	65412	0.75%	493.79	47.06%	232.37
Luxembourg	2595	0.00%	0.00		
Malta	315	0.00%	0.00		
Netherlands	37824	0.16%	60.47	25.00%	15.12
Poland	313851	0.48%	1502.46	52.73%	792.21
Portugal	88847	0.40%	355.19	22.22%	78.93
Romania	239068	0.54%	1287.39	28.89%	371.91
Slovakia	49026	1.71%	837.29	72.34%	605.70
Slovenia	20277	0.42%	84.27	75.00%	63.20
Spain	498502	0.16%	793.40	57.50%	456.20
Sweden	449896	0.02%	84.62	80.00%	67.70
UK	165152	0.08%	138.09	14.29%	19.73
EU28	4295513	0.34%	14461.04	58.74%	8493.80

Around a 60% of the total homegardens in the EU have woody cover (Table 1). Countries like Netherlands, Portugal, United Kingdom, Belgium have percentages of woody homegardens below 25% while other like Luxembourg and Malta have no woody homegardens as part of the landscape. On the contrary, there are other countries with the highest percentage of woody homegardens in EU like such as Czech Republic and Cyprus while others like Finland, Ireland, have percentages reaching almost the 100% of the homegardens with a woody component. Considering the extension Czech Republic and Germany have more than 1,000 km^2 of wooded homegarden meanwhile United Kingdom, Netherlands, Ireland and Belgium have less than 20 km^2. As show Table 2, the woody homegardens have a similar distribution than the homegardens (Table 1), with a correlation R^2 = 0.92.

Table 2: Total (km²) and percentage of homegardens with presence of a woody cover and those including fruit trees and vineyards and olive by EU member states.

Countries	Fruit trees homegardens		Vineyards and olive homegardens	
	%	km^2	%	km^2
Austria	100.00%	228.06	0.00%	0.00
Belgium				
Bulgaria	92.00%	332.49	8.00%	28.91
Croatia	75.00%	240.52	25.00%	80.17
Cyprus	50.00%	21.48	50.00%	21.48
Czech Rep.	100.00%	1146.10	0.00%	0.00
Denmark	100.00%	23.62	0.00%	0.00
Estonia	100.00%	69.00	0.00%	0.00
Finland	100.00%	83.97	0.00%	0.00
France	88.06%	672.52	11.94%	91.19
Germany	100.00%	1009.25	0.00%	0.00
Greece	53.33%	169.59	46.67%	148.39
Hungary	75.00%	216.02	25.00%	72.01
Ireland	100.00%	14.43	0.00%	0.00
Italy	62.50%	576.70	37.50%	346.02
Latvia	100.00%	256.03	0.00%	0.00
Lithuania	100.00%	232.37	0.00%	0.00
Netherlands	100.00%	15.12	0.00%	0.00
Poland	100.00%	792.21	0.00%	0.00
Portugal	75.00%	59.20	25.00%	19.73
Romania	53.85%	200.26	46.15%	171.65
Slovakia	97.06%	587.88	2.94%	17.81
Slovenia	100.00%	63.20	0.00%	0.00
Spain	86.96%	396.70	13.04%	59.50
Sweden	100.00%	67.70	0.00%	0.00
UK	100.00%	19.73	0.00%	0.00
EU28	86.40%	7338.44	13.60%	1155.36

Discussion

LUCAS can be successfully used to identify agroforestry homegardens as was previously shown for general agroforestry (den Herder 2017) and hedgerows (Santiago-Freijanes et al. 2018). This is specifically important because LUCAS surveys are carried out every three years which allows policy makers and researchers to evaluate the evolution of this type of land use and to promote this type of land use in EU. Types of homegardens such as allotment gardens have been declined in the last years, but a recent renascence of this land use have been noticed (Bell et al. 2016). The large density of homegardens in central EU can be explained by the traditional use of these lands as orchards surrounding the houses. For example, different initiatives such as that developed in (i) Leipzig (Germany) where playgrounds for children were started to favour learning in conditions close to nature, that were later on used to produce food for the most disadvantaged populations or (ii) in the Czech Republic and Slovakia where homegardens were favoured during the Soviet period (Štěpánková et al. 2015), but where recently declined (Spilkova and Vágner 2016). The highest extension of homegardens in countries as France can be explained by the bigger dimension of the countries and the recent policy development.

Only a 60% of the homegardens have been identified as an agroforestry practices, however we can expect that the real figure is indeed higher. This can be explained by the fact that linear woody features (hedgerows, hedges, etc.) and isolated trees are not identified in the LUCAS database as part of the survey of LUCAS when all the points are taken. In fact, Eurostat (2015) recognizes that the plots destined for the homegarden cover often present hedgerows or fences, that are not identified. Moreover agroforestry -the integration of a woody component with vegetables or crop production- is recognized as essential to deliver ecosystem services and can be identified as a new form of agriculture (La Rosa et al. 2014) on which both public and private stakeholders are involved and acting in supporting food supply for urban and periurban areas (Duvenoy 2018).

All woody homegardens are permanent crops. The distribution between the two categories of permanent crops (fruits and olive groves / vineyards) is related with the climatic conditions and the tradition as the olive groves and vineyards are present only in Mediterranean and Medium and low Danube basins, where are typical those plantations, but another typical vine regions as the Rhin basin have not presence of this trees cover in their homegardens. This means that adequate policies should support homegarden creation and development with woody vegetation adapted to the edaphoclimatic and social conditions of the areas.

Conclusions

- Homegardens are present in most of the EU countries, but not with similar tree density.
- The distribution of wooded homegardens is very similar than the homegardens.
- Woody homegardens linked to fruit trees and vineyards/olives can be mapped by the use of LUCAS.
- There are not direct data available of linear features and isolated trees that could show a real extension of wooded homegardens in the EU, and therefore of this agroforestry practice.
- All identified wooded homegardens are linked to permanent crops.
- The distribution between the two types of permanent crops is related with climate and cropping tradition.

Acknowledgements

This work is part of AFINET PROJECT. Grant Agreement 727872. Call H2020-RUR-2016-2017 (Rural Renaissance ─ Fostering innovation and business opportunities).

References

LUCAS (2015) http://ec.europa.eu/eurostat/web/lucas/data/primary-data/2015 (accessed 20/1/2018).

Bell S, Fox-Kämper R, Keshaverz N, Benson M, Caputo S, Noori S, Voigt A (2016) Urban allotment gardens in Europe. Routledge.

den Herder M, Moreno G, Mosquera-Losada MR, Palma JHN, Sidiropoulou A, Santiago-Freijanes JJ, Crous-Durán J, Paulo JA, Tomé M, Pantera A, Papanastasis VP, Mantzanas K, Pachana P, Papadopoulo A, Plieninger T, Burgess PJ (2017) Current extent and stratification of agroforestry in the European Union. Agric Ecosyst Environ 241: 121–132.

Duvernoy, I., 2018. Alternative voices in building a local food policy: Forms of cooperation between civil society organizations and public authorities in and around Toulouse. Land Use Policy. In Press,

Eurostat (2015): LUCAS 2015 Technical Reference Document C3 Classification. Luxembourg: Eurostat.

La Rosa D, Barbarossa L, Privitera R, Martinico F (2014) Agriculture and the city: A method for sustainable planning of new forms of agriculture in urban contexts. Land Use Policy, 41, pp.290–303.

Mosquera-Losada, M. R. et al. (2016): Extent and Success of Current Policy Measures to Promote Agroforestry across Europe. https://www.agforward.eu/index.php/en/extent-and-success-of-current-policy-measures-to-promote-agroforestry-across-europe.html (accessed 20/1/2018).

Santiago-Freijanes JJ, Rigueiro-Rodríguez A, Aldrey JA, Moreno G, den Herder M, Burgess P, Mosquera-Losada MR (2018) Understanding agroforestry practices in Europe through landscape features policy promotion. Agroforest Syst https://doi.org/10.1007/s10457-018-0212-z

Spilková J, Vágner J (2016) The loss of land devoted to allotment gardening: The context of the contrasting pressures of urban planning, public and private interests in Prague, Czechia. Land Use Policy 52, 232–239.

Štěpánková R et al (2015) Allotment Gardens in Slovakia. Unpublished. https://doi.org/10.13140/rg.2.1.3990.4886 (accesed 18/01/2018).

Session

Agroforestry as a form of sustainable land use to fight against climate change

SHADE INCREASES CEREAL PRODUCTION IN MEDITERRANEAN CONDITIONS FACING THE CLIMATE CHANGE

Arenas-Corraliza MG[1*], López-Díaz ML[1], Moreno G[1]

(1) INDEHESA (Instituto de Investigación de la Dehesa), University of Extremadura, Plasencia, Spain

*Corresponding author: garenascorraliza@unex.es

Abstract

A greenhouse trial with three levels of shade (0%, 10% and 50%) was performed in Mediterranean latitude to assess the influence of solar radiation intensity in the biomass and grain yield of winter wheat and barley. Nine cultivars of each species were studied and most of them, especially those of barley, increased their production under shade conditions. The quality of the grain in terms of N was also studied, and it was lower in the shade treatments in wheat compared to full sunlight, unlike barley, which did not experiment any change in N content in the different treatments. Our results suggest that tree shade in silvoarable systems could be a strategy of adaption to climate change, although a selection of cultivars adapted to shade is necessary to maximize the production of the system.

Keywords: barley; wheat; shade; silvoarable; climate change

Introduction

Throughout the second half of the twentieth century, crop yields grew up due to improved agronomic techniques, using of fertilizers, energy and pesticides and genetic selection and breeding (FAO 1996). These advances, known as "green revolution", allowed an increase in the crop yield per unit of cultivated soil by using high inputs (chemical and energy) and a small selection of crop species and cultivars, most of them adapted to full light conditions.

Despite the need to double food production in this century to feed the increasing human population, yields have stagnated in recent years. Decreases in crop yield are increasingly reported as a result of climate change and recurrence of extreme weather events (e.g. heat waves and long droughts) (Brisson et al. 2010; Ray et al. 2012). Brisson et al. (2010) showed that although genetic improvements are still being made to crops, this has been partly counteracted since the 1990 by climate changes which are unfavorable to cereals in temperate climates due to heat-stress during the grain filling phase and drought during stem elongation. Therefore, there is a need to design more productive and sustainable production systems. One approach is ecological intensification where the aim is to increase yield through a better use of the land's own resources (Cassman 1999; Doré et al. 2011; Bommarco et al. 2013). One approach is Agroforestry (Carsan et al. 2013; Tittonell 2014) since trees regulate the climate beneath them, reducing extremes of temperature, sheltering against wind and reducing evaporation from the soil surface. But most cultivars have been traditionally selected for full light conditions and that is why selection programs are needed to find cultivars adapted to partial shade.

Materials and methods

In 2016-2017, a greenhouse trial of winter cereal varieties was carried out at the Ecological and Mountain Agriculture Center (CAEM) in Plasencia (Cáceres, Spain). The study included different cultivars of each winter cereal species (wheat and barley) to select those that showed a better behaviour under partial shade conditions for cropping in agroforestry systems. The seeds of these varieties were provided by the La Orden-Valdesequera Agricultural Research Institute, which collaborates with the Group for the Evaluation of New Varieties for Extensive Crops in Spain (GENVCE: http://www.genvce.org/). The nine varieties of each species were selected according to three categories of precocity (dates of sprout). These categories were: very early, early and medium.

Three treatments were established: full light with anti-bird net ("Light"), 10% shade ("Partial shade") and 50% shade ("Shade"). In each treatment a table was installed with six pots per variety, sowing four seeds in each pot (13 x 13 x 17 cm). On April 7, 2017 shading nets were introduced, coinciding with the leaf sprout of walnuts. The soil mixture was based on three parts of black peat, one part of sand and one part of perlite. Its soil water capacity was 119 % and pH was 5,8. All plots were fertilized in November with 58 kg ha^{-1} N, 100 kg ha^{-1} P_2O_5 and 58 kg ha^{-1} K_2O. In February, 200 kg ha^{-1} N were applied in each plot with urea 46 %. All plots were regularly irrigated in order to maintain soil water capacity above 50 % to exclude impact of soil water stress factor.

Results

In general, grain production increased with shade (Figure 1). While barley did not show an increase at 10% shade, it showed a significant increase at 50% shade. By contrast, wheat grain yields increased significantly from full sunlight to 10% shade and kept the same grain yield at 50% shade. Tables 1 to 3 show original data for different cultivars growing at different sinlight conditions (full sunlight, 10% shade, and 50% shade).

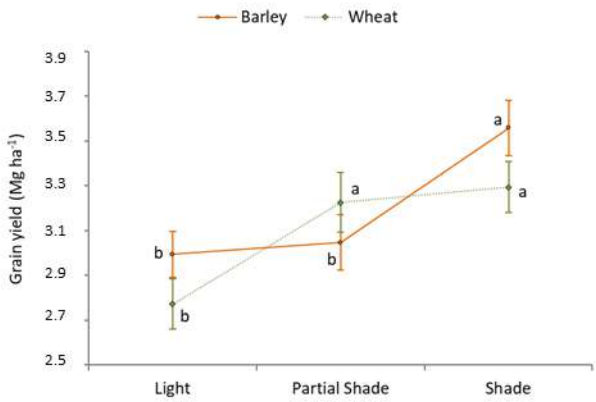


Figure 1: Grain yield (Mg ha^{-1}) of barley and wheat in the different treatments: full sunlight (Light), 10 % shade (Partial shade) and 50 % shade (Shade).

Grain yield trend to be higher under 50% shade compared to full light for most of the barley cultivars, being significant higher for “Lagalia” and “Meseta” (Table 1). In wheat, the highest grain yields were mostly found for 10% shade (Figure 1), being significant for ”Sohelio” (Table 1). “Paledor” showed a better behaviour in 50% shade (Table 1).

Table 1: Grain yields (Mg/ha) for the cultivars tested in the different treatments: full sunlight (Light), 10 % shade (Partial shade) and 50 % shade (Shade).

Species	Maturation	Cultivars	Grain yield (Mg/ha)		
			Full sunlight	10% shade	50% shade
Barley	Very early	Hispanic (T)	2.82	2.88	3.39
		Lavanda	3.48	2.9	3.49
		Luzia	2.89	3.34	3.38
	Early	Kalea	2.76 ab	1.88 b	**2.90 a**
		Lagalia	3.14 b	3.43 ab	**4.13 a**
		Carolina	2.78	3.54	3.57
	Medium	Meseta (T)	2.57 b	3.29 ab	**4.02 a**
		Ibaiona	2.96	3.09	3.28
		Crescendo	3.53	3.08	3.85
Wheat	Very early	Nogal (T)	2.92	2.51	2.86
		Nudel	3.24	3.76	4.06
		Tocayo	3.33	4.18	3.89
	Early	Alogoritmo	2.95	3.3	2.75
		Paledor (T)	2.16 b	2.36 b	**3.40 a**
		Solehio	2.08 b	**3.33 a**	2.84 ab
	Medium	Toskani	2.05	2.15	2.91
		Somontano	3.1	3.55	3.41
		Nemo	3.13	3.9	3.52

For barley, grain size (weight of 1000 grains) was slightly higher in 10% shade than in full sunlight (Figure 2), especially “Kalea”, “Meseta” and “Crescendo” cultivars, and decreased significantly in 50% shade. For wheat, grain size was significantly higher in 10% shade compared to 50% shade and full sunlight (Figure 2), especially the cultivars “Nudel”, “Tocayo” and “Solehio”.

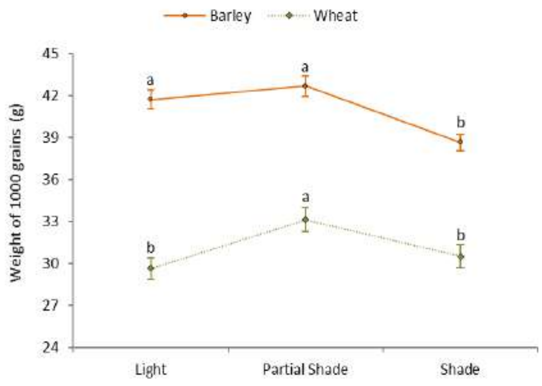


Figure 2: Weight of 1000 grains (g) of barley and wheat in the different treatments: full sunlight (Light), 10 % shade (Partial shade) and 50 % shade (Shade).

Barley had the same Nitrogen content in all treatments, slightly decreasing with shade (Figure 3). However, wheat experimented an important decrease in the shade treatment compared to full light (Figure 3) and showed lower values for the cultivars ”Algoritmo” and ”Paledor” in partial shade and shade respectively compared to full light.

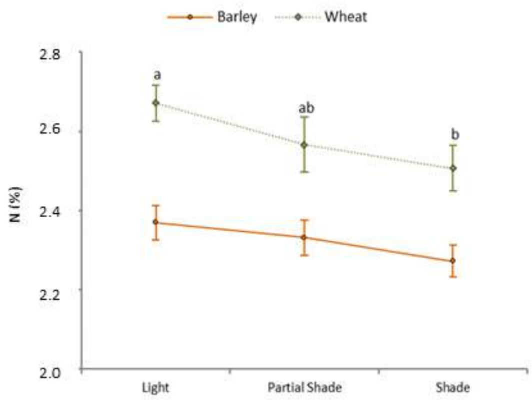


Figure 3: Grain Nitrogen content (%) of barley and wheat in the different treatments: full sunlight (Light), 10 % shade (Partial shade) and 50 % shade (Shade).

Discussion

Grain yields were higher under shade, where maximum temperatures were buffered. This is especially important in years with dry/warm climate events in spring which constrain cereal yields. These extreme weather events are common in Mediterranean areas and are expected to increase in the next years as a consequence of the climate change. In the study, several consecutive days with high temperatures (maximum daily > 30ºC) in the month of April and May, when the flowering and grain formation of the cereal take place, could decrease the cereal yields in full light conditions. In fact, Romero and German (2001) indicated that at temperature above 25°C the translocation of the available carbohydrates towards the grain was constrained. In these conditions, shade could be a safeguard compared to light conditions, helping to maintain higher yields.

Shade appears to be more positive for barley than for wheat, presumably because of the earlier development of barley plants. In addition to being more premature, barley has a fast ripening and a short period of grain filling compared to wheat (Cossani et al. 2009). It is known that wheat is a full-light plant (Guerrero 1999), hence providing shade was not anticipated to improve the grain yield as it does in barley. In fact, in Mediterranean agrosystems, under unfavorable conditions (arid and/or low fertility), barley is prioritized over other cereals (López-

Bellido 1992), since its precocity and rapid ripening have advantages in the use of water by avoid the common terminal stresses. Besides, the inclination angle of the leaves of barley and its foliage structure allows a greater interception of solar radiation (Muurinen and Peltonen-Sainio 2006), so it may be less sensitive than wheat to the possible negative effects of excessive tree shading. Barley seemed to not reduce its grain nitrogen content under any shade conditions, so the malting quality was maintained. However, in wheat, this contain was reduced in the shade treatment, which could deteriorate its flour for pasta and feed quality.

Conclusion

In general terms, slight shade did not reduce the production of cereals. On the contrary, it increased grain yields, especially in barley, in which, in addition, nitrogen content was not reduced with shade, unlike wheat. In this way, shade could be a way to mitigate excessive solar radiation in Mediterranean latitudes and high temperatures during the spike development and grain fill and increase yields. However, the effect of the shade depends on the cultivars and it is need to study its relation with other cereal stress factors (soil water deficit, nutrient content and phenology). Our results suggest the need of selection of cereal cultivars adapted to partial shade for implementation of silvoarable systems as strategy of adaptation to climate change. Besides, selection should not only be based on the optimal grain yield but also in functional traits indicative of important ecological processes such as water use efficiency and pest resistance.

References

Bommarco R, Kleijn D, Potts SG (2013) Ecological intensification: harnessing ecosystem services for food security. Trends Ecol Evol 28: 230–238.

Brisson N, Gate P, Gouache D, Charmet G, Oury FX, Huard F (2010a) Why are wheat yields stagnating in Europe? A comprehensive data analysis for France. F Crop Res 119: 201–212.

Carsan S, Stroebel A, Dawson I, Kindt R, Mbow C, Mowo J, Jamnadass R (2013) Can agroforestry option values improve the functioning of drivers of agricultural intensification in Africa? Curr Opin Environ Sustain 6: 35–40.

Cassman KG (1999) Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture. Proc Natl Acad Sci USA 96: 5952–5959.

Cossani MC, Slafer GA, Savin R (2009) Yield and biomass in wheat, and barley under a range of conditions in a Mediterranean site. F Crop Res 112: 205–213.

Doré T, Makowski D, Malézieux E, Munier-Jolain N, Tchamitchian M, Tittonell P (2011) Facing up to the paradigm of ecological intensification in agronomy: revisiting methods, concepts and knowledge. Eur J Agron 34: 197–210.

FAO (1996) Enseñanzas de la revolución verde: hacia una nueva revolución verde. Cumbre mundial sobre la alimentación. http://www.fao.org/docrep/003/w2612s/ w2612s06.htm (accessed 01/01/2016).

Guerrero A (1999) Cultivos herbáceos extensivos, 6a. Mundi Prensa, Madrid.

López-Bellido L (1992) Mediterranean cropping systems. In: Pearson CH (ed) Field Crop Ecosystems - Ecosystems of the World. Elsevier, pp 311–356

Muurinen S, Peltonen-Sainio P (2006) Radiation-use efficiency of modern and old spring cereal cultivars and its response to nitrogen in northern growing conditions. F Crop Res 96: 363–373.

Ray DK, Ramankutty N, Mueller ND, Wesr PC, Foley JA (2012) Recent patterns of crop yield growth and stagnation. Nat Commun. doi: 10.1038/ncomms2296

Romero R, German S (2001) Consideraciones sobre el clima y el desarrollo fenológico de la cebada cervecera. Instituto Nacional de Investigación Agropecuaria. Montevideo (Uruguay).

Tittonell P (2014) Ecological intensification of agriculture — sustainable by nature. Curr Opin Environ Sustain 8: 53–61.

QUANTIFYING C STOCKS IN HIGH-YIELD, SHORT-ROTATION WOODY CROP PRODUCTION SYSTEMS FOR FOREST AND BIOENERGY VALUES AND CO_2 EMISSION REDUCTION

Coleman B[1]*, Bazrgar A[1], Sidders D[2], Gordon A[1], Thevathasan N[1]

(1) School of Environmental Sciences, University of Guelph, Guelph, Ontario, Canada (2) Canadian Wood Fibre Centre, Natural Resources Canada, Edmonton, Alberta, Canada

*Corresponding author: colemanb@uoguelph.ca

Abstract

Short-rotation woody crop (SRWC) systems sequester atmospheric CO_2 in their fibre and surrounding soil. Studies have promoted the carbon (C) sequestration potential of concentrated SRWC systems, but most examine only aboveground biomass and soil organic carbon (SOC) stocks on young systems (<6 years). The objectives of this study were, (a) to quantify above- and belowground carbon stocks within an 8-year-old concentrated SRWC system and (b) to compare SOC stocks between SRWC systems and an adjacent conventional agricultural system. Fibre C accumulations among clones in concentrated SRWC systems ranged from 1.02 to 5.34 t y^{-1}. SOC stocks for concentrated SRWC averaged 78.66 t C ha^{-1} (0-30cm), with an increase of 1.16 t C ha^{-1} y^{-1} compared to the baseline measurements in 2009 (69.42 t C ha^{-1}). SOC stocks for the agricultural system (0-30cm) have dropped to 63.80 t C ha^{-1}, averaging a loss of 0.70 t C ha^{-1} y^{-1} since 2009.

Keywords: bioenergy; carbon sequestration; carbon stocks, climate change mitigation, short-rotation woody crops; soil organic carbon

Introduction

The Canadian government has turned its efforts towards carbon pricing strategies leading to the adoption of the 2017 cap-and-trade program in the province of Ontario (ECCC 2016). This program meets the Paris Agreement's emphasis on efficient carbon pricing, but also provides an incentive for the development of carbon sinks and reservoirs. Short rotation woody crops (SRWC) have attracted the focus of both private and public enterprise for both their potential as a bioenergy source and their value as a long-term carbon (C) sink by sequestration of atmospheric CO_2 into tree biomass and soils (Montagnini and Nair 2004). Moreover, concentrated SRWC systems have the potential to enhance C sequestration even further due to planting densities of ~20 000 stools ha^{-1} (Cardinael et al. 2012).

SRWC systems sequester atmospheric CO_2 in their fibre, as well as in the soil through the decomposition of litterfall and fine-root turnover. Recent studies have promoted the carbon sequestration potential (CSP) of concentrated SRWC systems, but most examine only aboveground biomass and soil organic carbon stocks on young systems (6 years or less). More robust and longer term studies quantifying system level carbon stocks in concentrated SRWC systems are lacking for the temperate region. The objectives of this study are therefore, (a) to quantify above- and belowground C stocks within an 8-year-old concentrated SRWC system, (b) to compare SOC stocks between various SRWC systems, a conventionally managed agricultural system, and an old growth forest, all adjacent to one another (Figure 1). Under Ontario's new cap-and-trade program, biomass growers may potentially earn offset carbon credits as compensation for carbon sequestration and gain additional revenue through trading of their respective credits within the market (ECCC 2016). The results from this study will provide biomass growers with better information regarding the CSP of concentrated SRWC systems in southern Ontario, enhancing the economic outlook of such systems. Furthermore, this research may also contribute towards policies promoting concentrated SRWC systems based on their environmental benefits, in addition to their bioenergy potential.

Figure 1: Study sampling locations at the Guelph Agroforestry Research Site, Guelph, Ontario, Canada.

Materials and methods

The experimental SRWC field site is located at the University of Guelph Agroforestry Research Station in Guelph, Ontario (Figure 1). In 2009, concentrated SRWC plantations (20,000 stems ha^{-1}) of *Populus* (*2293-19, DN-136, DN-154, and NM-6*) and *Salix* (*India, SX64, SX67, and Viminalis)* were established on Class 3-4 agricultural land, which is denoted by the Canadian Land Inventory as land with moderate to severe limitations and restricted crop choice. This study featured a 8 x 2 factorial treatment design (clone x design), arranged in a Randomized Complete Block Design with three replications for each clone x design combination (3 x 8 x 2 = 48 plots). Clone cuttings were planted under two different designs: two-row (2R) and three-row (3R). In 2R plots, spacing adhered to the European double-row design (Cardinael et al. 2012). In 3R plots, spacing within each triple row was 0.75 m, while triple rows were spaced 2.00 m apart and each stool within each row was 0.60 m apart. The concentrated SRWC systems were coppiced following their initial growing season in 2009, and commercially harvested every three years (2012 and 2015).

System fibre C accumulation

Aboveground biomass was assessed in the fall of 2015 (cycle 2 harvest), while belowground biomass and leaf litter biomass were assessed in the fall of 2016. Moisture content was assessed and above- and below-ground biomass values were converted into oven dry tonnes per hectare per year (odt ha^{-1} yr^{-1}). For the calculation purposes of this paper, a value 47.7% was used to represent the proportion of carbon in all tree components (Thomas and Martin 2012). Annual aboveground fibre accumulation was calculated by dividing total aboveground biomass by three to obtain the average annual accumulation for the second growing cycle. Annual belowground fibre accumulation was calculated by dividing the total belowground biomass by 8, which represents the age of root system. Annual fine-root turnover (FRT) was estimated at 50% of the annual litterfall C input (Peichl et al. 2006).

Soil organic carbon

Soils within the treatment blocks were randomly sampled in both 2009 (0-30cm) and 2016 (0-30cm and 30-60cm) using a soil auger. For comparative purposes, soil samples were also collected at four other adjacent fields, at depth of 0-30cm and 30-60cm, under three different land-uses, including a conventionally managed agricultural field on a corn-soybean-wheat crop rotation, two SRWC afforestation sites (established in 2005 and 2009, respectively) planted with a variety of poplar clones, as well as a nearby old growth forest (University of Guelph Arboretum; Figure 1). Samples were processed in lab and analyzed using the combustion method with a LECO CR-12 Carbon Analyzer as described by Cardinael et al. (2012). Triplicate bulk density samples were also obtained for each land-use at 0-30cm and 30-60cm depths to allow carbon stocks to be calculated for each depth. The value of SOC gain was divided by years of growth to determine the average annual rate of C addition to the soil.

Results

Annual system fibre C accumulation in SRWC systems

Differences in annual system fibre C accumulation were not found to be significantly influenced by design and ranged from 1.02 t C ha^{-1} for NM6 to 5.34 t C ha^{-1} for SX64 (Figure 2). Annual aboveground biomass C accumulations accounted for 59.6 to 73.9% of total annual fibre C accumulations, while belowground biomass C accumulations accounted for 17.3 to 32.2% of total annual fibre C accumulations. Leaf litter C inputs accounted for 1.5 to 6.5% of total annual fibre C accumulations, while estimated fine-root turnover inputs accounted for 0.8 to 3.2% of total annual fibre C accumulations.

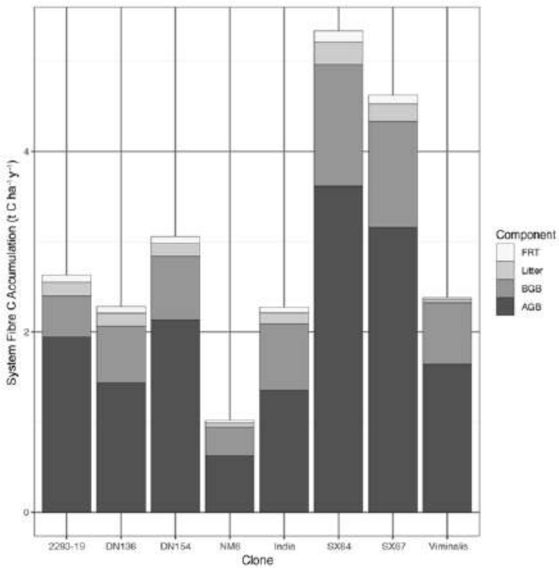


Figure 2: Estimated annual fibre C (t ha^{-1}) accumulation from aboveground biomass (AGB), belowground biomass (BGB), litter, and fine-root turnover (FRT) for eight short-rotation clones in an 8-year-old concentrated SRWC production system in southern Ontario, Canada (n=6).

Soil carbon in SRWC systems

SOC was significantly higher ($p<0.001$) at a depth of 0-30cm (2.02 ± 0.06%) than at a depth of 30-60cm (1.69% ± 0.06; see Table 1). Average SOC in 2016 at a depth of 0-30cm (2.02 ± 0.06%) was also significantly higher ($p<0.001$) than baseline SOC measured in 2009 (1.78 ± 0.03%; data not presented). When factoring in bulk density, SOC stocks were not found to be significantly different between treatment combinations but ranged from 71.29 to 83.77 t C ha^{-1} at a depth of 0-30cm (mean= 78.66), while ranging from 71.16 to 88.91 t C ha^{-1} at a depth of 30-60cm (mean= 79.01). SOC stocks at 0-30cm depth in 2016 (78.66 t C ha^{-1}) were found to be significantly higher ($p<0.001$) than 2009 baseline SOC stocks (69.42 t C ha^{-1}), with these systems sequestering an average of 1.16 t C ha^{-1} y^{-1} during the first eight years following establishment.

Table 1: Comparison of mean soil organic carbon (SOC) measurements at two depths (0-30cm and 30-60cm) for five land-use systems in southern Ontario, Canada (Afforestation established in 2005, n=9; afforestation established in 2009, n=9; agricultural field, n=3; old growth forest, n=3; concentrated short rotation woody crops (SRWC) established in 2009, n=24).

	SOC (%)		SOC (t C ha^{-1})	
Land-use	0-30cm	30-60cm	0-30cm	30-60cm
Afforestation (2005)	2.15 (0.07) ^{bx}	1.61 (0.08) ^{by}	70.99 (2.34) ^{bcx}	63.73 (2.98) ^{ax}
Afforestation (2009)	1.72 (0.04) ^{by}	2.01 (0.09) ^{abx}	61.94 (1.55) ^{cy}	79.59 (3.76) ^{ax}
Agricultural Field (2016)	1.64 (0.18) ^{bx}	1.70 (0.13) ^{bx}	63.80 (7.04) ^{bcx}	79.56 (6.21) ^{ax}
Old Growth Forest	**3.35 (0.61)** ^{ax}	**2.53 (0.11)** ^{ax}	**104.06 (8.88)** ^{ax}	86.41 (3.05) ^{ax}
Concentrated SRWC (2009)	2.02 (0.06) ^{bx}	1.69 (0.06) ^{by}	78.66 (2.31) ^{bx}	79.01 (2.74) ^{ax}

*Superscripts (a-b) indicate significant differences between land-uses (down columns), as determined by one-way ANOVA and subsequent Tukey HSD test ($p<0.05$). The highest ranking value for the land-use comparison at each depth is indicated in bold. Additionally, superscripts (x-y) indicate significant differences between depths (0-30cm vs 30-60cm) for each land-use, as determined by respective t-tests ($p<0.05$).

Land-use Comparison

SOC at a depth of 0-30cm ranged from 1.64% for the agricultural field to 3.35% for the old growth forest, with the concentrated SRWC having 2.02% SOC (Table 1). At a depth of 30-60cm, SOC ranged from 1.61% in the 2005 planted afforestation plots to 2.53% for the old growth forest, with the concentrated SRWC having 1.69% SOC. When factoring in bulk density, SOC stocks at 0-30cm ranged from 61.94 t C ha^{-1} in the 2009 planted afforestation to 104.06 t C ha^{-1} in the old growth forest, with the concentrated SRWC having 78.66 t C ha^{-1}. SOC stocks at 30-60cm ranged from 63.73 t C ha^{-1} in the 2005 planted afforestation to 86.41 t C ha^{-1} in the old growth forest, with the concentrated SRWC having 79.01 t C ha^{-1}.

Discussion

Overall, annual system fibre C accumulation averaged from 1.02 to 5.34 t C ha^{-1} y^{-1} across all tested clones (Figure 2). SOC stocks for concentrated SRWC averaged 78.66 t C ha^{-1} from 0-30cm in depth, with an average increase of 9.24 t C ha^{-1} (1.16 t C ha^{-1} y^{-1}) sequestered compared to the baseline measurements in 2009 (69.42 t C ha^{-1}) (Table 1). In contrast, SOC stocks for the agricultural field have dropped to 63.80 t C ha^{-1} from 0-30cm in depth, meaning an average loss of 0.70 t C ha^{-1} y^{-1} compared to 2009 levels. Differences were less pronounced and non-significant between land-uses at a depth of 30-60cm.

Results from this study suggest that selecting high performing clones (i.e. SX64), even on marginal lands, can enhance system level carbon sequestration by more than 5 t C ha^{-1} y^{-1} in above- and belowground system fibre, in addition to more than 1 t C ha^{-1} y^{-1} in soil as SOC. Over the plantation lifespan (~21 years), this concentrated SRWC system may be expected to sequester nearly 25 t C ha^{-1} in SOC alone. These findings are significant as the monetization of carbon may provide an additional revenue stream to biomass growers, further enhancing adoption. Furthermore, concentrated SRWC systems may be implemented within or in conjunction with more traditional agroforestry systems to derive beneficial ecosystem services, including carbon sequestration, while producing harvestable biomass on shorter (~3 year rotations) timescales. Additional research is required to examine such systems in later stages of growth (cycles 5-7), with attention also paid to belowground root decomposition following the productive lifespan of such plantations.

References

Cardinael R, Thevathasan NV, Gordon AM, Clinch R, Mohammed I, Sidders D (2012) Growing woody biomass for bioenergy in a tree-based intercropping system in southern Ontario, Canada. Agrofor Syst 86: 279-286.

Environment and Climate Change Canada [ECCC] (2016) Canada's Second Biennial Report on Climate Change. Ottawa: Government of Canada. https://www.ec.gc.ca/GES-GHG/default.asp?lang=Enandn=02D095CB-1 (accessed 3/04/2017).

Montagnini F, Nair PKR (2004) Carbon sequestration: An underexploited environmental benefit of agroforestry systems. Agrofor Syst 61: 281-295.

Peichl M, Thevathasan NV, Gordon AM, Huss J, Abohassan RA (2006) Carbon sequestration potentials in temperate tree-based intercropping systems, southern Ontario, Canada. Agrofor Syst 66: 243-257

Thomas SC, Martin AR (2012) Carbon content of tree tissues: a synthesis. Forests 3: 332-352.

USING ECOYIELDSAFE TO COMPARE SOIL CARBON DYNAMICS UNDER FUTURE CLIMATE IN TWO CONTRASTING AGROFORESTRY SYSTEMS

Palma JHN[1]*, Crous-Duran J[1], Graves AR[2], Garcia de Jalon S[2, 5], Upson M[2], Oliveira TS[1], Paulo JA[1], Ferreiro-Domínguez N[1, 3], Moreno G[4], Burgess PJ[2]

(1) Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda, 1349-017 Lisboa, Portugal (2) School of Energy, Environment and Agrifood, Cranfield University, Cranfield, Bedfordshire, MK43 0AL, UK (3) Crop Production and Project Engineering Department, Escuela Politécnica Superior de Lugo, University of Santiago de Compostela; Campus Universitario s/n, 27002 Lugo, Spain (4) INDEHESA, Universidade de Extremadura, Plasencia, Spain (5) Basque Centre for Climate Change (BC3). Parque Científico de UPV/EHU, 48940. Leioa, Basque Country, Spain

*Corresponding author: joaopalma@isa.ulisboa.pt

Abstract

In recent decades, modern agroforestry systems have been proposed at European level as land use alternatives for conventional agricultural systems. The potential range of benefits that modern agroforestry systems can provide includes farm product diversification, soil and biodiversity conservation and carbon sequestration. This paper compares simulations of the EcoYieldSAFE model, integrated with the widely used soil carbon model RothC, a model simulating soil organic carbon turnover. Two case study systems are examined: a cork oak system in south Portugal and a poplar system in the UK, in current and future climate. Simulations suggest, under future climate for the Mediterranean case study, a reduction in carbon storage of about 2 Mg ha^{-1} and 5 Mg ha^{-1} in the agroforestry and arable systems, respectively. In the Atlantic environment, climate change, although having a negative impact, was not as dramatic as in the Mediterranean case. The agroforestry resiliency under future climate is discussed.

Keywords: modeling; Mediterranean; Atlantic; ecosystem services; benefits, sequestration

Introduction

Agroforestry, while present in Europe on 15.4 million hectares of land covering almost 10% of the utilized agricultural area (den Herder et al. 2017), is also a promising option for designing new systems of sustainable agriculture. These systems sequester carbon at higher rates than if the trees and crops are grown separately, they store carbon also in standing biomass or introduce carbon to the soil through, for example, leaf fall, root turnover or crop residues, reducing carbon in the atmosphere, which is essential for mitigating the effects of global warming (Schroeder 1994; Montagnini and Nair 2004; Upson 2014).

This work explores state of the art modelling tools to compare two different land use systems (agriculture and agroforestry) in two different environments (Mediterranean and Atlantic) in current and future climate.

The usage of EcoYieldSAFE model, that includes a soil carbon module (Palma et al. 2017) in the original YieldSAFE model (van der Werf et al. 2007), to compare different land use systems (agriculture and agroforestry) in different environments (Mediterranean and Atlantic) in current and future climate.

Materials and methods

We used the EcoYieldSAFE model, a recent update of the daily time step YieldSAFE model (van der Werf et al. 2007) that included a soil carbon module (Palma et al. 2017). A comparison between conventional arable and agroforestry land use alternative was made for two different locations and different growth rate tree species for a simulation horizon of 80 years. The first was in a Mediterranean climate, and compared an arable system with a wheat-wheat-fallow rotation to an agroforestry system with the same rotation and a density of 78 trees ha^{-1} (holm oak – *Quercus rotundifolia* L.) over a 80 year time horizon. The second was in an Atlantic climate, and compared an arable system with a wheat-wheat-barley-oilseed rotation to an agroforestry system with the same rotation and a density of 78 trees ha^{-1} (poplar – *Populus* sp) over a 20 year time horizon. The daily climate input for the simulations was obtained through Clipick (Palma 2017) – AR5 RACMO evaluation and RCP8.5 datasets (van Meijgaard 2012) - for locations near Montemor (South Portugal) and Silsoe (Central UK). Evaluation and RCP8.5 were considered climate for current or future climate respectively.

Results and discussion

The simulations predicted that in both environments, agroforestry would increase soil organic content when compared to conventional arable agriculture. Although this is somewhat expected through previous studies (Schroeder 1994; Montagnini and Nair 2004), the ability to assess soil carbon dynamics and quantify carbon storage in the long-term through dedicated agroforestry models is an improvement to the set of tools that are available for assessing agroforestry land use changes.

In the Mediterranean scenario, the effect of the cork oak trees was to increase SOC by about 1 Mg ha^{-1}, but when compared to conventional agriculture, after 80 years, there was a difference of 2.5 Mg ha^{-1} because agricultural land use tends to decrease the carbon content of the soil (Figure 1), with or without conservation measures (Hermle et al. 2008; Oberholzer et al. 2014). Similar results for similar systems are reported by Francaviglia et al. (2012) in Sardinia where input plant materials for a cork oak forest were of 3.74 Mg ha^{-1} (and considering 0.5 Mg ha^{-1} of manure from livestock) giving an increase of 10% of SOC in about 90 years. However, simulations seem conservative when compared to results obtained by Cardinael et al. (2017) that found carbon being accumulated in about 0.24 Mg C ha^{-1} y^{-1} (9.6 Mg C ha^{-1} for 40 years).

In the Atlantic scenario, during the 80-year simulation horizon, there was additional carbon added by coarse roots of the poplar when each 20-year tree rotation ended. These fluctuations in soil carbon increased the mean carbon content of the soil over the 80-year simulation time horizon. However, even when not considering the carbon peaks created by the coarse roots input, the results still showed a difference, after 80 years, of about 10 Mg ha^{-1} between the arable and agroforestry systems.

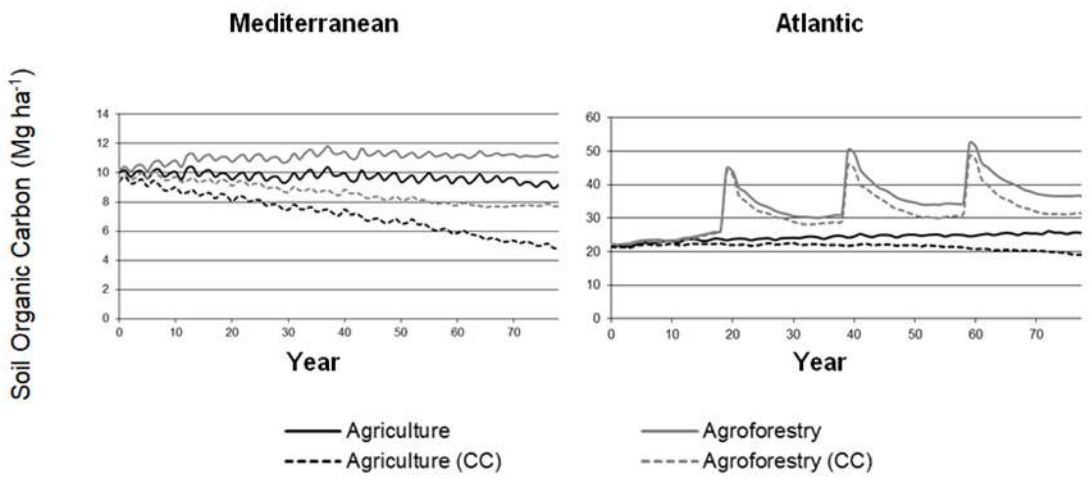


Figure 1: Comparison of simulated soil organic carbon between agroforestry and conventional agriculture in Mediterranean and Atlantic environments without and with climate change (CC). Both agroforestry systems are simulated with 78 trees ha^{-1}. Mediterranean system has a rotation of wheat-wheat-fallow and the agroforestry system has a perennial tree (*Quercus rotundifolia* L.). Atlantic system has a rotation of wheat-wheat-barley-oilseed and the agroforestry system has a deciduous tree (*Populus* sp) harvested each 20 years. Future climate is the Representative Concentration Pathway 8.5 simulated by the KNMI RACMO climate model (see Palma 2017 for details).

Under future climate change, the simulations suggested that, in Mediterranean areas, soil carbon storage was more resilient under agroforestry systems. The model suggested a reduction in carbon storage of about 2 Mg ha-1 and 5 Mg ha-1 in the agroforestry and arable systems, respectively (Figure 1A). The reduction of yields where rain fed yields are already low, was mainly due to increased water scarcity, a projected characteristic of future climate for Mediterranean areas, which will need adaptive management (Christensen et al. 2007; Palma et al. 2015). In the Atlantic environment, climate change, although having a negative impact, was not as dramatic as in the Mediterranean case (Figure 1). Furthermore, the agroforestry scenario still increased carbon in the soil showing, as in the Mediterranean case, that in terms of soil carbon storage, agroforestry land use was more resilient to climate change than arable land use.

Conclusions

The integration of a carbon dynamics module (RothC) into YieldSAFE has improved our ability to assess long-term soil carbon storage under different land uses, including agroforestry land uses, which could have an important role to play in mitigation of climate change impacts.

This assessment indicated that agroforestry is a more resilient land use system under future climate change, and will retain and input higher levels of carbon in the soil in comparison with conventional arable agriculture. The trends in our simulated results is consistent with existing data and theory but now, integration of RothC and YieldSAFE, can allow quantitative predictions to be made to assess how land use systems, including agroforestry systems, will impact carbon storage levels in the long-term.

Acknowledgements

We acknowledge support of the European Commission through the AGFORWARD FP7 research project (contract 613520). This work was also partially supported by the Portuguese Science Foundation (FCT) under Project SOLAR (PTDC/GEOMET/7078/2014) and CEF PEst (UID/AGR/00239/2013).

References

Cardinael R, Chevallier T, Cambou A, Béral C, Barthés BG, Dupraz C, Durand C, Kouakoua E, Chenu C (2017) Increased soil organic carbon stocks under agroforestry: A survey of six different sites in France. Agric Ecosyst Environ 236:243–255.

Christensen JH, Hewitson B, Busuioc A, Chen A, Gao X, Held I, Jones R, Kolli RK, Kwon WT, Laprise R, Magaña Rueda V, Mearns L, Menéndez CG, Räisänen J, Rinke A, Sarr A, Whetton P (2007) Regional Climate Projections. In: Solomon, S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 847–940.

den Herder M, Moreno G, Mosquera-Losada MR, Palma JHN, Sidiropoulou A, Santiago-Freijanes JJ, Crous-Durán J, Paulo JA, Tomé M, Pantera A, Papanastasis VP, Mantzanas K, Pachana P, Papadopoulo A, Plieninger T, Burgess PJ (2017) Current extent and stratification of agroforestry in the European Union. Agric Ecosyst Environ 241: 121–132.

Francaviglia R, Coleman K, Whitmore AP, Doro L, Urracci G, Rubino M, Ledda L(2012) Changes in soil organic carbon and climate change - Application of the RothC model in agro-silvo-pastoral Mediterranean systems. Agric Syst 112:48–54.

Hermle S, Anken T, Leifeld J, Weisskopf P (2008) The effect of the tillage system on soil organic carbon content under moist, cold-temperate conditions. Soil Tillage Res 98:94–105.

Montagnini F, Nair PKR (2004) Carbon sequestration: An underexploited environmental benefit of agroforestry systems. Agroforst Syst 61:281–295.

Oberholzer HR, Leifeld J, Mayer J (2014) Changes in soil carbon and crop yield over 60 years in the Zurich Organic Fertilization Experiment, following land-use change from grassland to cropland. J Plant Nutr Soil Sci 177:696–704.

Palma JHN, Paulo JA, Pacheco Faias S, Garcia Gonzalo J, Boges JG, Tomé M (2015) Adaptive management and debarking schedule optimization of Quercus suber L. stands under climate change: case study in Chamusca, Portugal. Reg Environ Chang 15: 1569-1580.

Palma JHN (2017) CliPick – Climate change web picker. A tool bridging daily climate needs in process based modelling in forestry and agriculture. For Syst 26. Tool available @ http://www.isa.ulisboa.pt/proj/clipick/ (accessed 27/04/2018).

Palma JHN, Crous-Duran J, Graves AR, Garcia de Jalon G, Upson M, Oliveira TS, Paulo JA, Ferreiro-Domínguez N, Moreno G, Burgess PJ (2017) Integrating belowground carbon dynamics into Yield-SAFE, a parameter sparse agroforestry model, Agrofor Syst. https://doi.org/10.1007/s10457-017-0123-4.

Schroeder P (1994) Carbon storage benefits of agroforestry systems. Agroforst Syst 27: 89–97.

Upson M (2014) The carbon storage benefits of agroforestry and farm woodlands. PhD Thesis. Cranfield University, UK.

van der Werf W, Keesman K, Burgess P, Graves A, Pilbeam D, Incoll LD, Metselaar K, Mayus M, Stappers R, van Keulen H, Palma J, Dupraz C (2007) Yield-SAFE: A parameter-sparse, process-based dynamic model for predicting resource capture, growth, and production in agroforestry systems. Ecol Eng 29: 419–433.

van Meijgaard E, Van Ulft LH, Lenderink G, de Roode SR, Wipfler L, Boers R, Timmermans RMA (2012) Refinement and application of a regional atmospheric model for climate scenario calculations of Western Europe. Climate changes Spatial Planning publication: KvR 054/12.

HOW IMPORTANT IS ADAPTING REGIONAL CLIMATIC PROJECTIONS TO THE LOCAL ENVIRONMENT? A PROCEDURE FOR MICROCLIMATIC CORRECTIONS MAKES THE DIFFERENCE FOR CROP GROWTH IN A VIRTUAL EXPERIMENT

Reyes F[1]*, Gosme M[1], Blanchet G[1], Dupraz C[1]

(1) INRA, System, University of Montpellier, Montpellier, France

*Corresponding author: reyes.francesco@protonmail.com

Abstract

Climatic conditions drive plant metabolism and growth and their projections are used as drivers in modelling experiments for the prediction of crop yields. However, these are generally issued at regional scale, and do not consider microclimatic variations. In this study we question the impact of taking into account microclimate adjustments on simulated crop yield. A procedure for the correction of temperature and humidity to the local microclimate is proposed and applied on climatic predictions for a site, resulting in modifications of about 2% in mean daily relative humidity and 2.5°C in mean daily maximum temperature. Crop yield is predicted with a process-based agroforestry model, for the pure crop and in the alley-cropping system, using both climatic series. Predicted crop yield differed by up to 58% in individual years and overall by 22% (CV RMSE) across climatic series. A significant trend in crop yield disappeared after corrections. This study highlights the importance of taking into account microclimatic corrections when using climatic projections to predict crop growth on realistic sites.

Keywords: microclimate; model; Hi-sAFe; temperature; climatic series; alleycropping

Introduction

Temperature is the primary driver of plant metabolic processes and phenology, and its variations lead the plant closer or further from its optimal growth conditions. As such, microclimatic variation might have important impact on crop yields, no matter if they are the result of spatial heterogeneity or temporal dynamics, such as in climate change. Climate change projections at regional scale are important tools to develop adaptation strategies in agriculture (e.g. development of new varieties). Conversely, knowledge of the microclimatic conditions at local scale is essential in parcel design (e.g. species selection), especially in areas with high morphological heterogeneity. Given the long lifetime of the trees, agroforestry parcel design might need to take into account both the temporal scale relevant in climate change projections and the microclimatic effects of a particular location on the plants. In this regard, we question the need to adapt regional scale climatic projections to the microclimatic conditions present in the specific site, for which a virtual experiment is performed. First, we present a procedure to adapt climatic series, provided at regional scale, to specific field sites. Then, the impact of this procedure is assessed by adjusting a climatic projection issued at regional scale to the microclimate of a given site. Both climatic series are used to drive crop development in monoculture and alley-cropping in a processed-based crop model. Crop growth results are compared and the impact of the different climatic series is discussed.

Materials and methods

Data extraction

We used the the Clipick website (Palma 2017) to extract three climatic projections issued by two Global Climate Models (HadCM3Q0 and RACMO22E-KNMI models, Assessment Reports 4 and 5 respectively, of the Intergovernmental Panel on Climate Change) and downscaled via Regional Climate Models. The climatic series were extracted for an experimental plot present in Restinclieres (Montpellier, Southern France, lat: 43.7, long: 3.5, 62m ASL). Two of them represented historical (*hist* scenario, years 1951 to 2005) and predicted (*RCP8.5* scenario, years 2006 to 2070) climatic conditions according to the RACMO22E-KNMI Global Climate Model (Assessment Report 5, IPPC). These were later adjusted to the local microclimate, and used in a virtual experiment to drive crop growth. The third series represented the whole period from 1951 to 2070, according to the HadCM3Q0 Global Climate Model, *A1B* scenario (Riahi et al. 2011; Palma 2017) (Assessment Report 4, IPPC) and was used to indirectly estimate two meteorological variables (minimum and maximum relative humidity) necessary to run simulations with our crop growth model (see *Simulations*), but missing in the *hist* and *RCP 8.5.* All series had a daily time resolution. Spatial resolution was of 11 km for *hist* and *RCP 8.5*, and of 25km for *A1B* (Palma 2017).

Data adjustments: temperature and relative humidity

The area surrounding the study site is characterized by a high morphological heterogeneity, suggesting that relevant temperature (T) and relative humidity (RH) differences could be present between the retrieved datasets at regional scale (*hist* and *RCP 8.5*) and measurements performed in the field (data available from year 1995 to 2014). Beside them, also other meteorological variables, such as the incoming radiation and precipitation, might be influenced by local microclimate but, we suppose, at a relatively larger spatial scale, and are not included in the presented procedure for meteorological corrections.

First step of the proposed method (Figure 1) is the correction of maximum (T_{max}) and minimum (T_{min}) daily temperatures, and is based on the periods of overlap between field measured and downloaded data series. For each period of overlap between measured and projected data:

i) the mean monthly differences (biases) between T_{min} and T_{max} of the two data series were calculated;

ii) the calculated biases were used to adjust T_{min} and T_{max} of the projected daily temperatures by subtraction.

Corrections in RH were then necessary in order to: i) take into account temperature adjustment and ii) provide maximum and minimum RH (RH_{min} and RH_{max}), available in *A1B*, but not in *RCP 8.5* (in *RCP 8.5* only the mean RH is provided). Therefore, mean daily RH was computed in *A1B* as the mean of max and min RH. Two multiple linear models were then built to predict RH_{min} and RH_{max} from mean RH, T_{max}, T_{min}, precipitation and global shortwave radiation on *A1B*. The same models were then used to predict RH_{min} and RH_{max} for the *RCP 8.5* temperature adjusted data series.

Completion of climatic series: CO_2 and water table depth

In order to be able to run simulations with the Hi-sAFe model, carbon dioxide concentration and the depth of the water table needed to be added to dataset. Carbon dioxide concentration were added by linear interpolation between historical and predicted values in years 1950 and 2100 (Meinshausen et al. 2011), without taking into account seasonal variations. An empirical model calibrated on the same parcel (Talbot 2011) was then used to predict the fluctuation in the depth of the water table from the climatic data.

Simulations

In order to estimate the impact of the climatic adjustments on simulated crop yields for an alley-cropping (AF) and a monoculture (A) parcel, we simulated crop growth under both the *base* and the *adjusted* climatic series, for the historical period between years 1951-1990. Simulations were run with the Hi-sAFe model, a process based, purely deterministic, spatially explicit agroforestry model. This represents the three dimensional development of an alley-cropping system including tree and/or crop species, their synchronous use light, water and nitrogen resources (Talbot 2011).

Parcel description

The simulated AF parcel included a 9 m deep, mixed clay-limestone soil, with a high maximum water holding capacity (about 3400 mm) and a water table fluctuating between 6.8 and 1.3 m below ground surface (mean -4.88 +- 1.05 m). Hybrid walnut (*Juglans nigra*) trees were spaced 9 meters along the tree row and 13 meters between tree rows in alley-cropping parcels, while durum-allur-wheat was sown (at DOY 300) in the alley. The A parcel was described and managed identically, but did not contain trees.

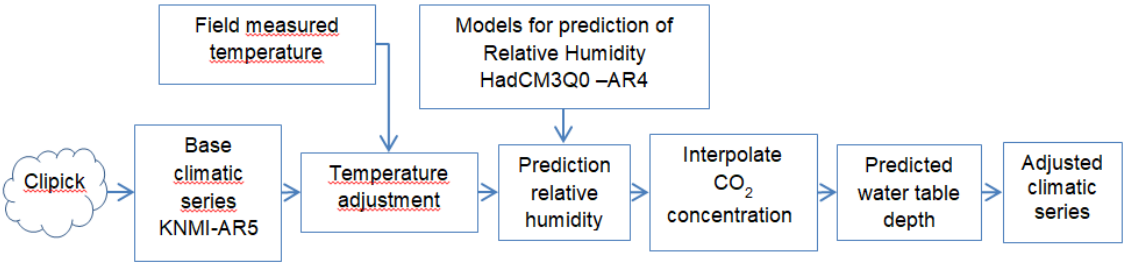


Figure 1: Adjustment and completion of climatic series.

Results and discussion

Climate change impact on temperature was of about 4 and 3 °C for mean daily T_{min} and T_{max} across the projected period (Figure 2). Differences between the base and the adjusted mean daily temperatures were negligible for T_{min} (0.1°C) and of about 2.5 °C for T_{max}. The linear models used to estimate min and max mean daily RH were quite robust (R^2_{RHmin} = 0.90, R^2_{RHmax} = 0.85). The predicted mean daily RH_{min} remained approximately stable across time, while RH_{max} decreased by 2.5%. Differences between the base and adjusted RH, were of about 2.5% for RH_{min} and of about 2% in RH_{max}.

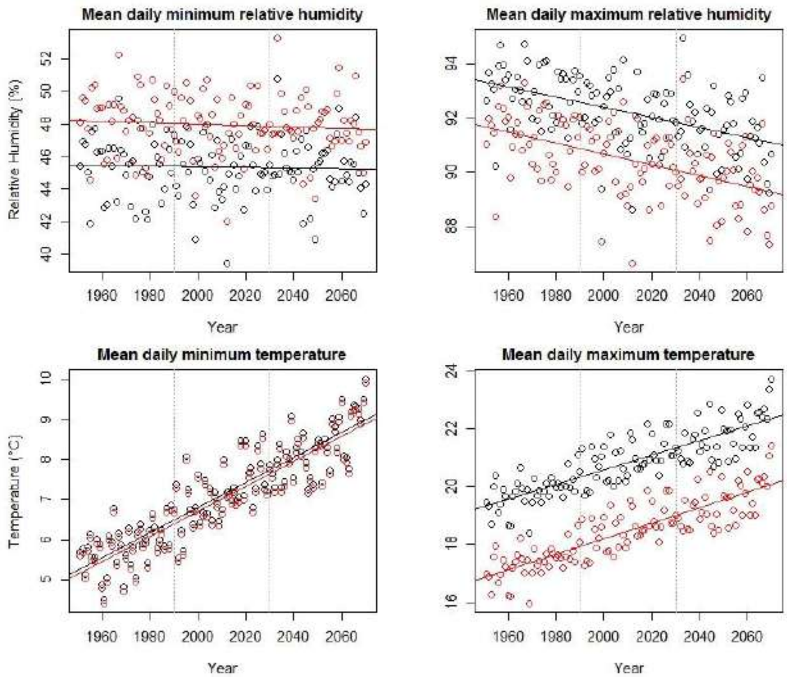


Figure 2: Base (red) and adjusted (black) climatic series with linear models of their trend lines. Vertical lines split the climatic series in three periods of 40 years each. Crop growth simulation was run during the first period.

Mean crop yield was, as reported in other agroforestry studies on wheat, lower in AF than in A (13%) (Dufour et al. 2013). Mean yield obtained in the adjusted series was higher (12%) than in the base series (Table 1). Crop yield variability in AF was also lower than in A, especially during the second half of each simulation, supposedly as a result of the milder microclimate established under mature trees (Table 1).

The relative difference in crop yields among climatic series (expressed by the coefficient of variation of the root mean squared error, CV RMSE) was about the same in A and AF (22%, Table 1). This suggests that the impact of the climatic corrections on crop yield was similar for both agricultural systems, when considering entire simulations. Also the maximum difference in mean crop yield was similar across parcel types (55% in A, 58% in AF).

Crop yield was generally lower or equal in the base series in respect to the adjusted one, especially during the first twenty years of growth (Figure 3). Yield significantly increased in A across the base series, following the increase in mean daily T_{max}, while not in the adjusted one, which was characterized by higher mean maximum daily temperatures.

These considerations suggest that the crop might have performed better over time under the base series thanks to the temperature entering more often the range of optimal crop growth conditions. Once in this range of temperatures, further increase, corresponding to the second half of the simulation with the base series (effect of global warming) and to the simulations with the adjusted series (effect of microclimatic correction), would not contribute any further in increasing crop yields. This hypothesis is also supported by the more constant crop yield variability obtained in A with the adjusted in respect to the base series, suggesting that the additional increases in temperature occurring in this simulation do not anymore systematically affect crop yield (Table 1). As such, using the climatic series after microclimatic corrections had a considerable impact both on the magnitude of the resulting crop yield and on the direction of the simulated trends in crop yield (the significant positive relationship between yields and time in A disappears after correction (Figure 3).

Table 1: Mean crop yield and crop yield variability (SD: standard deviation) across agricultural systems (A: pure culture, AF: alley-cropping) and data series.

Mean crop yield	A	AF
Base series (t/ha)	4.46	3.87
Adjusted series (t/ha)	4.82	4.21
CV(RMSE) (base-adjusted) (%)	22	21
Max difference (base-adjusted) (t/ha)	2.55	2.33

Crop yield variability	A		AF	
Period	Years janv-20	Years 21-40	Years janv-20	Years 21-40
SD Base (t/ha)	1.56	1.08	1.41	0.44
SD Adjusted (t/ha)	0.98	0.99	0.89	0.4

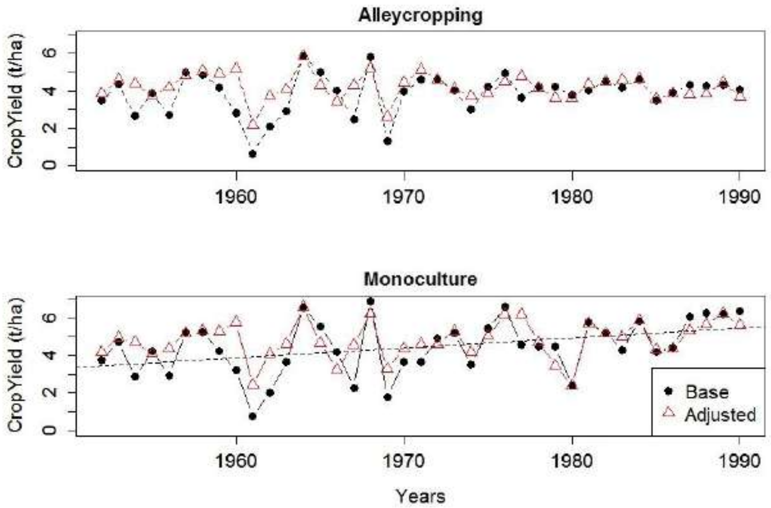


Figure 3: Simulated crop yield in alley-cropping and pure culture, with base and adjusted climatic series. A significative ($p < 0.01$) linear model between crop yield and time is showed by a trend line for the base simulation in pure culture.

Our case study showed that even modest differences between a climatic projection and field data (3°C in mean daily T_{max}, 2 to 2.5% in min and max mean daily RH) can result in relevant changes in simulated yields and their interannual variability, highlighting the importance of taking into account microclimatic differences when using climatic projections for virtual experiments. We proposed an automatized and fast procedure to adjust climatic projections from the regional to the parcel scale, accounting for microclimatic variations in temperature and relative humidity, that can be relevant to better adapt crop gwoth simulations to specific sites. When used in combination with a tool such as Clipick, this becomes applicable for any site reasonably close to a meteorological station.

References

Dufour L, Metay A, Talbot G, Dupraz C (2013) Assessing Light Competition for Cereal Production in Temperate Agroforestry Systems using Experimentation and Crop Modelling. J Agron Crop Sci 199: 217–227.

Meinshausen M, Smith SJ, Calvin K, Daniel JS, Kainuma MLT, Lamarque JF, Matsumoto K, Montzka SA, Raper SCB, Riahi K, ThomsonA, Velders GJM, van Vuuren DPP (2011) The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. Climatic Change 109: 213–241.

Palma JHN (2017) CliPick – Climate change web picker. A tool bridging daily climate needs in process based modelling in forestry and agriculture. Forest Syst 26: eRC01.

Riahi K, Rao S, Krey V, Cho C, Chirkov V, Fischer G, Kindermann G, Nakicenovic N, Rafaj P (2011) RCP 8.5—A scenario of comparatively high greenhouse gas emissions. Climatic Change 109: 33–57.

Talbot G (2011) L'intégration spatiale et temporelle du partage des ressources dans un système agroforestier noyers-céréales: une clef pour en comprendre la productivité?

THE EFFECT OF A YOUNG ALLEY CROPPING SYSTEM ON SOIL MICROCLIMATE

Vityi A[1*], Kiss-Szigeti N[1], Marosvölgyi B[1]

(1) University of Sopron Co-operational Research Centre Non-profit Ltd, Hungary

*Corresponding author: vityi.andrea@uni-sopron.hu

Abstract

The aim of the present research is to investigate the effect of such a young alley cropping system (planted for experimental purposes) on the soil microclimate, compared with a control site. The trial system, involving the agroforestry plantation and a control site has been implemented in 2013 in an intensive monoculture agricultural environment. Measurement of soil microclimatic parameters started in 2014. Based on the results of the examination carried out in an agroforestry and a monoculture production site, there is a clear difference between soil moisture and soil temperature of the two cultivation systems. This effect can be observed even from the second year of the fast growing tree (Paulownia) plantation.

Keywords: agroforestry; alley cropping; microclimate; soil parameters

Introduction

The more and more frequent occurrences of weather extremes such as drought and water floods, have a negative effect on natural vegetation and the qualitative and quantitative parameters of agricultural production as well as its ecological sustainability. One promising aspect of adapting to climate change is agroforestry, which integrates woody vegetation into agricultural cultivation, exploiting its various economic, social and ecological benefits. The importance of this land using system connecting to many disciplines is highlighted by more Hungarian and European literature (Vityi-Marosvölgyi 2014; Bitter 2014; Moreno et al. 2016; Westaway et al. 2016). In addition to traditional agroforestry systems with a history of thousands of years throughout Europe, new, innovative methods such as alley cropping are spreading too.

The aim of the present research is to investigate the effect of such a young alley cropping system (planted for experimental purposes) on the soil microclimate, compared with a control site.

The research was funded by the EU FP7 framework program AGRORWARD (AGroFORestry that Will Advance Rural Development), and implemented by the co-operation of the Co-operational Research Centre of University of Sopron and an agricultural cooperative in the Great Hungarian Plane.

Materials and methods

The trial system, involving the agroforestry plantation and a control site has been implemented in 2013 in an intensive monoculture agricultural environment. The soil tests show, that both the agroforestry and monoculture sites stand on the same soil parameters (alkaline clay / clayey loam type slightly solonchak soil). On the half of the total area of approximately 2 ha, 126 pieces of Paulownia tomentosa var. Continental E. tree saplings have been planted in 14 m distance between row and 5 m distance of trees, with alfalfa intercropping (agroforestry site). On the other site, with the same size and conditions, monoculture alfalfa cultivation was carried out without tree plantation (control area).

Measurement of soil microclimatic parameters started in 2014. On the experimental area, an agrometeorological station records the air temperature, precipitation, relative humidity, wind direction and strength. Tensiometers and soil thermometers installed on three substations measure the water potential and temperature of the soil at four different depths: 0-10 cm, 10-20 cm, 20-40 cm and 40-60 cm. The sensors have been installed so that the intercrop, the tree rows, and also control areas are monitored (Figure 1). Data has been collected automatically for four years, in two hours interval. The daily averages, calculated from the data series in the growing seasons (1. April to 30. September) of the four years has been analysed. The annual changes in soil moisture and temperature values are shown in box diagrams, which also indicate the deviation of data. In the arid periods, of which the agricultural cultivation is particularly sensitive, the typical processes are well illustrated by the curves of daily averages compared to the air temperature, rain amount and wind speed. Statements based on the diagrams has been controlled and supported by statistical t-tests.

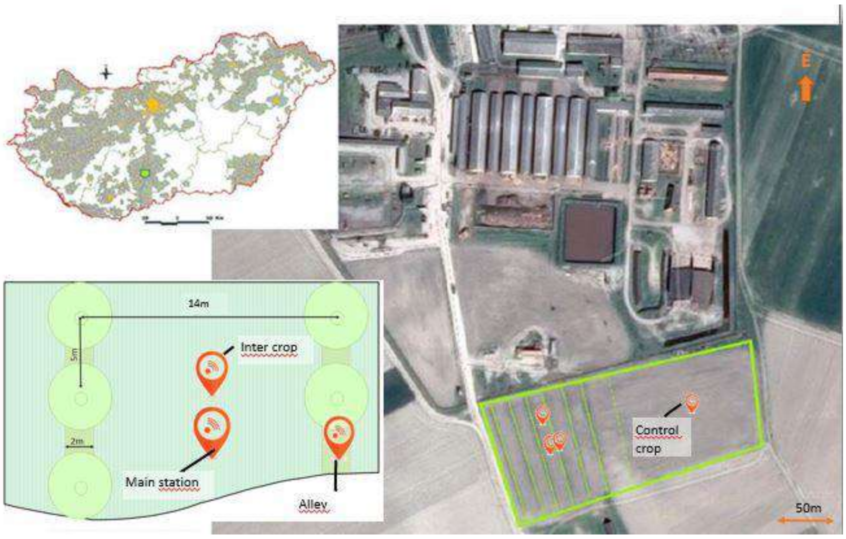


Figure 1: Installation of the sensors to monitor the intercrop, the tree rows and the control areas.

Results

In the upper layer of soil -up to 20 cm depth-, the control site proved to be significantly drier than the agroforestry site. Analysing the soil moisture values, a more frequent and higher soil dryness could be observed in monoculture production, while the majority of the data collected in the agroforestry system was located in a more favourable range, the total dehydration appeared only occasionally. In the deeper soil layers (> 20 cm) this tendency is not so clear; in the last examined growing season the soil moisture of the control area was more favourable (Fig 2). In this depth, soil moisture could be affected by the (partial) aquitard layer in 30 cm depth, the deep roots of trees and alfalfa, and the availability of ground water. According to the data, the presence of trees in the arable cultivation has a favourable effect on the water content of upper soil layers already in the first years, by reducing the drying effect of wind and direct sunlight.
During arid periods, dehydration occurred later in agroforestry site and took shorter periods in the upper soil layers than in the control plot. In the deeper soil layers (below 20 cm) the difference in soil moisture values of the agroforestry and control plots was smaller during the same drought period (Figure 2).

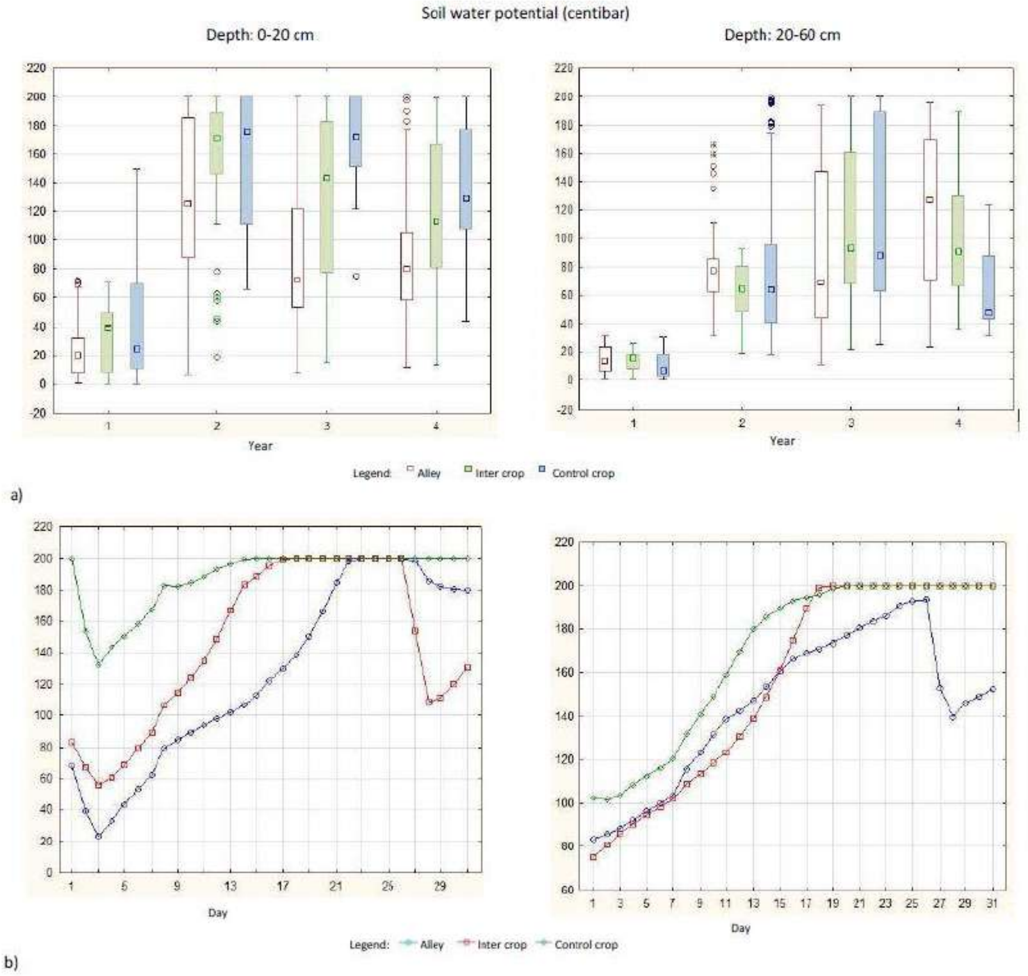


Figure 2: (a) The water potency of the soil moisture measured by tensiometer (water shortage) expressed in centibar in the upper and deeper soil layers in the four growing seasons and (b) during a drought period 21.08.2016 – 23.09.2016 (The soil moisture values measured with the tensiometer indicate the absorption capacity of the soil, so higher values mean drier soil conditions).

By examining the soil temperature data, we can state that the deviation in the control site was higher than in the agroforestry system in all four examined soil layers, but most at the upper measuring points. The annual average of the values and the majority of the data collected in the agroforestry site were in a more favourable range for productivity than in the monoculture.

In the drought periods, while the temperature of the upper (up to 20 cm depth) soil layer of the sites followed the changes of air temperature, the soil in the agroforestry system had a milder degree of warming on the one hand, and was considerably more temperate on the other hand. Although in a smaller extent, but this phenomenon can be observed even in layers up to 60 cm depth (Figure 3).

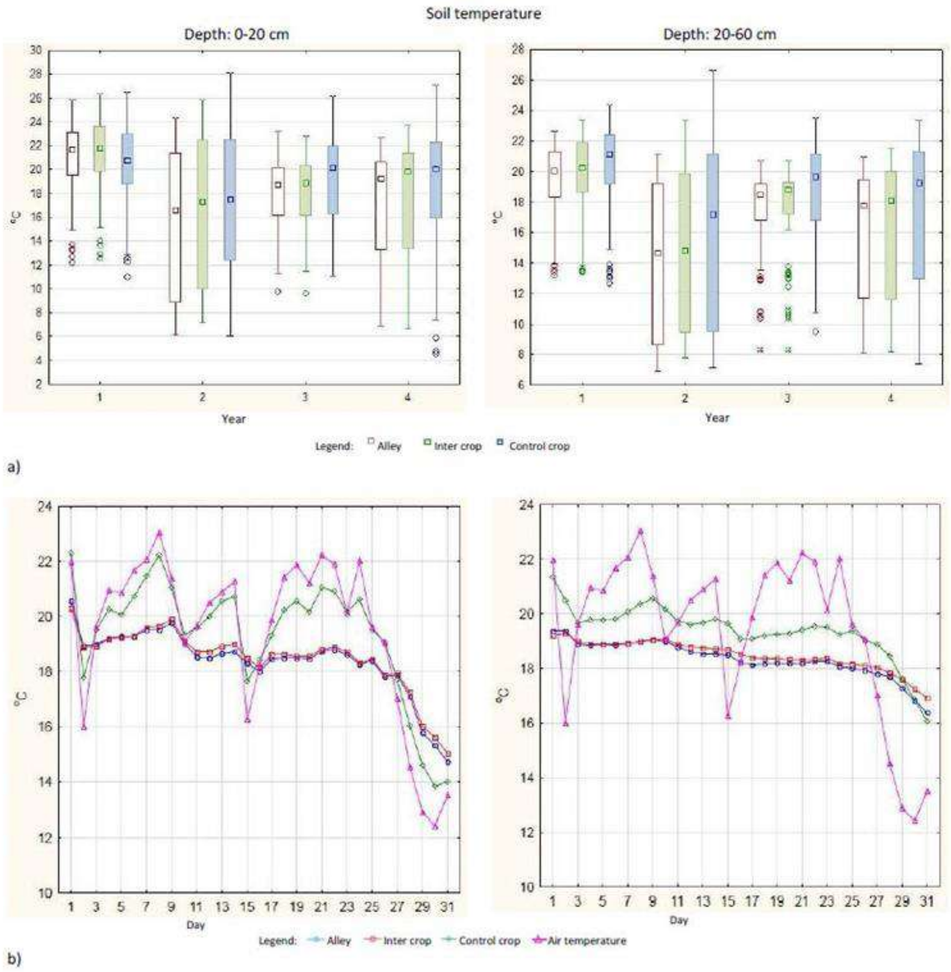


Figure 3: (a) soil temperature values in the upper and deeper soil layers during the four examined growing periods and (b) in a drought period 21.08.2016 – 23.09.2016.

Conclusion

Based on the results of the examination carried out in an agroforestry and a monoculture production site, there is a clear difference between soil moisture and soil temperature of the two cultivation systems. This effect can be observed even from the second year of the fast growing tree (Paulownia) plantation.

Woody vegetation helped to preserve soil moisture in the upper 20-30 cm layer, but caused a decrease in layers below 30 cm (under aquitard layer). The presence of trees is beneficial for the soil temperature; the soil microclimate is more balanced in the agroforestry system than in monoculture due to the decrease of the mean values in the upper layers, the smaller deviance of data and the less frequent prevalence of extreme values of temperature.

Overall, based on the results of the experiment, the alley cropping system can be particularly favourable for shallow-rooted intercrops, by controlling the water and heat balance of the soil and by moderating harmful extremities such as drought, extreme cold or heat.

Acknowledgement

We acknowledge the support of the European Commission through the AGFORWARD FP7 research project (contract 613520).

References

Moreno G, Berg S, Burgess PJ, Camilli F, Crous-Duran J, Franca A, Hao H, Hartel T, Lind T, Mirck J, Palma J, Pantera A, Paulo JA, Pisanelli A, Rolo V, Seddaiu G, Thenail C, Tsonkova P, Upson M, Valinger E, Varga A, Viaud V, Vityi A. (2016) Agroforestry systems of high natural and cultural value in Europe: constraints, challenges and proposal for the future. 3rd European Agroforestry Conference Montpellier, France.

Vityi A, Marosvölgyi B. (2014) Agroerdészet egykor és ma. Agroforum 25. Évf. 10. Sz, pp. 80-81.

Westaway S, Crossland EM, Chambers EM, Gerrard C, Smith J (2016): Does harvesting hedges for woodfuel conflict with their delivery of other ecosystem services? 3rd European Agroforestry Conference Montpellier, France.

HEDGEROW AGROFORESTRY IN ENGLAND AND WALES: INCREASING WIDTH TO SEQUESTER ADDITIONAL CARBON

Axe MS[1*], Grange ID[1], Conway JS[1]

(1) Royal Agricultural University, Cirencester, UK

*Corresponding author: matthew.axe@pobroadband.co.uk

Abstract

Developing temperate agroforestry practices can potentially sequester carbon (C), mitigating for rising levels of Green-House Gasses. Hedgerows are a prominent agroforestry system in England and Wales, an estimated 456 000 km of these being actively managed, chiefly using a mechanical flail. Here the relationships between increasing hedge height, width, basal area, and the C stock of hedges on a lowland farm are examined. Compared to increasing the hedge height, widening hedges was more efficacious at sequestering C into Above Ground Biomass (AGB). At the same stage of growth, a 1.6 m wider hedge had 7.5 t C km^{-1} more AGB C, but only gained a further 4.2 t C km^{-1} when 1.6 m taller. Hedges in England and Wales are generally narrow, (77% < 2 m wide), giving extensive capacity to sequester C through widening hedges. This can be aided by a propensity for blackthorn to colonise outwards from hedges.

Keywords carbon sequestration; hedgerow carbon stocks; hedge management; hawthorn; blackthorn; flail

Introduction

Hedgerow systems are one of the more prominent agroforestry systems in temperate European agriculture, and the UK has the second largest extent of these in the European Union (Herzog 2000; den Herder et al. 2016). An estimated 456 000 km of hedge in England and Wales has been actively managed (Carey et al. 2008); which limits hedge outward growth, and maintains an effective barrier to livestock (Pollard et al. 1974). This management consists of a short period trimming cycle every 1 - 3 years, and a long period structural restoration cycle, after approximately 40 years growth (Staley et al. 2015). A mechanical flail is used for the short period trimming cycle by 92% of farmers in England and Wales (Britt et al. 2011). Typical 'Enclosure' hedges in England and Wales were planted with only hawthorn (*Crataegus monogyna*), in single, or double rows, from the 16th Century onwards (Maclean 2006). Hawthorn is still the dominant woody species, found within 90% of hedges in England and Wales, but a mix of woody species is common, and blackthorn (*Prunus spinosa*) is the second most frequent species, found within 50% of these hedges (Barr et al. 2000).

The potential for temperate agroforestry to sequester carbon (C), and mitigate rising levels of Green-House Gasses (GHG), is beginning to receive more attention (Udawatta and Jose 2012). Axe et al. (2017) showed the potential to sequester C where wider managed hedges had greater C stocks (t C km^{-1}). Allowing such hedges to grow wider from lateral branch growth only, without increasing planting density, may not be the most effective way to accumulate Above Ground Biomass (AGB) C. It also introduces uncertainty in using area C stock values (t C ha^{-1}) to estimate AGB C (t C), as this parameter assumes a linear relationship with hedge width.

Here new data on the contribution made by blackthorn to AGB C stock, and the correlation between hedge width and t C km^{-1}, from the pilot study of triennially flailed hedge biomass (Axe et al. 2017), along with supporting evidence on shrub growth in unmanaged hedges (Küppers 1985), is examined to advance how atmospheric C could be sequestered by increasing hedge width.

Materials and methods

The study hedges were located at Harnhill Manor Farm, Harnhill, Gloucestershire, (51°41′N, 1°54′W) owned by the Royal Agricultural University. In November 2013, three replicates each from three sample hedges were selected for biomass C stock quantification by stratified random sampling. Hedges 1 and 3 were comprised of hawthorn and Hedge 2 was a hawthorn/blackthorn mix. Hedges had been present from at least 1884 (Ordnance Survey 1884). Hedge 1 grew in a pelocalcaric gley soil; and Hedges 2 and 3 grew in a lithomorphic brown rendzina (Table 1). Each AGB replicate was a 1 m length of hedge. The height from ground level for each replicate was recorded of, a) height of the lowest previously trimming; identified by severed stems with new regrowth, and b) most common existing stem height (the mode). These two heights were differentiated as growth stages 1 and 2. Widths of each hedge section at 1.3 m high were recorded along with stem basal area (BA) at 10 cm above ground. The replicate biomass samples were isolated from the hedge with two vertical cuts through branches, and by horizontal cuts through all stems at ≤ 10 cm above ground level. Only the sections of branches and stems found within the replicate boundary were included in the sample. Surface woody litter was collected by hand. Component parts of each replicate were separated, weighed fresh, and sub-sampled to determine dry matter and C content. (See Axe et al. 2017 for further details of methodology).

Statistical analysis was carried out with Genstat 15th Edition. Data normality was determined by an Anderson-Darling test (normality accepted at $p > 0.1$ where $n < 30$) and homoscedasticity by Bartlett’s test. Effects of species/soil type/age since hedge laid, were combined in the single treatment factor Hedge number, and tested against the parameters hedge width, height, and AGB C stock using ANOVA. Multivariate analysis was by Tukey’s test. Where data was parametric, associations were analysed with Pearson’s correlation coefficient, otherwise Spearman’s rank correlation coefficient was used. Linear regressions were not reported due to data heteroscedasticity.

Table 1: Descriptive data for sampled hedges.

Hedge No.	**1**	**2**	**3**
Species	Hawthorn	Hawthorn/ Blackthorn	Hawthorn
Soil description	Pelocalcaric gley soil	Lithomorphic brown rendzina	Lithomorphic brown rendzina
Aspect	NW:SE	NW:SE	NW:SE
Management method: Long cycle	Hedge laying (2001)	Hedge laying (1995)	Hedge laying (1999)
Short cycle	Triennial flailing (since 2007)	Triennial flailing (since 2007)	Triennial flailing (since 2007)
Width (m)	$2.6^{a} \pm 0.13$	$4.2^{b} \pm 0.13$	$2.9^{a} \pm 0.07$
BA (cm^2)	73.5 ± 14.26	143.3 ± 32.85	115.4 ± 25.90
Stems (mean integer)	18	39	25
Height at growth stage 1 (trimmed) (m)	1.9 ± 0.06	2.0 ± 0.03	1.9 ± 0.03
Height at growth stage 2 (untrimmed) (m)	3.4 ± 0.03	3.5 ± 0.15	3.5 ± 0.13
Area C stock at growth stage 1 (trimmed) (t C ha^{-1})	27.9 ± 3.95	35.8 ± 3.95	32.9 ± 6.66
Area C stock at growth stage 2 (untrimmed) (t C ha^{-1})	35.8 ± 4.06	45.7 ± 6.60	44.5 ± 9.06
Linear C stock at growth stage 1 (trimmed) (t C km^{-1})	7.5 ± 1.46	15.0 ± 2.03	9.7 ± 2.13
Linear C stock at growth stage 2 (untrimmed) (t C km^{-1})	9.5 ± 1.59	19.2 ± 3.25	13.2 ± 2.89

Superscript letters denote significant difference at $p < 0.05$ (Tukey's test)

Results

Hedge 2 was 1.6 m and 1.3 m wider than Hedges 1 and 3 respectively, ($F = 49.53$, $p < 0.001$; Table 1). While hedge heights were comparable between the hedges at each growth stage, there was a 1.6 m difference between growth stages 2 and 1, with the mean hedge area AGB C stock data falling from 42.0 ± 3.78 t C ha^{-1} to 32.2 ± 2.76 t C ha^{-1} when hedges were trimmed back to 1.9 m tall. Since there were no significant differences in area AGB C stock (t C ha^{-1}) between the hedges, at the same growth stage, no effects from differences in species mix, soil type, or age since hedge laid, were detected. A significant correlation existed between C stock and hedge replicate height at growth stage 2 ($\rho_{adj} = 0.496$, $p < 0.05$), and with both stages combined ($\rho_{adj} = 0.399$, $p < 0.05$).

The linear AGB C stocks (t C km^{-1}) for the hedges at both growth stages were analysed to examine the width effect on C stocks. These data varied between growth stage 1 with a mean of 10.7 ± 1.47 t C km^{-1} (median 10.5 t C km^{-1}; $n = 9$) and growth stage 2, with a mean of 14.0 ± 1.94 t C km^{-1} (median 13.1 t C km^{-1}; $n = 9$). There were significant correlations between these data and hedge section width, BA at 10 cm, and stem frequency (Table 2).

Table 2: Correlation matrix for sampled hedges at two growth stages.

Growth stage 1	**Linear AGB C Stock (t C km^{-1})**	**Width (m)**	**BA at 10 cm height (cm^2)**
Width (m)	0.8684, p<0.01		
BA at 10 cm height (cm^2)	0.9038, p<0.001	0.7108, p<0.05	
Stem Frequency at 10 cm height (*n*)	0.3180, p< 0.05	0.8287, p<0.01	0.4709, *n.s.*
Growth stage 2			
Width (m)	0.8334, p<0.01		
BA at 10 cm height (cm^2)	0.9497, p<0.001	0.7108, p<0.05	
Stem Frequency at 10 cm height (*n*)	0.6453, *n.s.*	0.8287, p<0.01	0.4709, *n.s.*

The replicates from the widest hedge, Hedge 2, comprised of a core with one blackthorn shrub, and many hawthorn shrubs, and also an outer layer of blackthorn stems from root suckers along both sides of the hedge. The C stock quantities from the blackthorn sucker growth, at growth stages 1 and 2, were 1.5 ± 0.62 t C km^{-1}, and 2.6 ± 1.21 t C km^{-1}, respectively (Figure 1).

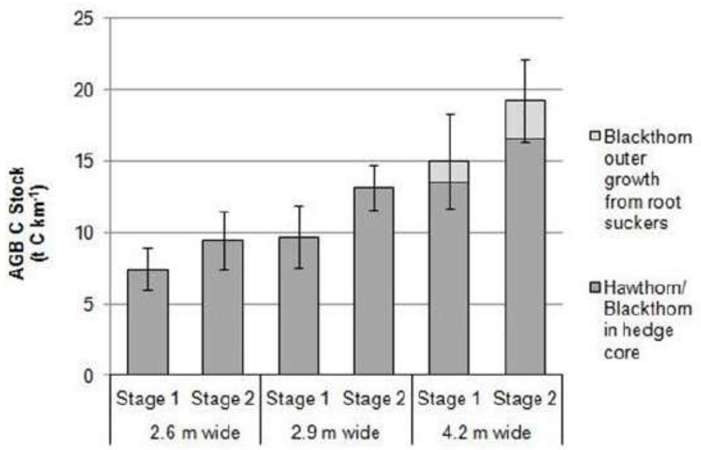


Figure 1: Linear AGB C stock for sampled hedges at three widths and two stages of growth.

Discussion

The mechanism that AGB C increases with taller hedges was supported by the results, with a positive addition to each hedge replicate AGB C stock as height increased. The height of the hedge replicates, and the AGB C stocks (t C ha^{-1}), were significantly correlated when both growth stages were included in the dataset. A height increase of 1.6 m (growth stage 1 to 2), over 6 years, including an intermediate episode of trimming, yielded an average increase of 3.3 t C km^{-1} across all hedges. Increasing height of managed hedges on a national scale could thus be a useful means to sequester C, however such hedges would still be regularly flailed, and as with the examples here, some of this reported AGB C gain would be lost when the hedges are next trimmed.

Estimating individual hedge C quantities from area C stocks (t C ha^{-1}) assumes a linear scaling with the hedge width, but utilising the linear C stocks (t C km^{-1}) removed this assumption and gave a better representation of C quantity for an individual hedge. The positive correlation between these linear C stocks and width supported the principle that C quantities increase with hedge width, but a stronger correlation was found with the BA. Thus the mechanism that increased hedge C was more dependent on increasing numbers and/or diameter of vertical stems, rather than hedge width; which would increase from lateral branch elongation alone. The make up of Hedge 2 showed it was wider than the other hedges in part due to the presence of blackthorn from sucker growth, along the outer edge of both sides of the hedge. This species is clonal, spreading mainly by root suckers, and is intolerant of shade. Küppers (1985) also observed blackthorn growing along the outer hedge canopy in mature untrimmed spontaneous hedgerows; concluding that, in response to competition for light, it used root suckering to migrate into open space, rather than the woody community. This was in contrast with *Crataegus spp.,* which responded to competition for light with epitonic shoots and vertical growth into the hedge canopy, not lateral migration (Küppers 1985). The increase in width in the example of Hedge 2, sampled 18 years after restorative management, of a managed hedge with a hawthorn core, and developing blackthorn outgrowths, represented a viable plant association from natural succession. Wider managed hedges could be realised by deliberately planting additional rows of shrubs, but the blackthorn regeneration observed here increased basal area, hedge width, and AGB C, at a minimal cost.

Allowing managed hedges to grow wider is very likely a more efficient practice to sequester C in AGB, compared to allowing them to grow taller. At growth stage 1, Hedge 2, was 1.6 m wider than Hedge 1, and had 7.5 t C km^{-1} more AGB C, but when Hedge 2 grew 1.6 m taller (growth stage 2), it only gained a further 4.2 t C km^{-1} AGB C. Hedges in England and Wales are generally narrow, (77% < 2 m wide; Barr et al. 2000) so there is potential capacity in the landscape to increase AGB C stocks through this practice.

Conclusion

Compared to increasing the hedge height, widening hedges was more efficacious at sequestering C into hedge AGB. This can be achieved using a propensity for blackthorn to naturally colonise outwards from hedges. Hedges are narrow in England and Wales, giving an extensive capacity to sequester C through this mechanism.

References

Axe MS, Grange ID, Conway JS (2017) Carbon storage in hedge biomass—A case study of actively managed hedges in England. Agric Ecosyst Environ 250: 81-88.

Barr CJ, Stuart RC, Smart SM, Firbank LG (2000) Results from MAFF-funded work in the CS2000 programme (woody species in hedgerows). Centre for Ecology & Hydrology.

Britt C, Sparks TH, Roberts A, Kirkham F (2011) Hedgerow management in England and Wales: Current practice and factors influencing farmers' decisions. Asp Appl Biol 108:1-12.

Carey PD, Wallis S, Chamberlain PM, Cooper A, Emmett BA, Maskell LC, McCann T, Murphy J, Norton LR, Reynolds B, Scott WA, Simpson IC, Smart SM, Ullyett JM (2008) Countryside Survey: UK Results from 2007. (CEH Project Number: C03259) NERC/Centre for Ecology & Hydrology.

den Herder M, Moreno G, Mosquera-Losada MR, Palma JHN, Sidiropoulou A, Santiago Freijanes JJ, Crous-Duran J, Paulo J, Tomé M, Pantera A, Papanastasis V, Mantzanas K, Pachana P, Papadopoulos A, Plieninger T, Burgess PJ (2016) Current extent and trends of agroforestry in the EU27. Deliverable Report 1.2 for EU FP7 Research Project: AGFORWARD 613520. https://www.agforward.eu/index.php/es/current-extent-and-trends-of-agroforestry-in-the-eu27.html (accessed 23/04/2018).

Herzog F (2000) The importance of perennial trees for the balance of northern European agricultural landscapes. Unasylva 200: 42-48.

Küppers M (1985) Carbon relations and competition between woody species in a Central European hedgerow – IV Growth form and partitioning. Oecologia 66: 343-352.

Maclean M (2006) Hedges and hedgelaying: a guide to planting, management and conservation. Crowood Press, Ramsbury.

Ordnance Survey (1884) Part of Driffield. 1:2500 first ed. OS 51/16 L116. Gloucester Records Office.

Pollard E, Hooper MD, Moore NW (1974) Hedges. New Naturalist Series 58. Collins, London.

Staley JT, Amy S, Adams NP, Chapman RE, Peyton JM, Pywell R (2015) Re-structuring hedges: Rejuvenation management can improve the longterm quality of hedgerow habitats for wildlife in the UK. Biol Conserv 186:187–196.

Udawatta RP, Jose S (2012) Agroforestry strategies to sequester carbon in temperate North America. Agrofor Syst 86: 225-242.

TEMPORAL COMPARISON OF GREENHOUSE GAS EMISSIONS BETWEEN FOUR DIFFERENT RIPARIAN LAND-USE TYPES IN SOUTHERN ONTARIO, CANADA

Baskerville M[1*], De Carlo N[1], Oelbermann M[1]

(1) Environment, University of Waterloo, Waterloo, Canada

*Corresponding author: mabaskerville@uwaterloo.ca

Abstract

Soils are one of the largest contributors of greenhouse gas (GHG) emissions, particularly CO_2, but the emissions from riparian buffer soils are largely un-accounted for. It is important to quantify and compare land-use types in order to find the best way to potentially mitigate or offset GHG emissions, while protecting stream quality. The goals of the study are to determine and compare GHG (CO_2, CH_4, N_2O) emissions between a grassed buffer, an undisturbed natural forest, a 32-year old rehabilitated forested riparian buffer, and an agricultural field (corn-soybean rotation) found along Washington Creek, Oxford County, Ontario. Highest seasonal CO_2 emissions were observed from the grassed buffer and highest seasonal N_2O emissions were found at the AGR site. Neither of these were found to be statistically significant. However, the UNF site had significantly higher seasonal CH_4 emissions than all other land-use types. Further comparisons of soil characteristics were conducted to determine influences on emissions between land-use types.

Keywords: greenhouse gas; riparian buffer; soil; carbon dioxide; nitrous oxide, methane; land-use type

Introduction

When managed as an agroforestry land-use system, riparian buffers (RBs) are defined as a tree-based vegetative strip between agricultural fields and water courses that intercept indirect sources of pollution from upland agricultural runoff (Tufekcioglu et al. 1999). The role of RBs is to provide various environmental services, such as reducing streambank erosion and sedimentation, creating wildlife habitat, enhancing carbon sequestration, enhancing streamside microclimate, and filtering contaminants and pollutants from surface agricultural runoff (Gregory et al. 1991; Montagnini and Nair 2004; Verhoeven et al. 2006). These services result in increased water quality and habitat. However, there are potential environmental disservices as a result of RBs being efficient at filtering nitrogen (N) runoff and the high carbon (C) availability, working together to make RBs potential hot spots for soil greenhouse gas (GHG) emissions (Shrestha et al. 2009). Despite this concern of RBs as a GHG source, there is a lack of studies that directly compare different types of RBs (ex. forested vs. grassed). This information is crucial as it will provide insight into which RB is the most effective in mitigating GHG emissions, as this has future implications for contributions to climate change. Therefore, the goal of this study is to quantify and compare GHG emissions from four different land-use systems on a temporal scale. The specific objectives of the study are (1) to determine and compare GHG (CO_2, CH_4, N_2O) emissions between a grassed buffer (GRS), an undisturbed natural forest (UNF), a 32-year old rehabilitated riparian forest buffer (RH), and an agricultural field (corn-soybean rotation) (AGR); and (2) to quantify and compare the relationship between temporal GHG emissions, soil moisture, soil temperature, soil organic C, and ammonium and nitrate in the GRS, UNF, RH and AGR land-uses.

Materials and methods

This study will be conducted at sites found along Washington Creek, a spring-fed first-order tributary, in the Township of Blandford-Blenheim in Oxford County (43"18'N, 80"33'W). Simple random sampling was used to distribute four (n=4) GHG chambers in each land-use type. Chambers consist of white, non-reflective PVC piping (25 cm height, 10 cm radius), and ventilated PVC caps, covered in an insulated reflective coating (Lutes et al. 2016). Deployed chambers were permanently sit 10 cm into the soil, with 15 cm of headspace above the soil surface (Lutes et al. 2016). Gas samples will be taken bi-weekly and at the time of sampling, gas samples were extracted from the headspace using a syringe for each chamber at 0, 10, 20 and 30 minutes. All gas samples will be analyzed on a Gas Chromatograph. At the same time as GHG sampling, soil temperature and moisture were quantified using a W. E. T. sensor, and soil samples were collected to a 10cm depth within a 1m radius of each GHG chamber (Estefan et al. 2013). These soil samples were analyzed for ammonium and nitrate using a UV-Vis Spectrophotometer (Doane and Horwath 2003).

Linear mixed models were used to make comparisons where there were within- and between-sample variation, due the observations not being independent (i.e. repeated measures). Linear mixed models were run on both GHG data and soil characteristic data. Tukey's post hoc test was used to find significant differences between land-use type.

Results

Mean soil temperature in the summer and the fall were 18.89°C and 10.71°C, respectively. Throughout the sampling period, the highest soil temperature was 26.90°C recorded at the AGR site and the lowest was 4.00°C recorded at the UNF site. The AGR experienced the highest mean soil temperature in the summer, while the GRS experienced the highest in the fall; though, this was quite similar to the AGR (0.11°C difference) (Table 1). However, the soil temperature at the AGR site was found to be significantly higher than all other land-use types. The lowest mean soil temperature for both summer and fall was recorded at the UNF site. Variation between land-use types is most apparent between the AGR and UNF sites, with a mean temperature difference of 3.91°C. For all land-use types, the temperature significantly decreased in the fall. Mean volumetric moisture content in the summer and fall were 37.97% and 40.04% respectively, with the highest recording being 63.50% at the UNF site and the lowest recording being 13.40% at the AGR site. In the summer, the RH has a significantly higher soil moisture than the AGR site, and the UNF site was significantly higher than all the other land-use types (Table 1). In the fall, the UNF site was once again significantly higher than all the other land-use types. There appears to be no significant difference in moisture content between seasons.

Table 1: Mean seasonal soil temperature (°C) and soil moisture content (% volume) for an agricultural field (AGR), grassed buffer (GRS), rehabilitated riparian forest buffer (RH) and an undisturbed natural forest (UNF) along Washington Creek, southern Ontario, Canada during 2017. Standard errors are shown in brackets.

	Season	AGR	GRS	RH	UNF
Soil Temperature (°C)	Summer	**21.43 (0.46)^{AX}**	18.67 (0.35)^{BX}	18.04 (0.30)^{BX}	17.52 (0.20)^{BX}
	Fall	11.68 (1.21)^{AY}	11.79 (1.27)^{AY}	10.49 (1.09)^{AY}	**9.33 (1.07)^{AY}**
Soil Moisture (% vol)	Summer	**25.64 (2.04)^{AX}**	32.42 (1.22)^{ABX}	38.33 (1.15)^{BX}	55.00 (1.10)^{CX}
	Fall	28.93 (1.23)^{AX}	37.41 (1.18)^{AX}	35.79 (2.20)^{AX}	**55.26 (1.11)^{BX}**

*Significant differences between land use type is detonated by ABCD, while significant differences between seasons are shown with XY.

Mean seasonal GHG emissions for the summer were 43.65, 211.23 and 179.89 measured in µg GHG m^{-2} h^{-1} for N_2O, CO_2 and CH_4, respectively. For the fall, mean GHG emissions were 24.94, 161.88 and 239.31. The GRS site had the highest mean summer and fall CO_2 emissions, while the other 3 land-use types had similar mean emissions (Table 2). The GRS site did not have much seasonal variation in CO_2 emissions, but all other land-use types decreased in the fall. However, there were no significant differences between land-use types for CO_2 emissions in the summer or the fall. The RH site had the lowest mean summer N_2O emissions. The RH site was significantly lower in CO_2 emissions than all the other land-use types. The AGR site had the highest mean summer and fall N_2O emissions, with the GRS and UNF sites producing similar emissions. The AGR site and GRS site didn't vary substantially between seasons, but the UNF site roughly doubled its mean N_2O emissions between the summer and fall. These differences between seasons were not found to be statistically significant. Finally, the highest mean seasonal CH_4 emissions for both the summer and fall were observed at the UNF site, with emissions almost doubling in the fall (Table 2). CH_4 emissions were significantly higher at the UNF site compared to all the other land-use types, with the next highest at the RH site. Both the AGR and GRS sites were on average not emitting CH_4 in the summer and fall, while the RH site had positive mean CH_4 emissions for the summer but not for the fall. Seasonal differences in CH_4 emissions were not found to be statistically significant.

Table 2: Mean seasonal CO_2-C emissions (μg CO_2-C m^{-2} h^{-1}), N_2O-N emissions (μg N_2O-N m^{-2} h^{-1}), and CH_4-C emissions (μg CH_4-C m^{-2} h^{-1}) for an agricultural field (AGR), grassed buffer (GRS), rehabilitated riparian forest buffer (RH) and an undisturbed natural forest (UNF) along Washington Creek, southern Ontario, Canada during 2017. Standard errors are shown in brackets.

	Season	AGR	GRS	RH	UNF
CO_2-C	Summer	159.14 (18.90)^{AX}	**366.15 (86.06)^{AX}**	163.13 (21.13)^{AX}	154.34 (26.81)^{AX}
	Fall	**73.13 (18.41)**^{AX}	316.90 (88.31)^{AX}	93.82 (17.82)^{AX}	116.70 (35.77)^{AX}
N_2O-N	Summer	**64.03 (15.48)^{AX}**	21.98 (5.66)^{AX}	38.93 (12.22)^{AX}	21.33 (17.72)^{AX}
	Fall	62.27 (16.87)^{AX}	18.55 (3.33)^{AX}	**5.30 (2.96)^{BX}**	53.94 (28.23)^{AX}
CH_4-C	Summer	-13.14 (19.74)^{AX}	**-59.16 (26.91)^{AX}**	22.86 (30.59)^{AX}	760.97 (279.89)^{BX}
	Fall	-55.10 (39.33)^{AX}	-44.46 (13.88)^{AX}	-12.37 (11.46)^{AX}	**1272.05 (470.82)^{BX}**

*Significant differences between land use type is detonated by ABCD, while significant differences between seasons are shown with XY.

Discussion

The GRS site had substantially higher CO_2 emissions than all other land-use types in both the summer and fall. Gritsch et al. (2015) did a similar study and yielded similar results, for they also observed the grassland site having the highest CO_2 emissions, followed by forested and arable land, which had similar emissions. Schaufler at al. (2010) also found similar results, indicating that the high C and N contents, dense root systems and high C inputs from decaying matter result in grassed sites having high CO_2 emissions. Additionally, in higher latitudes emissions are highly effected by temperature increases (Schaufler et al. 2010). This likely explains the drop in CO_2 emissions across all land-use types in the fall, for moisture content remained similar but the temperature decreased for all land-use types. Soil needs some air-filled pore space in order for soil microbes to carry out decomposition and subsequent respiration (Gristch et al. 2015), which explains why there were little emissions from the UNF site as the soil was oversaturated.

The highest CH_4 emissions were observed at the UNF site. This is again consistent with Schaufler et al. (2010), as there is a positive relationship between CH_4 emissions and moisture content of soil. Additionally, CH_4 production requires anaerobic conditions, which indicates why both the AGR and GRS sites had no emissions (Smith et al. 2003). The RH site had very little CH_4 emissions on average in the summer, and then no emissions in the fall. This likely, again, can be attributed to the soil not being fully anaerobic (Smith et al. 2003). Temperature has been shown to have little effect on CH_4 emissions, therefore changes in emissions likely cannot be attributed to falling temperatures in the fall or differences between land-use type (Schaufler et al. 2010; Smith et al. 2003).

Seasonal precipitation will have the largest impact on N_2O emissions, and proportion of soil pores occupied by water will determine the magnitude (Rochette et al., 2018). Therefore, the low soil moisture content at all land-use types likely explains low N_2O emissions, except the UNF site where soil moisture was often above 50%. Since the soil at the UNF site was oversaturated, the lack of oxygenated pores for N_2O to escape likely resulted in denitrification leading to the release of N_2 (Smith et al. 2003). The slightly elevated emissions at the AGR site may be explained by synthetic inputs of N, though, it has been proven that in well-aerated soils or dry climates the impact of this input is masked, as soil environmental conditions are the main drivers of N_2O emissions and denitrification (Rochette et al. 2018; Pilegaard et al. 2006). Therefore, these higher emissions are more likely a result of increased soil temperature (Smith et al. 2003).

In the fall, the RH site had much higher emissions of N_2O. A study by Pilegaard et al. (2006) looked at regional differences in forest soil N_2O emissions and found that in deciduous forests N_2O emissions are higher due to a compact and moist litter layer. This likely explains higher rates in the RH and UNF sites in the fall, for both are predominantly deciduous.

Conclusion

GHG emissions do not appear to be higher at any one land-use type along Washington Creek, Ontario. Highest CO_2 emissions were seen at the grassed buffer site, which is in tune with other studies' findings, but they were not found to be statistically significant. Similarly, the seasonal N_2O emissions were highest at the AGR site, but this was not significant. However, the RH site produced significantly lower emissions than all other sites in the fall. This is very important, as the riparian buffer has the potential to be a hot spot for N_2O emissions due to the incoming plant available nitrogen from the neighbouring agricultural field. Temperature likely played a role in this result. The highest CH_4 emissions were at the UNF site, showing significantly higher emissions than all other land-use types. This is likely due to the soil being oversaturated. Another field season will be conducted to observe spring emissions to include the freeze-thaw emissions, as well as another summer and fall field season to strengthen comparisons. Further comparison studies will be conducted to see what soil characteristics are influencing emissions, as in accordance with the Agricultural Greenhouse Gas Project (AGGP).

References

Doane T, Horwath WR (2003) Spectrophotometric determination of nitrate with a single reagent. Anal Lett 36: 2713-2722.

Estefan G, Sommer R, Ryan J (2013) Methods of soil, plant, and water analysis: a manual for the West Asia and North. ICARD, Africa Region, Beirut.

Gregory SV, Swanson FJ, McKee WA, Cummins KW (1991) An ecosystem perspective of riparian zones. Bioscience 41: 540-551.

Gritsch C, Zimmermann M, Zechmeister-Boltenstern S (2015) Interdependencies between temperature and moisture sensitivities of CO2 emissions in European land ecosystems. Biogeosciences 12: 5981–5993.

Lutes K, Oelbermann M, Thevathasan NV, Gordon AM (2016) Effect of nitrogen fertilizer on greenhouse gas emissions in two willow clones (Salix miyabeana and S. dasyclados) in southern Ontario, Canada. Agrofor Syst 90: 785-797.

Montagnini F, Nair PFK (2004) Carbon sequestration: an underexploited environmental benefit of agroforestry systems. Agrofor Syst 61: 281–295.

Pilegaard K, Skiba U, Ambus P, Beier C, Bruggemann N, Butterbach-Bahl K, Zechmeister-Boltenstern S (2006) Factors controlling regional differences in forest soil emission of nitrogen oxides (NO and N_2O). Biogeosciences 3: 651–661.

Rochette P, Liang C, Pelster D, Bergeron O, Lemke R, Kroebel R, … Flemming C (2018) Soil nitrous oxide emissions from agricultural soils in Canada: Exploring relationships with soil, crop and climatic variables. Agric Ecosyst Environ 254: 69-81.

Schaufler G, Kitzler B, Schindlbacher A, Skiba U, Sutton M, Zechmeister-Boltenstern S (2010) Greenhouse gas emissions from European soils under different land use: effects of soil moisture and temperature. Eur J Soil Sci 61: 683-696.

Shrestha RK, Lal R, Penrose C (2009) Greenhouse gas emissions and global warming potential of reclaimed forest and grassland soils. J Environ Qual 38: 426-436.

Smith K, Ball T, Conen F, Dobbie K, Massheder J, Rey A (2003) Exchange of greenhouse gases between soil and atmosphere: interactions of soil physical factors and biological processes. Eur J Soil Sci 54: 779-791.
Tufekcioglu A, Raich JW, Isenhart TM, Shultz RC (1999) Fine root dynamics, coarse root biomass, root distribution, and soil respiration in a multispecies riparian buffer in Central Iowa, USA. Agrofor Syst 44: 163-174.
Verhoeven JTA, Arheimer B, Yin C, Hefting MM (2006) Regional and global concerns over wetlands and water quality. Trends Ecol Evolut 21: 96–103.

CAN AGROFORESTRY IMPROVE SOIL WATER AND TEMPERATURE DYNAMICS IN AGRICULTURE? A CASE STUDY WITH SYNTROPIC FARMING IN BAHIA, BRAZIL

Damant G[1*], Villela F[2]

(1) Rue de Marteau 21, 5537 Sosoye, Belgium (2) HAS University of Applied Sciences, Onderwijsboulevard 221, 5223 DE ‘s-Hertoghenbosch, Netherlands

*Correponding author: geoff@renaturefoundation.nl

Abstract

We investigated the potential of Syntropic agriculture (SA) to improve rural soil water and temperature resilience in Northeastern Brazil. Water content in SA was found to be 13% higher on average than in cocoa monoculture (MO) and, after several days without rain, also higher than in a regrowth forest (RF). Mean soil temperature was lowest in RF, intermediate in SA and highest in MO, where it was also more affected by the hour of the day and by precipitation. Factors likely responsible for these differences include canopy density and stratification, litter type and thickness, soil organic matter and compaction. SA thus markedly improves soil water and temperature dynamics over MO, and can be at least as performant as natural succession at restoring a healthy water cycle on degraded soils. Indications suggest that SA would be capable of similar improvements in Europe, opening the door for further research.

Keywords: climate change; soil water; soil temperature; water retention capacity; temporal variability; agroforestry; ecosystem restoration

Introduction

Conventional agriculture practices have made soil processes increasingly vulnerable to extreme weather events, which are predicted to intensify worldwide in the face of climate change (e.g., Madsen et al. 2014; Min et al. 2011). In this context, we investigated the potential of Syntropic agriculture, a successional and process based form of agroforestry, to improve soil water and temperature resilience in agricultural production.

Materials and methods

The Syntropic agriculture (SA) system was developed by Swiss farmer and researcher Ernst Götsch in the humid tropics of Bahia, Brazil. The aim of the current study was to gain insight into how these techniques influence soil water and temperature dynamics over time and as a reaction to wet and dry periods. Therefore, we compared Ernst’s farm with a neighboring cocoa monoculture (MO) and unmanaged regrowth Atlantic rainforest (RF). The latter two systems were chosen as controls since they are the most common land uses in the region for, respectively, economically viable agricultural production and for nature preservation, i.e. the two functions which SA aims to combine (de Souza 2015; Passini 2017; Peneireiro 1999).

For each of the three systems, one study site was selected in such a way that all sites were in close proximity of each other and had similar characteristics of hillside position, slope, orientation, soil type, soil texture and site history. The dynamics were monitored daily on each site during a 30 day period in November – December 2017. Measurements were taken via electromagnetic induction with the WET-2 sensor from Delta-T instruments and carried out in the upper 7cm of topsoil, i.e. the soil horizon expected to show the most variation within the timeframe of the experiment. To ensure statistical significance, 3 plots were demarcated per site, each with 4 fix measurement points and 5 replicates per point. Rainfall data was collected using a pluviometer. Finally, soil moisture and temperature data were analyzed using linear mixed models, as well as Student's t-tests for pairwise comparison of sites.

Results

During the experiment, 3 rainy periods were observed, each separated by 4 to 7 dry days. Water content in SA was found to be on average 13% higher than in MO, being significantly higher on all days except the first days of rain events. From the second day of rain events onward, water content in SA would consistently and significantly surpass MO. Despite this fact, surface runoff was observed only in MO, indicating a lower water retention capacity in the latter. When rains stopped and a dry period progressed, levels in SA would remain superior to MO. Soil moisture in the RF site evolved similarly to SA during rain events. However, after 2 to 5 dry days, levels became significantly lower, i.e. closer to MO (Figure 1a).

Soil temperature was on average lowest in RF, intermediate in SA and highest in MO, each separated by 0.6-1°C. In the latter system it was also significantly more variable, depending on the hour of the day and on wet and dry spells (Figure 1b).

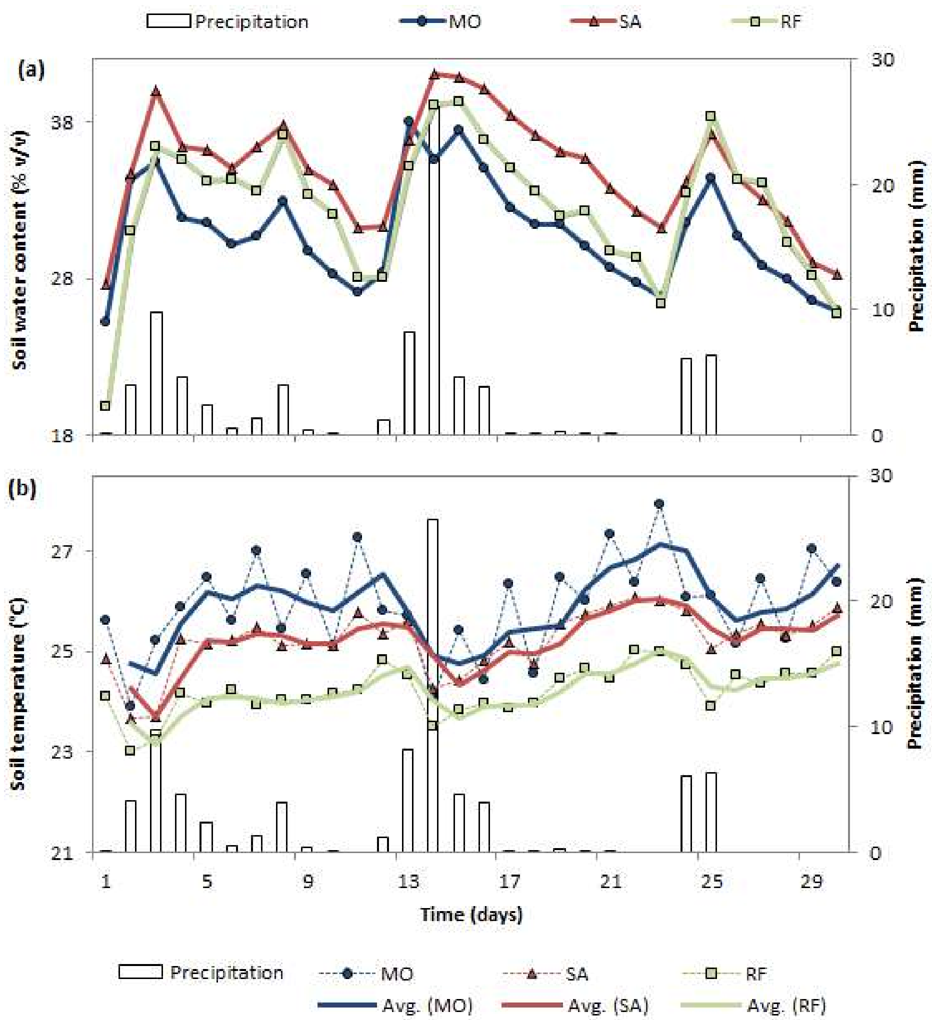


Figure 1: Evolution through time for the 3 studied systems of (a) average water content and (b) average soil temperature. In (b) both daily means (dotted lines) and two-day averages (continuous lines) are included. Note: A dry period of 14 days had preceded the first day of measurements.

Discussion

Among the factors affecting our results, the lower organic matter content and more compacted soil structure in MO likely explain its reduced capacity to absorb rain water and prevent runoff compared to the other sites (Charman and Murphy 1998).

However, of even greater influence is soil cover by litter and canopy. Firstly, this cover slows the wetting of soil by buffering the effect of rain (Greene and Hairsine 2004; Gyssels et al. 2005). This explains why, on the first day of rain events, soil moisture levels rose more slowly in SA whereas the exposed soil in MO wetted faster. Secondly, it also slows the drying of soil by insulating from solar radiation, evaporation and wind (e.g., Baptista et al. 2014; Villegas et al. 2010). This in turn likely explains the higher moisture content in SA compared to MO overall, and to RF in the case of prolonged dry periods. The latter finding may seem remarkable and counterintuitive, and additional studies would be required to confirm this effect conclusively. Nevertheless, it is possible that soil cover is indeed more insulating in SA even than in an unmanaged forest due to the specific management. Namely, the intense pruning in SA creates a biomass flux to the litter layer 25% to 150% higher than values for unmanaged secondary Atlantic forests found in literature (Schulz et al. 1994; Martinelli et al. 2017). Moreover, it provides a higher fraction of woody material such as branches and logs, which could further enhance water absorption and retention. According to Ernst Götsch, the canopy stratification pattern maintained between species in his system also contributes to conveying more moisture towards the ground than in an unmanaged forest. A final relevant effect of litter and canopy cover is to lower soil temperature (e.g., Tan and Layne 1993).

On the basis of these effects, one would expect systems with higher water retention to also show lower temperatures, both driven by soil cover. This was mostly the case except for RF compared to SA in dry periods, when the latter system showed higher water content as well as higher temperatures. Possibly, a different *balance* between litter and canopy cover plays a role here. Indeed, pruning in SA may result in a particularly insulating litter layer and a moisture-conveying canopy stratification. Yet it also opens up this canopy which increases incident sunlight and therefore temperatures. While this would enhance evaporative potential in SA (Baptista et al. 2014), our results suggest that the effect of litter cover prevails.

In a tropical context, higher temperatures enhance soil nutrient release but in the long term also nutrient depletion and thus the need for external fertilization (BassiriRad 2005). It also increases the loss of soil carbon and nitrogen through volatilization (Kirschbaum 1995). These effects imply negative ecosystem consequences for MO, which had the highest and by far the most variable temperatures.

The European context

In Europe too, soil water and temperature management in agriculture is becoming an increasingly ‘hot’ topic. Extreme precipitation events are likely to intensify across Europe in the wake of climate change (Madsen et al. 2014), making the ability of landscapes to absorb rainwater ever more crucial to prevent flooding and soil loss. In turn, water retention during dry periods is especially relevant in the Mediterranean climate zone where, in addition to the already dry summers, occurrence of drought years is predicted to increase (Gudmundsson and Seneviratne 2016).

While the drivers behind our findings would also hold in a temperate climate, their relative importance may vary and change the overall picture to some extent. For instance, at lower temperatures primary production is reduced but organic matter breakdown is reduced even further, promoting net accumulation (Kirschbaum 1995). The additional litter input from pruning in Syntropic farming would thus not be as great as in a tropical situation, but it would persist longer. As a result it is probable that, in Europe, these techniques also provides a more protective cover to absorb and retain moisture compared to an unmanaged ecosystem. However, the extent remains to be researched and likely depends on site-specific climate, soils and species used.

Farms in both the Netherlands and around the Mediterranean which we contacted and which apply Syntropic agriculture or very similar techniques, have also reported various improvements of soil processes both over the time and compared to neighboring conventional farms. These included a more constant soil temperature and increased humidity.

Conclusion

Our results show that SA markedly improves soil water and temperature dynamics over a conventional monoculture. They also suggest that this system is at least as performant as unmanaged natural succession, if not more so, at restoring a healthy water cycle on degraded soils in the humid tropics. This establishes SA as a valuable ally in mitigating the effects of climate change. There are good indications that these findings would hold in a temperate European environment. Our work may thus serve as an invitation and guide for further research to investigate this question and consolidate the body of evidence. It is after all crucial for shaping policies and raising awareness of the public that hard data on this subject of global importance be gathered, whether or not it confirms what people working with these techniques may readily observe.

References

Baptista I, Ritsema C, Querido A, Ferreiro AD, Geissen V (2014) Improving rainwater-use in Cabo Verde drylands by reducing runoff and erosion. Geoderma 237: 283–297.

BassiriRad H (2005) Nutrient Acquisition by Plants: An Ecological Perspective. Springer, Berlin, pp 277–311.

Charman PEV, Murphy BW (1998) Soils: their properties and management, 5th edn. Oxford university press, Melbourne

de Souza Bessa Luz I (2015) Sistemas agroflorestais sucessionais: viabilidade financeira para a agricultura familiar. Universidade de Brasília.

Greene RSB, Hairsine PB (2004) Elementary processes of soil-water interaction and thresholds in soil surface dynamics: A review. Earth Surf Process Landforms 29: 1077–1091

Gudmundsson L, Seneviratne SI (2016) Anthropogenic climate change affects meteorological drought risk in Europe. Environ Res Lett 11:44005.

Gyssels G, Poesen J, Bochet E, Li Y (2005) Impact of plant roots on the resistance of soils to erosion by water: a review. Prog Phys Geogr 29: 189–217.

Kirschbaum MUFF (1995) The temperature dependence of soil organic matter decomposition, and the effect of global warming on soil organic C storage. Soil Biol Biochem 27: 753–760.

Madsen H, Lawrence D, Lang M, Martinkova M, Kjeldsen TR (2014) Review of trend analysis and climate change projections of extreme precipitation and floods in Europe. J Hydrol 519: 3634–3650.

Martinelli LA, Lins SRM, dos Santos-Silva JC (2017) Fine litterfall in the Brazilian Atlantic Forest. Biotropica 49: 443–451.

Min SK, Zhang X, Zwiers FW, Hegerl GC (2011) Human contribution to more-intense precipitation extremes. Nature 470: 378–381.

Passini F (2017) A Agricultura Sintrópica de Ernst Götsch : história , fundamentos e seu nicho no universo da Agricultura Sustentável. Universidade Federal do Rio de Janeiro.

Peneireiro FM (1999) Sistemas Agroflorestais didigidos pela sucessão natural: um estudo de caso. Universidade de São Paulo.

Schulz B, Becker B, Götsch E (1994) Indigenous knowledge in a “modern” sustainable agroforestry system - a case study from eastern Brazil. Agroforst Syst 25: 59–69.

Tan CS, Layne REC (1993) Irrigation and ground cover management effect on soil temperature in a mature peach orchard. Can J Plant Sci 70: 857–870

Villegas JC, Breshears DD, Zou CB, Law DJ (2010) Ecohydrological controls of soil evaporation in deciduous drylands: How the hierarchical effects of litter, patch and vegetation mosaic cover interact with phenology and season. J Arid Environ 74: 595–602.

CARBON STORAGE IN THE SOIL UNDER DIFFERENT LAND USES IN THE SOUTH OF PORTUGAL

Ferreiro-Domínguez N[1, 2*], Palma JHN[2], Paulo JA[2], Rigueiro-Rodríguez A[1], Mosquera-Losada MR[1]

(1) Department of Crop Production and Engineering Projects, High Polytechnic School, University of Santiago de Compostela, 27002, Lugo, Spain (2) Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda s/n, 1349-017 Lisbon, Portugal

*Corresponding author: nuria.ferreiro@usc.es

Abstract

The semi-arid climate areas are strongly affected by climate change but land management options knowledge for these areas is scarce and usually focused on one single type of land use when mitigation is evaluated. The aim of this study was to evaluate the amount of carbon stored in the soil in three main land uses traditionally encountered in the semi-arid areas of the South of Portugal (natural forest vegetation, agroforestry and agricultural) after a period of 100 years of land use. The results of this experiment showed that after 100 years the trees established in the plots increased the carbon storage per hectare in the soil, mainly due to the high inputs of organic matter to the soil coming from the tree leaves and roots. Therefore, in similar edaphoclimatic conditions to those of this study it could be recommended the implementation of agroforestry systems such as montado as a land use to mitigate the effect of the climate change, allowing agricultural production.

Keywords: agroforestry; forest; agricultural; climate change

Introduction

Human activities related to land use have a high impact on climate change because the land use sector represents almost 25% of total global emissions (UN 2018). Currently, the effect of land use on climate change is a concern in the context of international policies, being necessary policies and incentives that promote land uses that act as mechanisms for mitigation and adaptation to climate change. Portugal has an agroforestry system called montado where *Quercus suber* L. and *Quercus rotundifolia* L. are combined with agricultural and/or pastoral activities (Pereira and Tomé 2004). Montado is highly valued by its capacity to mitigate climate change, mainly due to the higher potential to sequester carbon in both above and below (soil) ground biomass compared with the conventional agricultural systems (Pinto-Correia et al. 2011). Recent studies shown that *Quercus suber* L. stands from the entire Portugal are responsible for storing 14 748 500 t CO_2, from which 14 030 787 t CO_2 are derived from the area placed below theTagus River, where montado is the main land use (Branco et al. *2010). Soil carbon represents the 85% of the carbon stocks of terrestrial ecosystems, which makes the evaluation of land use systems impacts on soil carbon highly relevant.*

The aim of this study was to evaluate the amount of carbon stored in the soil of three main land uses traditionally encountered in the semi-arid areas of the South of Portugal (natural forest vegetation, agroforestry and agricultural) after a period of 100 years of land use.

Materials and methods

The experiment was carried out in the Perímetro Florestal of Contenda located in the Baixo Alentejo province, South of Portugal (WGS84 coordinates: 38.058 N, -7.040 W) and covered a total area of 5270 ha. Three plots of the Perímetro Florestal of Contenda were selected to compare the effect of the land use on the soil carbon stocks after a period of 100 years. The selected plots were: i) a plot with natural forest vegetation, dominated by uneven aged *Quercus rotundifolia* L. trees established through natural regeneration, ii) a plot with an agroforestry land use (montado), in which uneven aged *Quercus rotundifolia* L. trees were established and are currently at a low density (66 trees ha^{-1}) and combined with an extensive grazing with sheep, iii) a plot with an agricultural land use in which during the last six years the soil was tilled to sow a mixture of grasses (triticale, oat and wheat) and legumes (clover) for livestock feeding.

All plots included in this study are characterized by the presence of a water line. For this reason, three composite soil samples were collected in each plot at three distances from the water line (5, 10 and 15 m) to eliminate the effect of the water line in the statistical comparison of the land uses. The soil samples were collected at a soil depth of 25 cm in March 2017 using a cylinder of a known volume. In the plots with natural forest vegetation the soil samples were collected under the trees and in the agroforestry plots the soil samples were collected under the trees and in those areas not affected by the trees.

In the laboratory, roots of each soil sample were separated by hand, dried, and weighed. The soil root biomass was calculated using the known volume value of the cylinder. Soil samples were air dried and passed through a 2 mm sieve. Material that did not pass through the 2 mm sieve was separated, weighed and then discarded. The weight of the discarded fraction was used to convert the eventual data derived from the 2 mm sieved fraction back to field condition (Rodríguez-Murillo 2001). The percentage of carbon in the soil was analysed using a LECO CNS Elemental Analyzer. The percentage of carbon was used to calculate the carbon storage per hectare (Mg C ha^{-1}) in the soil according to Mosquera-Losada et al. (2015) and Ferreiro-Domínguez et al. (2016).

Data were analysed using ANOVA and differences between averages were shown by the LSD test, if ANOVA was significant. The statistical software package SAS (2001) was used for all analyses.

Results

In Figure 1 it can be observed that the carbon storage (Mg ha^{-1}) in the soil was significantly higher in the plot with natural forest vegetation and under the trees in the agroforestry plot compared with the plot with an agricultural land use and the open area of the agroforestry plot ($p<0.001$).

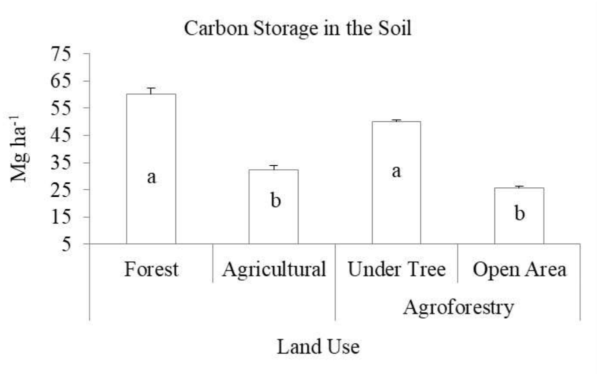


Figure 1: Carbon storage (Mg C ha^{-1}) in the soil under each land use (natural forest vegetation, agricultural and agroforestry). Different letters indicate significant differences between land uses. Bars indicate the standard error of the mean.

Root biomass was significantly affected by the land use ($p<0.01$). A higher root biomass was found in the plot with natural forest vegetation and under the trees in the agroforestry plot than in the agricultural plot and in the open area of the agroforestry plot (Figure 2).

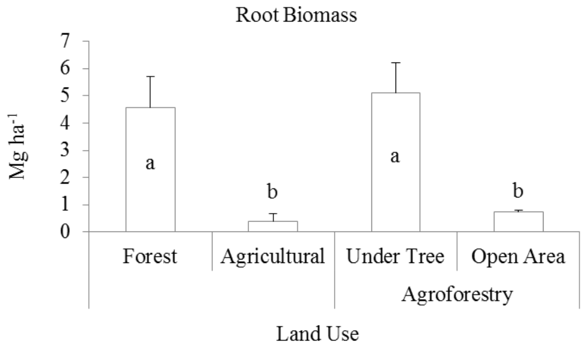


Figure 2: Root biomass (Mg ha^{-1}) under each land use (natural forest vegetation, agricultural and agroforestry). Different letters indicate significant differences between soil fractions in each land use. Bars indicate the standard error of the mean.

Discussion

The levels of carbon storage per hectare in the soils under natural forest and agricultural land use were similar to the levels reported by Sil et al. (2017) for broadleaved forest areas (60.51 Mg ha^{-1}) and agricultural areas (24.52 Mg ha^{-1}) of Portugal. In the case of the agroforestry plot, the mean levels of carbon storage per hectare, taking into account both the area under the trees and the open area, were similar to the levels found by Howlett et al. (2011) in a dehesa cork oak silvopasture of central-western Spain (29.9 Mg ha^{-1}).

The carbon storage in the soil was higher in the plot with natural forest vegetation and under the trees in the agroforestry plot compared with the plot with an agricultural land use and the open area of the agroforestry plot. The higher carbon stock associated to the presence of trees in the plots could be explained by the high inputs of organic matter to the soil from the tree leaves but also from the roots of trees and herbaceous species established in the understory (Mosquera-Losada et al. 2015) because the root biomass was higher in the plot with natural forest vegetation and under the trees in the montado than in the plot with an agriculture land use and in the open area of the montado. Moreover, in the case of the montado, trees generate micro-sites under their canopies which may favour the establishment of new herbaceous species (Rois et al. 2006), increasing the fine root biomass under the trees and therefore the carbon stocks compared with the open area. Sheep grazing in the montado could have also increased the carbon stock under the trees compared with the open area. Animals are generally close to the trees looking for feed and shade which can increase the soil nutrients around trees (from excreta) and therefore the development of fine roots in the trees mainly in winter when soil water is available (López et al. 2001). The important role of fine roots located in the upper few centimetres of the soil on the carbon storage in the soil have been previously described by several authors (Dresner et al. 2007; Mosquera-Losada et al. 2015; Ferreiro-Domínguez et al. 2016). Moreover, the shade generated by the trees probably decreased the mineralisation rate of the soil organic matter which favoured the carbon stock under the trees compared with the open area in the montado and the plot with agricultural land use in which the mineralisation rate of the soil organic matter could be high due to the soil tillage process carried out. These results demonstrate the important role of trees in carbon storage in the soil and therefore their potential mitigation role fighting against climate change climate. Moreover, this carbon can remain unalterable in the soil over very long periods of time as long as the tree management is adequate.

Conclusion

The presence of trees increases the carbon storage in the soil at long term, mainly due to the high inputs of organic matter to the soil from the tree leaves and roots. Therefore, in similar edaphoclimatic conditions to those of this study it could be recommended the implementation of agroforestry systems such as the montado as a land use to mitigate the effect of the climate change, allowing agricultural production.

Acknowledgements

We are grateful to XUNTA DE GALICIA (Consellería de Cultura, Educación e Ordenación Universitaria ("Programa de axudas á etapa posdoutoral DOG nº122, 29/06/2016 p.27443, exp: ED481B 2016/0710")), European Commission (AGFORWARD FP7-contract 613520) and the Municipality of Moura and Herdade da Contenda for their assistance and facilitation of facilities. We thank the Fundação para a Ciência e Tecnologia (Portugal) through the contracts SFRH/BPD/96475/2013, SFRH/BD/133598/2017 and UID/AGR/00239/2013.

References

Branco O, Bugalho M, Silva LN, Barreira R, Vaz P, Dias F (2010) Hotspots areas for biodiversity and ecosystem services in Montados. http://awsassets.panda.org/downloads/habeas_report2010.pdf (accessed 26/08/2017).

Dresner S, Ekins P, McGeevor K., Tomei J (2007) Forest and climate change global understandings and possible responses. In: Freer-Smith PH, Boradmeadow MSJ, Lynch JM (eds) Forestry and Climate Change. CAB International, Wallingford, UK, pp. 38-48.

Ferreiro-Domínguez N, Rigueiro-Rodríguez A, Rial-Lovera KE, Romero-Franco R, Mosquera-Losada MR (2016) Effect of grazing on carbon sequestration and tree growth that is developed in a silvopastoral system under wild cherry (*Prunus avium* L.). Catena 142: 11-20.

Howlett DS, Moreno G, Mosquera-Losada MR, Nair PKR, Nair VD (2011) Soil carbon storage as influenced by tree cover in the Dehesa cork oak silvopasture of central-western Spain. J Environ Monitor 13: 1897-1904.

López B, Sabaté S, Gracia CA (2001) Annual and seasonal changes in fine root biomass of a *Quercus ilex* L. forest. Plant Soil 230: 125-134.

Mosquera-Losada MR, Rigueiro-Rodriguez A, Ferreiro-Dominguez N (2015) Effect of liming and organic and inorganic fertilization on soil carbon sequestered in macro-and microaggregates in a 17-year old *Pinus radiata* silvopastoral system. J Environ Manag 150: 28-38.

Pereira H., Tomé M (2004) Non-wood products: Cork Oak. In: Burley J, Evans J, Youngquist JA (eds) Encyclopedia of Forest Sciences. Elsevier, Oxford, pp. 613-620.

Pinto-Correia T, Ribeiro N, Sá-Sousa P (2011) Introducing the montado, the cork and holm oak agroforestry system of Southern Portugal. Agrofor Syst 82: 99–104.

Rodríguez-Murillo JC (2001) Organic carbon content under different types of land use and soil in peninsular Spain. Biol Fert Soils 33: 53–61.

Rois M, Mosquera-Losada MR, Rigueiro-Rodríguez A (2006) Biodiversity indicators on silvopastoralism across Europe. European Forest Institute Technical Report 21 EFI, Joensuu.

SAS/Stat User's Guide: Statistics. SAS Institute Inc., Cary, NC, USA.

Sil A, Fonseca F, Gonçalves J, Honrado J, Pedroso CM, Alonso J, Ramos M, Azevedo JC (2017) Analysing carbon sequestration and storage dynamics in a changing mountain landscape in Portugal: insights for management and planning. Int J Biodivers Sci, Ecosyst Serv Manag 13: 82-104.

UN (United Nations) (2018) Land and climate change. http://www2.unccd.int/issues/land-and-climate-change (accessed 14/02/2018).

MICROCLIMATE OF A SPECIAL SHELTERBELT SYSTEM UNDER ARID SITE CONDITIONS IN HUNGARY

Honfy V[1*], Bakti B[1], Borovics A[2], Rásó J[1], Somogyi N[3], Keserű Z[1]

(1) Department of Plantation Forestry, NARIC Forest Research Institute, Püspökladány, Hungary (2) Department of Tree Breeding and Improvement, NARIC Forest Research Institute, Sárvár, Hungary (3) NARIC, Gödöllő, Hungary

*Corresponding author: honfy.veronika@erti.naik.hu

Abstract

In Hungary, agricultural land occupies cca. 60% of the land area. Of the arable land 85% can be found in agro-environmentally sensitive areas. In these areas the nutrient content is very low and floods and drought periods are very frequent. In 1998 a special shelterbelt system was established in Földes, under arid site conditions. Wind speed and soil moisture dynamics were monitored throughout 2017. The results show that changes in soil moisture content follow the pattern of the measured wind speed dynamics. The observations highlight the importance of shelterbelts, which can mitigate unfavourable site conditions, thus playing a crucial role to combat climate change.

Keywords: shelterbelt; drought; climate change; mitigation; soil moisture

Introduction

In Hungary, agricultural land (including crop and grasslands) occupy cca. 60% of the land area. Of the arable land 85% can be found in agro-environmentally sensitive areas. In these areas the nutrient content is very low and floods and drought periods are very frequent. Consequently we have to find the suitable growing technology that can provide the sustainable and profitable management under unfavourable site conditions.

The concept of agroforestry is rather new to Hungarian farmers and scientists. The Hungarian National Agricultural Research and Innovation Centre's (NARIC) Forest Research Institute (FRI) Department of Plantation Forestry started to study agroforestry systems and constructed its first trials in 2014. Since then further experiments have been set up and the institution has started to spread the knowledge of agroforestry, its characteristics and specialities, through agricultural and forestry forums and conferences, based on international literature, and examples. The aim is to establish trials across the whole country, to be able to study different sites where profitable plantation forestry and agroforestry technologies can be tested under the ecosystem of Hungary, providing models, and options to forestry and agriculture in marginal areas (Keserű et al. 2014).

Deflation is a serious problem in many arid areas of Hungary, as well as erosion in undulating areas where the soil is temporarily uncovered due to conventional agriculture. There is about 700 000 ha arable lands and 100 000 ha grasslands in Hungary with low agroecological potential, where production in the conventional way cannot be sustained (Borovics and Gyuricza 2015).

Agroforestry used to be a widespread technology of land use in Hungary during the past century. However during recent decades it has disappeared from large areas of the Hungarian countryside. The negative effects of climate change urge Hungary to address and find ways to adapt or to mitigate it. According to international literature, agroforestry systems significantly mitigate these negative effects. It is realized by excessive carbon sequestration per land unit. Agroforestry create favourable microclimate due to moderate radiation and higher relative humidity. The system's positive effects on biodiversity, water quality and soil protection (erosion, deflation) is significant as well. Shelterbelts can enhance resilient and sustainable management.

Materials and methods

In 1998 a proper agroforestry system was established in Földes by an organic farmer and beekeeper, Zsigmond Bíró and the Forest Research Institute, although that time agroforestry systems were barely presented in Hungary. The shelterbelt system was established in a 5.1 hectar organic agricultural field nearby Földes, where previously sugar beet was produced. The field characteristics are shallow site, meadow solonetz soil turning into steppe formation, with some periodic water effected area. The shape of the field is rectangular, divided into 3 parcels (80m x 80m, 80m x 80m, 80m x 120m) by the shelterbelt, so that the arable lands are surrounded with trees from all the 4 sides (Figure 1). The trees were planted in 8 rows, interrow spacing was 3 m and in-row spacing was 1 m, making up to 20 m each stripe, covering altogether 3 ha. The tree height varies between 15 and 20 meter in the shelterbelts.

Shelterbelts are significant in domestic honey production too. Valuable bee pastures can be established by choosing the species with good care, which provide pollens and nectar for bees (Keresztesi and Halmágyi 1975). The species used in the shelterbelt were originally chosen according to their significance to apiculture. There were determined by their blooming period to continuously provide pollen and nectar for the bees, and also to fulfill windbreak characteristics. Therefore application of shelterbelts can address some of the challenges that apiaries face and it also effects on carbon fixing advantageously, compared to the monocultural cultivation of plants.

Figure 1: Aerial photograph of the shelterbelt system in Földes, Hungary

Wind speed measurement

Repeated, point-like measurements were used to determine the wind speed reduction of shelterbelts. At four elevations were measured the temperature, relative humidity, wind direction and wind speeds of 35 cm, 70 cm, 100 cm, 135 cm using a mobile measuring device (EMOS digital meteorological station).

Soil moisture measurement

For the test, the soil moisture/soil resistance meter OT 001 was used to measure soil moisture and soil temperature by 1 cm in depth of 0 to 80 cm.

Results

Given an irrigated area surrounded by shelterbelts, the speed of replacement of humid air mass slows down, allowing a reduction of water used for irrigation. In the wintertime, snowdrift doesn't take place in these protected areas, so the soil doesn't get frozen in the deeper layers, only in the surface. The soil starts defrosting about the same time as the snow starts melting, so the majority of the precipitation can be absorbed by the soil (Frank and Takács 2012). Reducing evaporation is also important to prevent secondary salinisation (Tóth et al. 1972).

Windspeed was recorded before end during the vegetation period, when trees were in foliage, and when leafless (Figure 2 and 3).

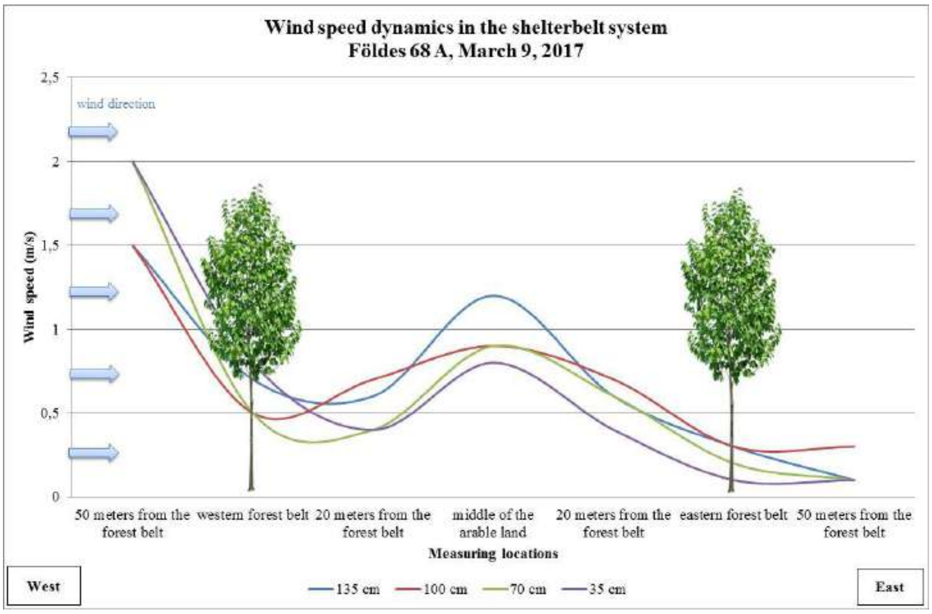


Figure 2: Wind speed dynamics in the shelterbelt system under leafless conditions.

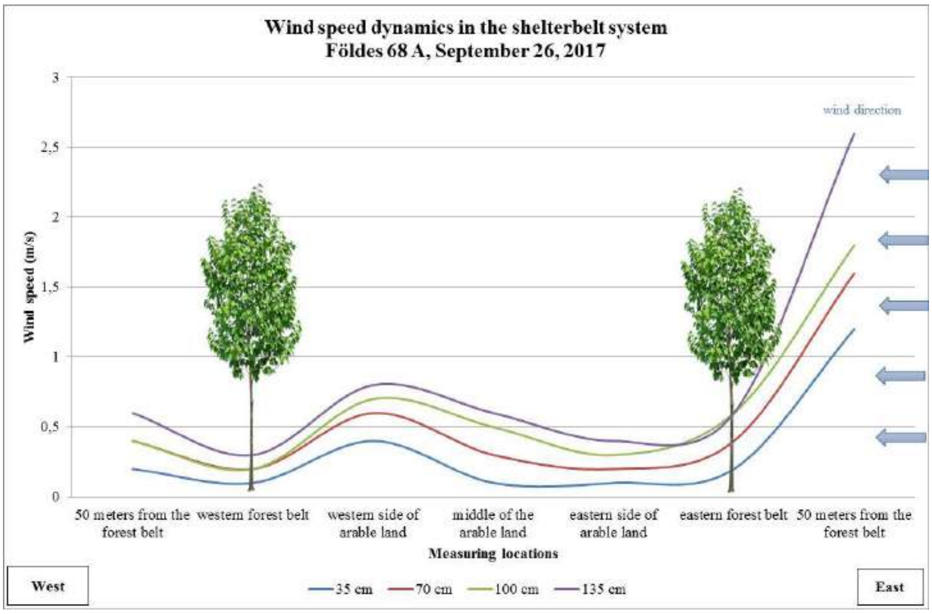


Figure 3: Wind speed dynamics in the shelterbelt system under foliage conditions.

The changes in soil moisture content are determined by the increasing water uptake of the shelterbelt. Soil moisture was measured in seven fixed locations in every 5 cm depth up to 30 cm (Figure 4).

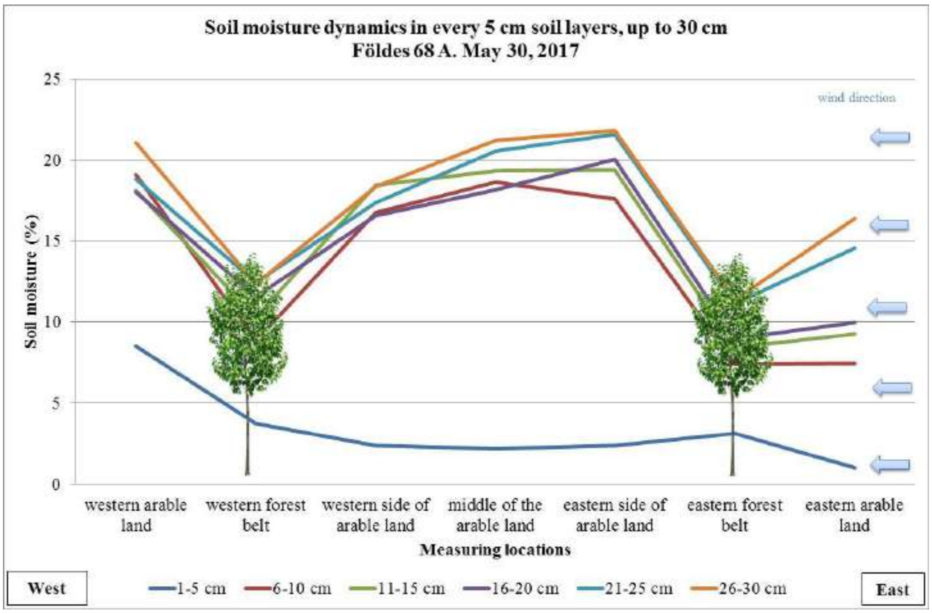


Figure 4: Soil moisture dynamics in the shelterbelt system.

The results show that changes in soil moisture content follow the pattern of the measured wind speed dynamics which is realized in higher yield. The above discussed investigations highlight the importance of shelterbelts, which can mitigate unfavourable site conditions, thus playing a crucial role to combat climate change.

Discussion

The value of the above discussed site has only been recognized recently, therefore further data acquisition, studies and researches are needed. We assume that the abundant blooming species in the shelterbelt with its increased surface exposed to full sun provides more flowers and more intense blooming throughout the vegetation period, resulting in a high value bee pasture serving increased amount of pollens and nectar.

One of the most effective ways to protect soil from degradation is the application of shelterbelts. The speed of the wind is decreased at the protected side of the field; therefore the wind’s drying affect gets reduced at the surface of the soil. By decreasing the velocity of the wind, evapotranspiration is also moderated, the dispersion of precipitation is balanced, hence soil moisture is increased and all these effects can contribute to higher yields.

Acknowledgments

This research focused on agroforestry has been partly financially supported by VKSZ_12-1-2013-0034 - Agrárklíma.2 project.

References

Borovics A, Gyuricza Cs (2015) Produce together with nature (in Hungarian). Agroforestry in focus. Agroinform 11: 12-17.

Frank N, Takács V (2012) Windbreaks and shelterbelts examination by their effect on decreasing the windspeed. Bulletin of Forestry Science 2 :151-162 p. (in Hungarian).

Keresztesy B, Halmágyi L (eds) (1975) The beepasture. Academic Publisher, Budapest, 791 p. (in Hungarian)

Keserű Zs, Csiha I, Rédei K, Kamandiné Végh Á, Kovács Cs, Rásó J (2014) Environment friendly and cost-effective agro-forestry systems, as land-use options for the future. Association for Lowland Forests 70-75 (in Hungarian).

Tóth B et al. (1972) Afforestation on salt effected soils. Academic Publisher, Budapest.

SOIL EROSION RISK AND AGROFORESTRY IMPLEMENTATION IN TUSCANY: LOCATING BEST PRACTICES FOR VULNERABILITY MANAGEMENT WITH A GIS-BASED SCENARIO APPROACH

Mantino A[1], Volpi I[1], Dragoni[1], Cappucci A[2], Mele M[2], Bonari E[1], Pecchioni G[1], Annecchini F[2], Ragaglini G[1]

(1) Institute of life sciences, Sant'Anna School of Advanced Studies, Pisa, Italy (2) Department of Agriculture, Food and Environment (DAFE), Pisa, Italy

*Corresponding author: alberto.mantino@santannapisa.it

Abstract

In the Mediterranean basin, water soil erosion is increasing by extreme rainfall events. Agroforestry practices could reduce erosion risk by enhancing soil cover. The aims of this study are to (i) model the potential erosion risk of the cropland of Tuscany Region and (ii) classify silvoarable practices to be implemented for reducing the risk. A GIS-based assessment was carried out to classify agroforestry support practices needed to keep erosion risk under a sustainable threshold (11 Mg ha^{-1} yr^{-1}). In the most part of cropland (58.7%) P-factors ranged from 0.99 to 0.1, thus alley cropping and multi-storey practices could maintain erosion risk under the threshold. Agroforestry practices combined with contour farming are suggested where the erosion risk is higher (P < 0.1, 12.4% of cropland). Overall, the implementation of agroforestry practices on total cropland surface could prevent the loss of about 69.5 Mg ha^{-1} yr^{-1} of soil at regional scale.

Keywords: silvoarable; soil loss; perennial crops; RUSLE

Introduction

In the Mediterranean region the increased frequency of extreme precipitation events leads to the increase of soil erosion risk due to the higher rainfall erosivity (Panagos et al. 2015a).

In Tuscany, Central Italy, rainfall erosivity shows high values due to the precipitation pattern (Borrelli et al. 2016) and soil erosion risk is increased by the prevalence of annual crops on arable land (ISTAT 2010). In fact, only 18% of the arable land is covered by temporary grasslands and perennial crops such as alfalfa or other meadows, that are able to enhance soil protection by a better soil coverage and a reduced tillage requirement, compared to annual crops.

Agroforestry systems - "the practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or animal systems to benefit from the resulting ecological and economic interactions" - can reduce soil erosion risk by enhancing cover-management factor (Palma et al. 2007). Based on this, the aims of this study are to: (i) model the potential erosion risk in Tuscany Region and (ii) classify silvoarable practices to reduce erosion risk under a recommended threshold.

Materials and methods

The study area included the arable land of Tuscany Region (593,464 ha), identified using the last version of a land-use map produced by the regional administration (Regione Toscana 2015). The map is composed by 121,959 polygons for irrigated and non-irrigated arable land (class 211 and class 212, respectively). Land-use data from the 2010 national census (ISTAT

2010) was used to assess the current partition of arable land into areas cultivated with different crops (Table 1). The coastal area of the region is characterized by the presence of winter cereals, industrial crops and maize-based cropping systems, whereas the inland hilly areas are covered by extensive grazing systems, mainly based on the presence of cool-season annual grasses and legumes.

For the aims of this study, a GIS-based assessment was implemented using the Revised Universal Soil Loss Equation (RUSLE, Renard et al. 1997) in which soil losses are calculated as in Eq.1:

Eq.1 – Revised Universal Soil Loss Equation:

$$A = R \ x \ K \ x \ LS \ x \ C \ x \ P$$

Where: *A* is the soil loss expressed as megagrams per hectare and year (Mg ha^{-1} y^{-1}); *R* is the rainfall erosivity factor (MJ mm h^{-1} ha^{-1} y^{-1}) extrapolated from the map proposed by the JRC-EU (Panagos et al. 2015a); *K* is the soil erodibility factor (Mg h MJ^{-1} mm^{-1}) calculated as reported by Vallebona et al. (2016), using the soil map of the Tuscany Region; *LS* is the slope length and steepness factor (dimensionless) derived using the algorithm proposed by Desmet and Govers (1996), computed using System for Automated Geoscientific Analyses (SAGA 2014) software and data from high-resolution (10 m) Digital Elevation Model (DEM) of the Tuscany Region; *C* is the cover management factor (dimensionless) calculated as weighted average of 11 different *C*-factors for all the crops or crop categories cultivated in Tuscany as reported in Table 1.

Table 1: C-factor for all the crops or crop categories cultivated in Tuscany used in the study.

Crop (or crop category)	**UAA* (ha)**	**% (on total arable land)**	**Crop C-factor**	
Wheat	122143	25.74%	0.20	Panagos et al. 2015b
Other cereals	29467	6.21%	0.20	Panagos et al. 2015b
Corn	13718	2.89%	0.38	Panagos et al. 2015b
Sunflower	18549	3.91%	0.32	Panagos et al. 2015b
Other industrial crops	11326	2.39%	0.30	Panagos et al. 2015b
Vegetable	10097	2.13%	0.34	Panagos et al. 2015b
Annual forage crop	69327	14.61%	0.30	Vallebona et al. 2016
Alfalfa	47412	9.99%	0.03	Vallebona et al. 2016
Other meadow	36505	7.69%	0.04	Vallebona et al. 2016
Pulses	17057	3.59%	0.32	Panagos et al. 2015b
Set-aside	98996	20.86%	0.22	Bazzoffi 2007

*UAA = Utilized Agricultural Area

In this study, erosion was estimated with *P*-factor = 1. Then, considering the maximum erosion limit (L) of 11 Mg $ha^{-1}yr^{-1}$ proposed by USDA Soil Conservation Service (1973), we estimated the *P*-factor values of the best agroforestry practices (*P*-bp) needed to keep the erosion risk under the proposed threshold.

Based on this, the estimated P-factor values were classified in three classes: (1) *P*-bp = 1, (2) 0.99 > *P*-bp > 0.1 and (3) *P*-bp < 0.1. The relative best agroforestry practices for the management of erosion vulnerability were associated to *P*-bp ranges according to Delgado and

Canters (2012): (1) border planting of trees or live-fencing (very low risk to low erosion risk); (2) alley cropping and multi-storey cropping (intermediate erosion risk) and (3) hedgerow contour planting (high to very high erosion risk). The soil loss mitigation rate was calculated as the difference between the average A and L value in each class.

Results and discussion

In the arable land of the study area, the R-factor ranged from 954 to 2,741 MJ mm h^{-1} ha^{-1} y^{-1}, similarly to what reported by Borrelli et al. (2016) in a national-scale study. The K-factor ranged from 0.015 to 0.044 (Mg h MJ^{-1} mm^{-1}), while the LS-factor showed the largest variation ranging from 0.001 to 103.64. The weighted average C-factor was equal to 0.21 due to the high presence of winter cereals in Tuscany, covering about 25% of the arable land (Table 1). The average soil loss rate ranged from 3.6 to 221.3 in class 1 and class 3, respectively (Table 2). Regarding support practices, the results of the study allowed to identify classes of agroforestry practices to keep the erosion risk under the threshold (11 Mg $ha^{-1}yr^{-1}$) as reported in the Table 2.

Table 2: Results of the estimation of erosion risk classes and P-factor values.

Class	**Erosion risk**	**Average soil loss rate* (Mg ha-1 yr-1)**	**Soil loss range (Mg ha-1 yr-1)**	**Soil conservation requirement**	**Best agroforestry practices**	**P-bp factor range**	**Surface (ha)**	**Class frequency**
1	very low to low	3.6	≤ 11	Conserve soil nutrients and fertility	Border planting of trees or Windbreaks	= 1	171,575	28.9%
2	Intermediate to high	38.6	11 - 110	Reduce erosion	Alley cropping and Multistorey cropping	0.99 - 0.1	348,311	58.7%
3	Very high	221.3	> 110	Stabilization of slopes and maintenance of ground cover to reduce soil erosion	Hedgerow contour planting of trees	< 0.1	73,577	12.4%

* Soil loss calculated using RUSLE Model and P-factor = 1

In particular, about one third of the cropland of the Tuscany Region was characterized by a low erosion risk with soil loss ratio under the recommended threshold (*P*-bp =1). These areas are mainly located in the coastal zone of the region and in the inland plain areas (Figure 1).

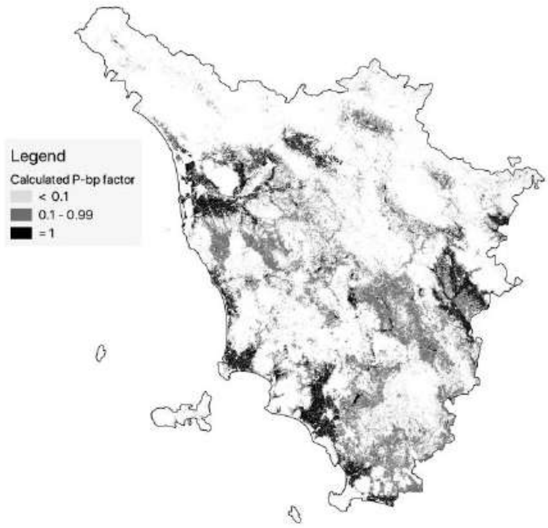


Figure 1: Map of the *P*-bp factor classes location in Tuscany Region.

In this case, agroforestry systems could contribute to conserve soil fertility and to reduce nutrient leaching by the implementation of silvoarable practices as windbreaks or border planting. However, the majority of the regional cropland (58.7%) showed *P*-bp ranging from 0.99 to 0.1, thus needing support practices to cope with an intermediate to high soil erosion risk. This class is mainly present in hilly inland areas due to their geomorphological characteristics that lead to higher vulnerability to water erosion. Thus, the introduction of alley cropping and multi-storey practices could be useful to maintain the soil loss risk under the recommended threshold in the hilly land of Tuscany Region. The area characterized by a very high risk (*P*-bp < 0.1) of erosion covers 12.4% of the investigated study area and it requires support practices to strongly reduce the soil loss, in order to stabilize and maintain slopes. In this case, agroforestry practices are more effective in increasing soil protection when combined with contour farming, as reported by other authors (Palma et al. 2007). The implementation of suggested agroforestry practices could prevent the loss of about 69.5 Mg Ha^{-1} Yr^{-1} of soil, calculated as the weighted average of potential mitigation rates of each proposed class.

Conclusion

In Tuscany, about 71% of the arable land suffers from intermediate to very high water erosion risk. Thus, the implementation of agroforestry practices, such as alley cropping and contour planting, should be encouraged in order to maintain the erosion risk under a tolerable soil erosion threshold. The potential soil loss could be reduced of about 69 Mg Ha^{-1} Yr^{-1} adopting appropriate agroforestry systems on about 422,000 ha of cropland, where the erosion risk is higher. To facilitate this process, regional policy-makers and advisors should be made aware of the potential ecosystem services provided by silvoarable systems through increased innovation transfer and networking activities.

References

Bazzoffi P (2007) Erosione del suolo e sviluppo rurale. In Fondamenti e manualistica per la valutazione agro-ambientale. Edagricole, Bologna.

Borrelli P, Diodato N, Panagos P (2016) Rainfall erosivity in Italy: a national scale spatio-temporal assessment. Int J Digit Earth 9: 835-850.

Delgado MEM, Canters F (2012) Modeling the impacts of agroforestry systems on the spatial patterns of soil erosion risk in three catchments of Claveria, the Philippines. Agroforst Syst 85: 411–423.

Desmet PJJ, Govers G (1997) Comment on “Modelling topographic potential for erosion and deposition using GIS.” Int J Geogr Inf Sci 11: 603–610.
ISTAT (2010). Agricultural census. http://www.istat.it/it/ censimento-agricoltura/agricoltura-2010. (accessed 17/02/2015).
Palma JHN, Graves R, Bunce RGH, Burgess PJ, De Filippi R, Keesman KJ, van Keulen H, Liagre F, Mays M, Moreno G, Reisner Y, Herzog F (2007) Modeling environmental benefits of silvoarable agroforestry in Europe. Agric Ecosyst Environ 119: 320–334.
Panagos P, Ballabio C, Borrelli P, Meusburger K, Klik A, Rousseva S, PerčecTadić M, Michaelides S, Hrabalíkova M, Olsen P, Aalto J, Lakatos M, Rymszewicz A, Dumitrescu A, Beguería S, Alewell C (2015a) Rainfall erosivity in Europe. Sci Total Environ 511: 801–814.
Panagos P, Borrelli P, Meusburger K, Alewell C, Lugato E, Montanarella L (2015b) Estimating the soil erosion cover-management factor at the European scale. Land Use Policy 48: 38–50.
Regione Toscana (2015) Uso e copertura del suolo della Regione Toscana 2007-2013. http://www502.regione.toscana.it/geoscopio/download/tematici/-ucs_rt_2013/index.html (accessed 15/12/2017).
Renard KG, Foster GR, Weesies GA, McCool D K, Yoder DC (1997) Predicting soil erosion by water: A guide to conservation planning with the revised universal soil loss equation (RUSLE). In Agriculture Handbook 703. Washington D.C., United States of America: United States Department of Agriculture (USDA).
USDA Soil Conservation Service (1973) Advisory notice. Soils-6. Washington DC, pp. 21.
Vallebona C, Mantino A, Bonari E (2016) Exploring the potential of perennial crops in reducing soil erosion: A GIS-based scenario analysis in southern Tuscany, Italy. Appl Geogr 66: 119–131.

SILVOPASTORAL AGROFORESTRY - AN OPTION TO SUPPORT SUSTAINABLE GRASSLAND INTENSIFICATION

McAdam JH[1*], Olave R[1], Fornara D[1]

(1) Agri-Food and Biosciences Institute, Newforge Lane, Belfast, United Kingdom, BT9 5PX

[*]Corresponding author: jim.mcadam@afbini.gov.uk

Abstract

Intensive and semi-intensive temperate grassland systems often revolve around landscapes which have poor ecosystem services delivery. This work demonstrates that the introduction of wide spaced trees in silvopastoral agroforestry systems can make these grassland landscapes more sustainable, deliver a wide range of ecosystem services and align with a sustainable grassland management strategy. The longer animals can remain on pasture in climates with high, unpredictable rainfall, the less ammonia will be emitted from the system. Silvopasture is shown to extend the grazing season to help higher grass utilisation and give resilience to grazing during extreme rainfall, while increasing short-term carbon storage and long term carbon sequestration.

Keywords: soil trafficability; water infiltration; carbon sequestration; reduced ammonia

Introduction

Agroforestry can be defined as the integration of agriculture and forestry on the same land unit. The interactions between the two components can be managed to produce a stream of production and environmental benefits over time. In silvopasture, a form of agroforestry, stock graze pasture between widely spaced trees. As such, agroforestry can be considered as a means of introducing trees into the farmed landscape while delivering objectives for sustainable grassland intensification. Agroforestry systems have been shown to be a welfare-friendly livestock system which delivers a wide range of ecosystem services (McAdam 2000) and economic predictions have been favourable (McAdam et al. 1999). To accelerate the pathway to a carbon neutral livestock system, a recent report (DAERA 2017) recommends that farmers should consider the benefits of establishing an agroforestry system on a proportion of their land to suit individual farm locations and catchments to add resilience to their grazing system in wet weather and allow earlier and later seasonal grazing. This paper reports the supporting evidence for this.

In Northern Ireland, current levels of grassland utilisation are low (in the order of 5t DM /ha/ yr DAERA 2017) in beef systems and most grassland systems are net carbon sources. It is also clear that, given the uncertain seasonal rainfall profile, grassland utilisation can be seriously impaired by soil trafficability. The longer animals need to be taken off pasture and housed, the greater will be the amount of ammonia emitted. Sustainable grassland intensification could be considerably facilitated by increasing the length of the grazing season through improved soil trafficability. Given predicted climate change for the region, the establishment of trees on pasture can reduce the flooding risk by significantly increasing the rate at which water can enter the soil, thus decreasing the flow of water into rivers and streams as well as creating drier grazing pastures for livestock.

Although the results reported here are from a large scale, long term silvopastoral trial, the objective of the study reported in this paper was to demonstrate that silvopastoral systems can increase the length of the livestock grazing season, a key feature towards sustainable grassland utilisation.

Materials and methods

A long-term silvopastoral agroforestry site was established in Northern Ireland at Loughgall, Co Armagh in 1989 (Sibbald et al. 2001) to compare three land use types - (1) a silvopastoral system with ash trees (*Fraxinus excelsior* L.) planted at 400 stems/ha, (2) planted woodland with ash trees (2,500/ha), and (3) permanent grassland. Soils at Loughgall are Brown Earth on Red Limestone Till with a soil pH range7.0 - 8.3, and clay content between 30 and 45%. There were 3 replicates of each treatment in a randomised block design, plots were approx. 1ha each and individually fenced. The trial has been consistently managed and documented since planting with some intensive periods of measurement. The trial was a unique resource to assess the long term impact of silvopastoral systems on a range of ecosystem services. Soil carbon storage was investigated by soil sampling to 20 cm and analysing carbon content by soil fraction size (Fornara et al. 2017). To estimate total carbon content in the tree component of the system, eight trees were completely excavated, soil washed off the stumps, the whole tree separated into leaves, twigs, small branches, large branches, trunk and roots (Olave et al. 2016) and carbon content assessed. Soil moisture content was measured weekly from 1st August 2016 until May 2017 (mean of 10 values per plot over 3 replicate plots per treatment) and soil resistance to penetration (a measure of infiltration potential) measured through the soil profile (to approx. 80cm) using a penetrologger weekly over Sept to Nov 2017.

Results and discussion

Carbon. 26 years after the conversion of permanent grassland to either silvopastoral or woodland systems, while tree planting on permanent grassland may not contribute to greater soil C stocks it may, in the long-term, increase the C pool of more stable (recalcitrant) soil micro-aggregate and silt and clay fractions, which could be more resilient to environmental change (Fornara et al. 2017). The mean carbon content of each tree was estimated at 336 kg and total C per unit area (at a tree density of 230 stems/ha) as 77.38 t/ha (Olave et al. 2016). Over the life of the crop this was an accumulation rate of 3.68 tC/ha/yr. Given that accumulation rates of C in permanent grassland are in the order of 1t/ha/yr and the nature of the carbon sequestered in the silvopasture, agroforestry has the potential to deliver a carbon neutral livestock system.

Soil trafficability. If a soil moisture content of 40% is taken as a notional limit for soil poaching to occur, between August 2016 and May 2017, the soil moisture content was below 40% for 17 weeks more in the agroforestry than the grassland (Figure 1).

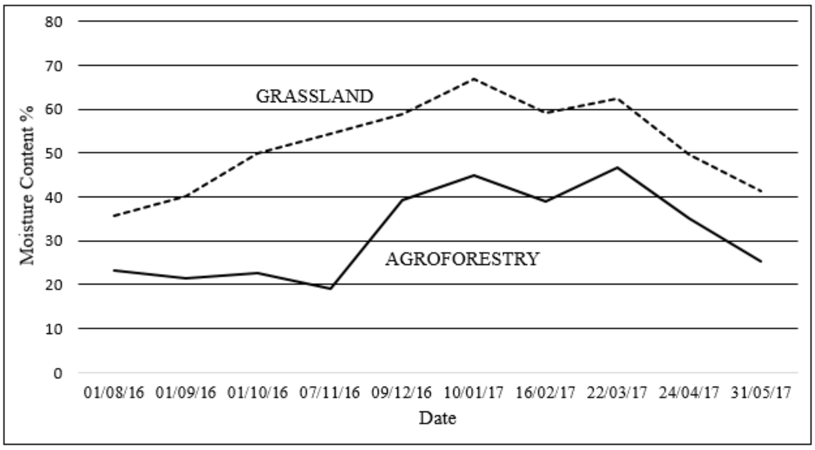


Figure 1: Soil Moisture from August 2016 to May 2017 from grassland and agroforestry in a long term (26yrs) grazing experiment at Loughgall, Co Armagh. (P<0.05 ese 3.506).

This represents a potentially substantial increase in grazing season length. As part of a rotational grazing strategy, agroforestry paddocks could be saved for grazing at the beginning or end of the grazing season and thus greatly increase grass utilisation.

Soil infiltration. The resistance to soil penetration (and hence infiltration) was greater in the agroforestry than the grassland to 76cm depth (Figure 2). Hence agroforestry has created a soil profile under grassland which will be much more resilient to potential flooding and predicted climate change and greatly increase the sustainability of grazed pasture.

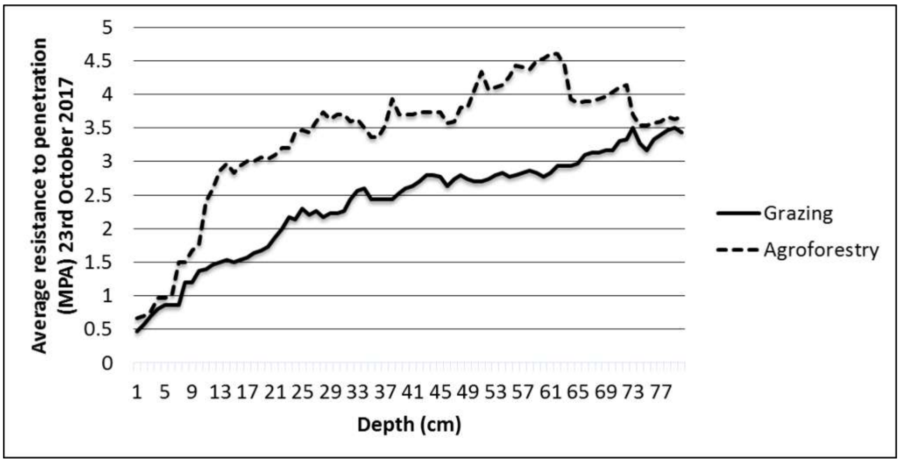


Figure 2: The average resistance to soil penetration (from Sept-Nov 2017) from grassland and agroforestry in a long term (26yrs) grazing experiment at Loughgall (P<0.001 ese 0.24).

Policy uptake. Economic predictions (McAdam et al. 1999) and farmer surveys of agroforestry have been favourable but it is when agroforestry is accepted for state support that on-farm planting is likely to increase. In 2015 agroforestry was included as an option in forestry measures in Ireland and in 2017 as an option in the DAERA Environmental Farming Scheme in Northern Ireland. In the latter, the planting and management specification stipulated was based on the research findings from the trial reported above. Uptake has been encouraging and these farmers will form the nucleus of a group of examples in practice which hopefully will encourage other applicants.

Conclusion

Silvopastoralism can reduce soil moisture, increase soil trafficability and thus significantly extend the grazing season to improve grass utilisation and sustainability.

References

DAERA (2017) Delivering Our Future, Valuing Our Soils; A Sustainable Agricultural Land Management Strategy for Northern Ireland. Department of Agriculture, Environment and Rural Affairs, Expert Working Group on Sustainable Land Management. https://www.daera-ni.gov.uk/topics/land-and-landscape/soilsps (accessed 21/04/2018)

Fornara DA, Olave R, Burgess P, Delmer A, Upson M, McAdam J (2017) Land use change and soil carbon pools: evidence from a long-term silvopastoral experiment. Agrofor Syst DOI 10.1007/s10457-017-0124-3.

McAdam JH (2000) Environmental impact of agroforestry systems. In: Hislop M et al (eds) Agroforestry in the UK. Forestry Commission Research Bulletin No. 122, pp 82-89.

McAdam JH, Thomas TF, Willis RW (1999) The economics of Agroforestry systems in the UK and their future prospects. Scottish Forestry 53: 37-41

Olave R, Higgins A, Sherry E, Fornara D, McAdam J (2016) Agroforestry as a land use option to sequester carbon in a cool temperate climate. World Congress Silvo-pastoral Systems. University of Évora, Portugal.

Sibbald AR, Eason WR, McAdam JH, Hislop AM (2001) The establishment phase of a silvopastoral national network experiment in the UK. Agrofor Syst 53: 39-5

COMPARISON OF OBSERVED DATA AND HIGH-RESOLUTION REGIONAL CLIMATE SIMULATIONS FOR PROCESS BASED MODELLING

Palma JHN[1*],Cardoso RM[2], Soares PMM[2], Oliveira TS[1], Tomé M[1]

(1) Centro de Estudos Florestais, Instituto Superior de Agronomia, Universidade de Lisboa, Tapada da Ajuda, 1349-017 Lisboa, Portugal (2) Instituto Dom Luiz, CGUL, Universidade de Lisboa, Lisbon, Portugal

*Corresponding author: joaopalma@isa.ulisboa.pt

Abstract

Land use management decisions rely more often on process-based models to provide information about climate change impacts. However, these models require climate data at a time scale and timeframe that is not frequently available for the area of interest. Modelled climate data is gradually becoming available at wide geographical scopes and increasingly finer resolutions. With the purpose of evaluating the use of modelled climate as an option for observational data, we compared the performance of a forest growth process-based model, using observed weather data and two datasets simulated with two climate models: a) the Regional Atmospheric Climate Model (RACMO) and b) the Weather Research and Forecast Modelling System and Program (WRF). Results suggest that there are minor losses in forest growth modelling performance while the best results occurred when using RACMO model and taking advantage of the higher spatial resolution. These results envisage further studies assessing impact of future climate.

Keywords: biophysical growth; datasets; IPCC; RACMO; WRF; climate change

Introduction

With climate change ahead, land use management decisions rely more often on process-based models to provide information about climate change impacts on the productivity of land use systems. Process-based models require climate data at a time scale and timeframe that is not frequently available for the area of interest. In the last decade different climate datasets have become available through the EURO-CORDEX initiative (Jacob et al. 2014) while some complementary tools have been developed to facilitate the use of datasets, either for calibration, validation, or simulation of forestry, agroforestry and agriculture process based modelling (e.g. Palma 2017). The use of modelled climate data to feed process based models seems an attractive resource due to its geographical scope and increasingly finer resolutions, being the only tool to characterize the future climate. However, comparison studies between biophysical simulations, e.g. forest growth, based on observed and modelled climate data is scarce. With the purpose of evaluating the use of modelled climate as an option for observational data, we compared the performance of a forest growth process-based model, 3PG (Sands and Landsberg 2002), previously calibrated for Eucalyptus (*Eucalyptus globulus* Labill.), when the inputs of the observational climatic data is replaced by regional climate simulations output. An evaluation of the quality of simulated datasets is here envisaged to provide support for assessments related to climate change where agroforestry is proposed as a land use to fight against climate change.

Materials and methods

Tree measurements were collected from different experimental plots from 1988 to 2013 located in different regions in Portugal representing wide climate range and soil variability. Trees' measurements included diameter at breast height and height, from which tree volume (following Tomé et al. (2000) equations) and total aboveground biomass and fractionated biomass per tree component (stem wood, stem bark, branches and leaves) with Antonio et al. (2007) equations were estimated. Tree values were summed up and reported to the ha and are designated as observed data. Measurements were available from 125 experimental from 12 sites with re-measurements during tree growth period, summing up 2682 tree measurements.

Resources of simulated climate data incorporated 1) the Regional Atmospheric Climate Model (RACMO) (van Meijgaard 2012) available through Clipick (Palma 2017) and 2) the Weather Research and Forecast Modelling System and Program (WRF) (Soares et al. 2012). Observed climate data was obtained through the Instituto Português do Mar e da Atmosfera (IPMA) and from the Serviço Nacional de Informação de Recursos Hídricos (SNIRH).

The evaluation consisted in the comparison of predicted growth of eucalyptus stands against observed data measurements when using 1) observed climate data (as a reference) and 2) regional climate simulated data. As the resolution of the simulated datasets is increasing, we further assessed if there is advantage of having finer resolution by testing simulated data from a grid coordinate a) near the weather station where the real climate data were registered (S) and b) near the plot of tree measurements (P).

Results and discussion

The reference performance of 3PG was the one achieved by the forest model previously calibrated (Fontes et al. 2006) with the observed climate data from the nearest climate station.

Figure suggests that when the forest growth simulations are based on simulated climate data, there are minor losses of performance in the forest growth predictions with an overall slight growth overestimation. The best performance with modelled climate was obtained with the RACMO model and when taking advantage of the high resolution of the datasets, i.e. enabling the use of climate near the location where trees grew, instead of using locations near the weather stations with measured data (Figure 1 RACMO P).

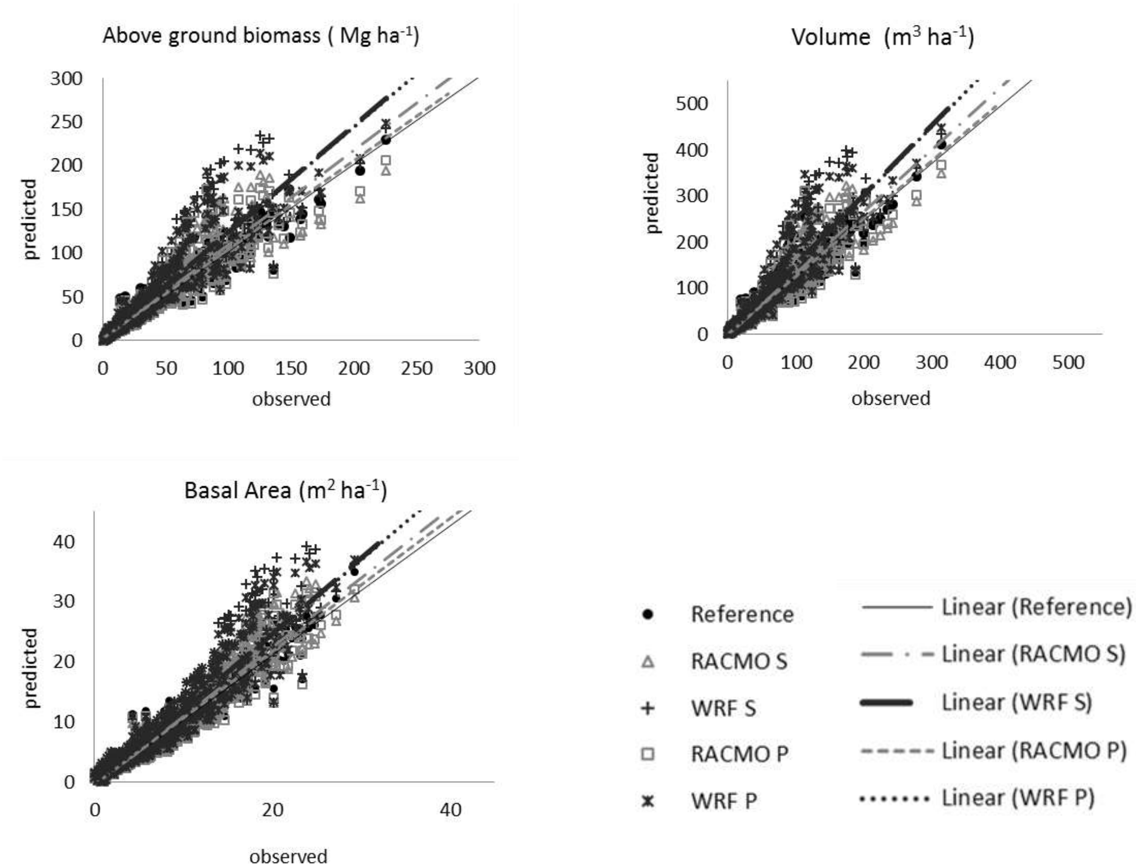


Figure 1: Observed and predicted above ground biomass, volume and basal area with simulations based on observed climate data from nearest station (reference), and simulated climate from models, RACMO and WRF, using coordinates near the observed climate station (S) and the tree plot (P).

A deeper analysis of the climate datasets suggests that improving the temperature accuracy of the climate model will reduce the overestimation of the predictions. The over estimation of minimum temperatures and the underestimation of maximum temperatures (Figure 2), creates better conditions for the optimal tree growth thresholds, i.e. more days when minimum and maximum temperature are near the optimal temperature threshold of 16º (Figure 2). Furthermore an over estimation of solar radiation may also be responsible for the overestimation of productivity. In fact, RACMO and WRF models seem to have a similar behaviour regarding temperature. However WRF consistently over estimates radiation and this seems to be the source of the productivity overestimation.

Despite the over estimations that can be improved in further developments of the climate models, Figure 1 suggests that by using the RACMO model, a reduced loss of forest growth models performance can be achieved with the use of simulated climate datasets.

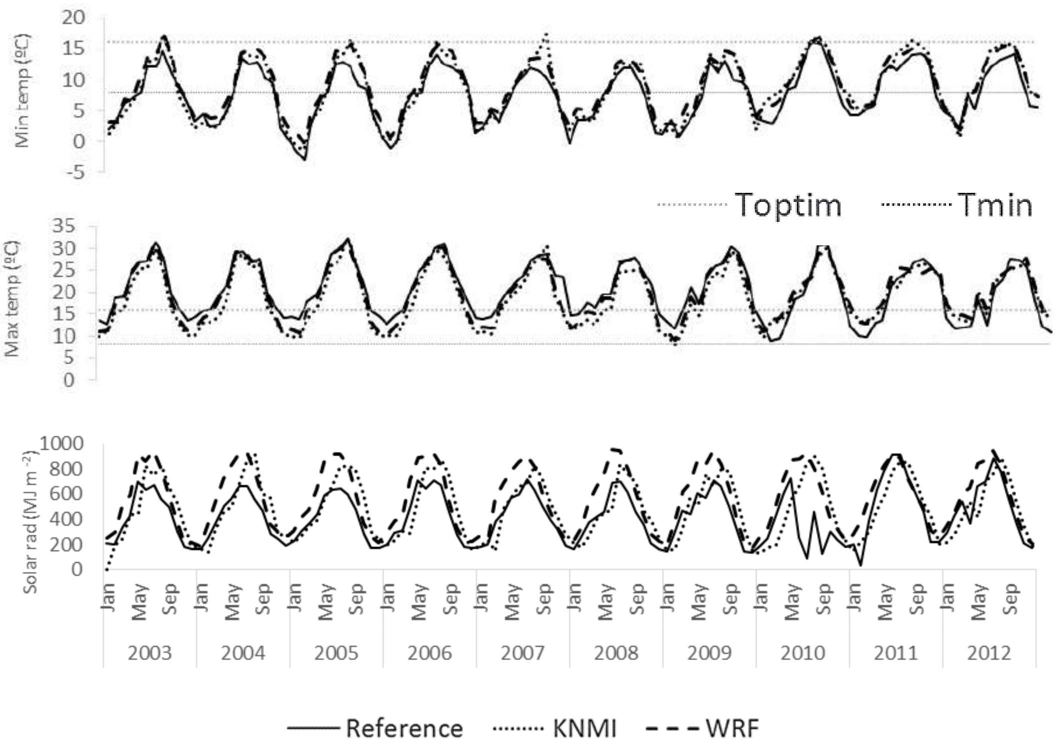


Figure 2: Reference (Observed) and simulated climate for the nearest coordinate of a location (Santo Varão – North West Portugal): average minimum and maximum temperatures (Tmin, Toptim are the growth thresholds for minimum and optimum growth temperatures) and solar radiation.

Eucalyptus is a fast growing tree species targeted in this study due to a large tree measurements database. However, these results are based on a process based biophysical interactions occurring in the model response to climate drivers. Therefore a similar mechanistic behaviour is expected regarding the response of other trees species relying on radiation, temperature and water resources.

Conclusions

This work recommends the use of simulated climate data with RACMO model, especially when the studies lack observed climate data or those are limited. The use of such data can certainly widen the usage of process based models, improving the support for decisions in land use management, especially when considering climate change, one of the cornerstones for what modelled climate is developed for.

Acknowledgements

We acknowledge support of ALTRI for providing access to eucalyptus data and the European Commission through the AGFORWARD FP7 research project (contract 613520). This work was also partially supported by the Portuguese Science Foundation (FCT) under Project SOLAR (PTDC/GEOMET/7078/2014) and CEF PEst (UID/AGR/00239/2013).

References

Antonio N, Tome M, Tome J, Soares P, Fontes L (2007) Effect of tree, stand, and site variables on the allometry of Eucalyptus globulus tree biomass. Can J For Res 37: 895–906.

Fontes L, Landsberg J, Tome J, Tome M, Pacheco CA, Soares P, Araujo C (2006) Calibration and testing of a generalized process-based model for use in Portuguese eucalyptus plantations. Can J For Res 36: 3209-3221.

Jacob D, Petersen J, Eggert B, Alias A, Christensen OB, Bouwer L, Braun A, Colette A, Déqué M, Georgievski G, Georgopoulou E, Gobiet A, Menut L, Nikulin G, Haensler A, Hempelmann N, Jones C, Keuler K, Kovats S, Kröner N, Kotlarski S, Kriegsmann A, Martin E, van Meijgaard E, Moseley C, Pfeifer S, Preuschmann S, Radermacher C, Radtke K, Rechid D, Rounsevell M, Samuelsson P, Somot S, Soussana JF, Teichmann C, Valentini R, Vautard R, Weber B, Yiou P (2014) EURO-CORDEX: new high-resolution climate change projections for European impact research. Reg Environ Chang 14: 563–578.

Palma JHN (2017) CliPick - Climate change web picker. A tool bridging daily climate needs in process based modelling in forestry and agriculture. For Syst 26(1), eRC01.

Sands PJ, Landsberg JJ (2002) Parameterisation of 3-PG for plantation grown Eucalyptus globulus. Forest Ecol Manag 163: 273-292.

Soares PMM, Cardoso RM, Miranda PMA, de Medeiros J, Belo-Pereira M, Espirito-Santo F (2012) WRF high resolution dynamical downscaling of ERA-Interim for Portugal. Clim Dyn 39: 2497–2522.

Tomé M, Tomé J, Ribeiro F (2000) Desenvolvimento de um sistema de apoio à avaliação da madeira em pé e povoamentos de eucalipto. Lisboa,Portugal.

van Meijgaard E, Van Ulft LH, Lenderink G, de Roode SR, Wipfler L, Boers R, Timmermans RMA (2012) Refinement and application of a regional atmospheric model for climate scenario calculations of Western Europe. Climate changes Spatial Planning publication: KvR 054/12.

DEVELOPMENT OF MULTI-USE CONCEPTS TO FIGHT AGAINST CLIMATE CHANGE IN THE PROJECT MUNTER

Wagener F[1*], Böhmer J[1], Seiler S[1], Thomas K[2], Plogmacher A[2]

(1) Institute for Applied Material Flow Management (IfaS), Environmental Campus Birkenfeld, Trier University of Applied Sciences, Birkenfeld, Germany (2) Department for Environmental Information Systems, Institute for Agroecology, RLP AgroScience GmbH, Neustadt/Weinstraße, Germany

*Corresponding author: f.wagener@umwelt-campus.de

Abstract

How can we make our landscapes resilient against climate change? And how can we even increase regional added value at the same time? How can village communities start over to manage these challenges commonly and not wait for the next problem to occur? Multifunctional land-use becomes feasible by regional economy and the development of individual solutions tailored to the local needs. The practical project MUNTER (funded by the EU and the state ministry MWVLW Rhineland-Palatinate through European Innovation Partnerships – 'Agricultural Productivity and Sustainability' – EIP agri, ELER) develops, implements and analyzes new land use options with energy crops that combine positive environmental effects with regional development aspects. One focus are agroforestry systems as a means of preventing erosion.

Keywords: agroforestry; energy crops; erosion prevention; climate protection; land use management; regional cooperation; material flow management

Introduction

For the people living in rural areas it is crucial that measures that contribute to environment and nature protection are not at the expense of regional economic cycles but ideally generate more added value and develop further opportunities for the region (Wagener et al. 2017). In the public discussion land-use-problems are often reduced to single factors. While the loss of biodiversity is repeatedly linked to the worldwide massive use of glyphosate, soil erosion is explained mainly through climate change and increased precipitation. The complexity of these issues remains unmentioned same on political level as well as in the media and in regional debates – the connection between geographical, technical, social and economic drivers in cultural landscape and their interactions are hardly ever explained in detail. However, in order to find sustainable solutions, it is necessary to take them into consideration. All this shows that a centralized common agricultural policy can only give a framework and not be seen as a guarantor for a regionally adapted sustainable land use. Solutions to regional land-use problems have to be found and implemented regionally. From the concern of individual municipalities and farmers, the practice project MUNTER[1] was born.

In most cases regional activities to counter floods and erosion are not pro-active and holistic. Involved key players rather tend to conform to their role and speak with a farmers or environmentalists voice than search for a common solution. The aim of MUNTER is to develop a management system for farmers and municipalities that allows for more environment and nature protection through an optimized energy plant cultivation. In concrete terms, tools for the strategic management of regional land use are developed by a cooperation of farmers, municipalities and other stakeholders. Partners at three project sites in two regions (Western

[1]"Development of a management system for farmers and municipalities for more environmental and nature conservation through optimized energy plant cultivation"

Palatinate and Vulkaneifel) in Rhineland-Palatinate are developing, implementing and improving multifunctional land use systems which offer ecological advantages and help to establish new value chains for regional bioenergy supply. The project team of three farmers, two institutes and one foundation together with the states´ water protection authorities design, implement and test big scale practical modifications in land use. Within the projects´ planning phase new land use and value chain options have been figured out in on site field workshops. Land use changes have been modelled in geographical information systems (GIS) and analyzed with regard to erosion protection. In the practical phase farmers, municipal representatives and experts put multi-use systems into place in such a way that they generate added value, that is being paid for (Wagener et al. 2017). These land use changes are monitored both ecologically and economically. An integrated material flow management makes sure that appropriate markets for the produced biomass can be established and generate local jobs and income.

So far the MUNTER team accompanies one location with an already established land use concept and two more that are going to be realized within the project. The synergies described can only be achieved through a moderated planning process. As a result, practical innovations in land use, taking social requirements into account, enable the development of new fields of business for agriculture at low social costs (Glemnitz and Wagener 2016).

Materials and methods

Starting point for MUNTER were the results of the previous project "Null-Emissions-Gemeinden" ("Zero Emission Municipalities") funded by the German Ministry of Education and Research (BMBF). As a result of a heavy rainfall event in 2014, considerable flood damage occurred in the municipality of Bisterschied (Western Palatinate). Two years earlier, a farmer had planted a small short rotation plantation in the surrounding lagerly cleared farmland above the village. After the flood it became obvious that the water runoff and soil discharge in this area was significantly reduced compared to the neighbouring fields. At the same time there was a discussion in the village about the renewal of the heating systems of several public buildings and the possible connection with other private households to a common energy supply. The idea to combine erosion protection, biomass production and climate protection in the village was started. In order to develop an integrated land use concept, the historical and current land use, the ownership structure of the agricultural areas, the water and biotope structures around Bisterschied were evaluated. On the other hand, the possibilities for a biomass-based joint district heating system or even a bioenergy village were discussed with municipal representatives. In a material flow analysis, initial calculations were made on achievable yields, raw material and heat demand.

In the following MUNTER project these results were taken up and continued. In addition to Bisterschied, the round of participants was extended by two further locations and numerous experts. This enables the consortium to benefit from an in-depth exchange of experience. Furthermore an extended research program is realized in MUNTER. Improved modelling of erosion protection effects with GIS helps in the targeted placement of new land use systems, mainly permanent crops for the production of energy wood and biogas substrates.

The GIS analyses on surface runoff and erosion effects of the agroforestry measures were conducted using terrain-based hydrological models. Agroforestry strips were implemented in GIS by modification of a high resolution (1m) digital elevation model (DEM) representing semipermeable relief barriers, which hold off runoff water and improve infiltration of water into the soil. Surface runoff was approximated by calculation of the specific catchment area, which is the accumulated contributing area of inflow for each of the DEM's raster cells. Runoff was calculated with and without consideration of the planned agroforestry measures. Comparison of those simulated values resulted in the measures‘ potential reduction effect on runoff processes.

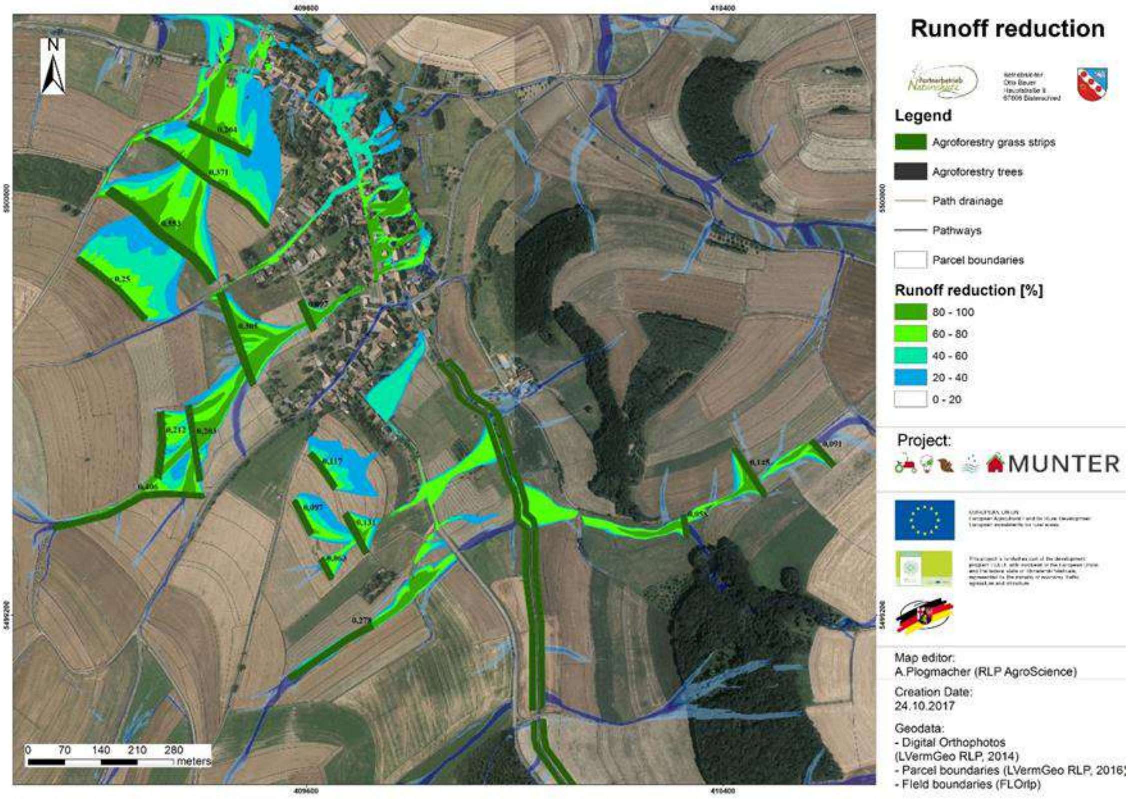


Figure 1: Drainage reduction through the cultivation of agroforestry strips around Bisterschied.

Agroforestry systems to protect Bisterschied (Western Palatinate)

The plantation of agro-wood strips has been evaluated in terms of their effectiveness to reduce erosion by a newly developed GIS-simulation for Bisterschied (Figure 1). An inspection of the site where different scenarios were applied was undertaken together with farmers to fit the agro-wood strips into the existing management structures. As a result, a map was created that shows the reduction of the runoff and therefore allows for a theoretical assessment and outlook in terms of the effectiveness of the energy hedges.

The community is now driving forward the development of the bioenergy village Bisterschied with these new wood potentials (Heck et al. 2014). The farmers shall gain an attractive price for the wood and the heat supply of the village shall be provided by renewable energies. If this connection works, climate protection and the adaption to climate change will be put into practice at the same time. The monetary resources of the village will stay within the village and will lead to an improved regional added value compared to a fossil-based energy supply (Wagener et al. 2016a).

Agroforestry systems to protect Rockeskyll (Vulkaneifel)

An agro-forestry system is being developed in Rockeskyll which is similar to the one in Bisterschied but will additionally contain a wild herb mixture at the lower part of the slope (Figure 2). This measure is necessary to achieve an additional reduction of erosion before the borders of the village.

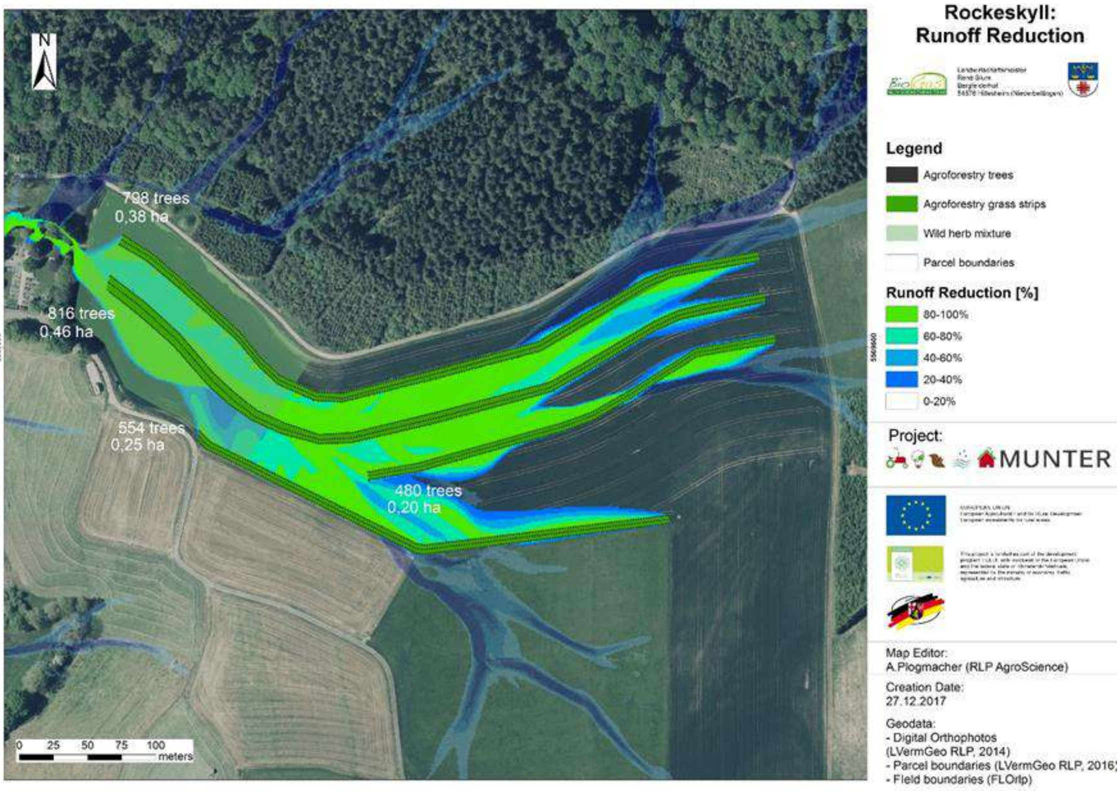


Figure 2: Drainage reduction through the cultivation of agro-wood strips und wild herb mixture

Wood and wild herb mixture are used for the heat provision of the existing neighboring bioenergy village Niederbettingen, too. The heat for the village is generated by a biogas plant and a woodchip heating system. At the moment first consultations are taking place in the neighboring Rockeskyll to inform the village about its possibilities of becoming a bioenergy village, too.

Water body restoration at Ingweiler Hof (Region of Westpfalz)

A former agricultural area in valley location of Ingweiler Hof has been transformed in the context of a water-management compensation measure. On the one hand, the course of the stream itself got restored and on the other hand, a cluster of agro-wood and a flood channel was implemented on the field (Figure 3). The flood channel breaks the dangerous flood peak of the stream. The poplars increase the pore volume and therefore enhance the absorption capacity of the agricultural area. The wider plantation spacing and individual gaps allow for the immigration of further tree species like black alder, birch, sycamore and oak. The biodiversity therefore increases and shall be evaluated in detail during the years 2019 and 2020 using different indicators of flora and fauna (Glemnitz et al. 2013, Wagener et al. 2016b).

The wood is used for providing a retirement home with heat. This measure again puts climate protection and the adaption to climate change into practice. Furthermore the biodiversity within and around the water body is increased without having to take agricultural land out of usage (Böhmer and Wagener 2013, Wagener et al. 2016). As a result, compensation measures can be developed that realize a high multifunctionality and regional added value by agricultural resource production (Böhmer and Wagener 2013; Wagener et al. 2013).

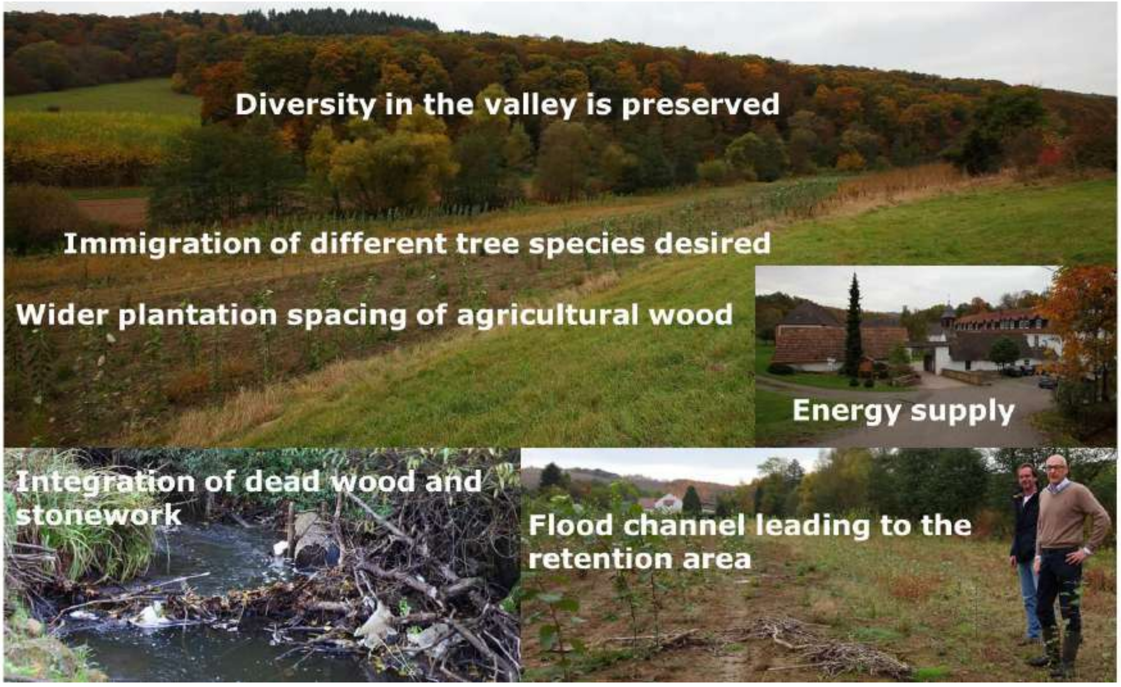


Figure 3: Water Compensation Measure in Germany

References

Böhmer J, Wagener F (2013) Agroforstsysteme als Kompensationsmaßnahmen – Ergebnisse aus drei Jahren Praxisforschung im Bundesverbundprojekt ELKE. In: Mitteilungen der Gesellschaft für Pflanzenbauwissenschaften (ed) Band 25. Verlag Liddy Halm, Göttingen, pp. 182–183.

Glemnitz M, Platen R, Krechel R, Konrad J, Wagener F (2013): Can short-rotation coppice strips compensate structural deficits in agrarian landscapes? In: Aspects of Applied Biology 118, Environmental management on farmland, pp. 153-161.

Glemnitz M, Wagener F (2016) Win-Win zwischen Energieproduktion und Naturschutz. In: Naturkapital Deutschland – TEEB DE (2016): Ökosystemleistungen in ländlichen Räumen – Grundlage für menschliches Wohlergehen und nachhaltige wirtschaftliche Entwicklung. Herausgeber Christina von Haaren und Christian Albert. Leibniz Universität Hannover, Helmholtz- Zentrum für Umweltforschung – UFZ. Hannover, Leipzig, pp. 138-141.

Heck P, Anton T, Böhmer J, Huwig P, Meisberger J, Pietz C, Reis A, Schierz S, Synwoldt C, Wagener F, Wangert S (2014) Bioenergiedörfer - Leitfaden für eine praxisnahe Umsetzung. Fachagentur Nachwachsende Rohstoffe e.V. (ed), Gülzow, 172. http://mediathek.fnr.de/leitfaden-bioenergiedorfer.html (accessed 18/04/2018).

Wagener F, Heck P, Böhmer J (2013) Schlussbericht „Entwicklung extensiver Landnutzungskonzepte für die Produktion nachwachsender Rohstoffe als mögliche Ausgleichs- und Ersatzmaßnahmen (ELKE) – Phase III – Umsetzung praxisbasierter Feldmodellprojekte, Forschungsvorhaben gefördert durch das BMELV über die FNR, FKZ 22007709, Umwelt-Campus Birkenfeld, 802. http://www.landnutzungsstrategie.de/elke/ergebnisse/phase-iii-umsetzung-erprobung-und-erforschung/ (accessed 18/04/2018).

Wagener F, Böhmer J, Heck P (2016a) Multifunktionale Landnutzungskonzepte. In: Deutsche Landeskulturgesellschaft (Hrsg.): Flächenkonkurrenz entschärfen: gemeinsam –maßvoll – zukunftsfähig. Schriftenreihe der Deutschen Landeskulturgesellschaft 14: 53-73.

Wagener F, Böhmer J, Heck P (2016b) Produktionsintegrierter Naturschutz mit nachwachsenden Rohstoffen - Leitfaden für die Praxis. Natur und Text, Rangsdorf.

Wagener F, Böhmer J, Heck P (2017) Entwicklung eines Managementsystems für Landwirte und Kommunen für mehr Umwelt- und Naturschutz durch einen optimierten Energiepflanzenanbau. In: Böhm C. (ed) Tagungsband 5. Forum Agroforstsysteme. Cottbus, pp. 175-184. http://nbn-resolving.de/urn:nbn:de:kobv:co1-opus4-41487 (accessed 18/04/2018).

Session

Testimonies of farmers from Europe

VARKENSBEDRIJF NEIMEIJER: EXPERIENCE IN DEVELOPING AN AGROFORESTRY SYSTEM FOR PIGS

Neimeijer N[1], Neimeijer J[1], San Giorgi X[2], Dawson A[2*], Kleijer G[3], Cremer H[4]

(1) Varkenshouderij Neimeijer, Heino, The Netherlands (2) Food Forestry Development, Utrecht, The Netherlands (3) Veterinary adviser, Utrecht, The Netherlands (4) Biomühle + Kräuterfutter GmbH, Kleve, Germany

*Corresponding author: info@FoodForestry-Development.nl

Abstract

Varkensbedrijf Neimeijer is an organic pig farm with a vision of local, regenerative and resilient food production. They are developing an agroforestry system for their pigs with the goal of producing healthy meat in a natural and economically feasible way, with a strong connection with the local people. The study explores how to achieve this and considers questions concerning: pig health, breed, meat quality, suitable agroforestry system, species choice and management. A literature review, expert consultation, design sessions and on farm trials were used to answer these questions. This highlighted the opportunities and challenges in developing this new system and the likely impacts that different choices would have on the farm. This resulted in a diverse multistory silvopastoral system being chosen to supplement the pigs diet with fruits, nuts, herbs and fodder leaves. The farm is in the early stages of implementation and further results are expected in the future.

Keywords: pig farm; agroforestry; animal health; medicinal herbs; organic; design

Introduction

Varkensbedrijf Neimeijer is the pig farm of Nieske and Jeroen Neimeijer. Since taking over the farm in 2012 they have been pursuing their vision of local, regenerative and resilient food production. Their first step was the transition to organic, but they wanted to go beyond this; to produce healthy meat in a natural and economically feasible way, with a strong connection with the local people. They saw agroforestry as their opportunity to achieve this.

In 2016 they brought together a team, made up of agroforestry designers, a veterinaire, and a feed expert and together they began to turn their vision into reality. The key questions at the beginning of the project were:

1. How can we support pig health?
2. Does this impact the quality and nutritional value of the meat?
3. What is the most suitable agroforestry system for the pigs?
4. What are the most suitable species for the system?
5. How to manage the pigs within this system?
6. What is the impact of an agroforestry system on the farms environmental impact?

Materials and methods

Theory of change – was used to help map out how activities and interventions will lead to the desired change. It is a method used for the planning and evaluation of change. The approach is to define the long-term goals and assess if the necessary preconditions can be achieved that lead to the goal. The method helps to show the distinction between desired change and what will actually be achieved.

Literature review and expert knowledge – A review of practical and scientific literature, in addition to the expert knowledge of the team members provided the basis for making informed decisions.

Experimentation – Many of the interventions are novel, or have little prior documentation, so the effects, interactions and optimization have yet to be fully explored. Thus, explorative trials are used to test some of the interventions.

Design – The knowledge gained through the consultation, literature review and experiments is used in the design of the overall agroforestry system for the farm.

Results

Health was one of the key factors in the farm development. We explored three main aspects that influence pig health: environment, breed and feed. In changing the environment, warmth, shelter and freedom from parasites were important considerations. For the pig breed, the intrinsic characteristics of the breed, or hybrid, were important. Different breeds have different qualities, for health, outdoor hardiness, litter size, mothering ability, foraging ability and so forth. Some breeds we considered for their characteristics were: Duroc, Saddleback, Berkshire, Large Black and Gloucestershire Old Spot. In our system we sought to find the balance between a breed good for outdoor production and one that satisfies the desired meat quality characteristics. Much of the available information on rare pig breeds were anecdotal, as scientific literature was limited, consequently this will be a stepwise breeding process. Finally, feed was explored. As we predicted, the feed a pig consumes has a large impact on its: health, growth rate, carcass composition, meat flavor and meat nutritional composition (Frankic et al. 2009; Cho et al. 2012; Rossi et al. 2013). Lack of certain nutrients leads to nutrient deficiencies, which may lead to an increased incidence of diseases, sickness and death. Conversely, many studies show that medicinal herbs, such as oregano, can be used to support pig health. Different medicinal herbs are known to have different effects, and have been used effectively to: reduce diarrhea, reduce infections, and support the digestive system. In standard use, dry herbs are added to feed, however, we have also explored the opportunity to use fresh herbs. Research shows that when the environment allows, animals carry out their own health promoting behaviors (Morris and Keilty 2006). Thus, part of the ongoing development is to explore if the animals will self-medicate. Interestingly, we also found literature that supported the idea that when pigs are fed a healthier diet they can produce meat that is healthier for the consumers. Thus, providing support for: healthy feed, healthy pigs, healthy meat. Current, research doesn't show changes to the meat quality characteristics due to herbal supplementation, but that oxidative status and sensory attributes can be improved (Rossi et al. 2013).

Of the different types of agroforestry possible silvopasture offered the greatest opportunity to meet the different needs of the farm. Of particular importance were: the integration of herbs with tree crops, providing a suitable environment for the pigs and creating a manageable system. The silvopasture system permits a high diversity of species and allows a medicinal pasture to be grown amongst seasonal fruit and nut trees. Species choices were determined predominantly by the suitability for the location, health value for the pigs and production capacity. By exploring different combinations of pasture and tree crops we obtained an insight into the crops contribution to the pigs' diet in general. This led to the initial sketch design of the farm seen in Figure 1. Here the large grass fields are divided into smaller plots surrounded by trees, creating smaller fields where rotational grazing can be performed.

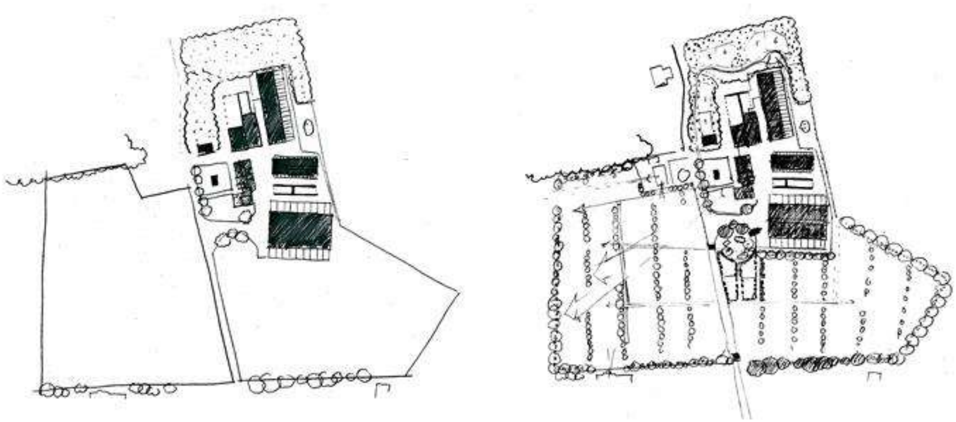


Figure 1: Left, the original farm with surrounding pastures. Right, the concept sketch of the farm as a silvopasture pig farm.

Management of the different elements is a key challenge. As seen in Figure 2 the pigs can be quite destructive to the pasture. Through developing new pasture mixtures, rotational management and breeding for grazing behavior, it is expected that a more permanent pasture can be achieved. Thus, improving forage production and supporting soil health. If a permanent pasture can be achieved, with rows of trees, then additional environmental benefits are also expected to be achieved, such as improved: carbon sequestration, rainwater infiltration and biodiversity. However, these aspects have yet to be studied in detail.

Figure 2: The common impact of pigs on pasture, the boundary between the grass and the bare soil is where the electric fence was placed.

Discussion

The development of the farm towards a silvopasture system for pigs shows promise to achieve the initial vision. The effect of different feed and genetics is already having an impact on pig health and this is expected to increase as the system becomes more established. Further monitoring will be necessary to assess the final impacts on both pig health and the nutritional quality of the meat. An additional study is also being carried out to access the impact on the ecosystem, and an assessment of the economic pros and cons of the system is planned in the future. The study has provided valuable information to support and oppose different decisions during the design of the farm. During the farms' ongoing development additional experiments will continue to aid in the optimization of the final silvopasture system.

References

Cho JH, Zhang S, Kim IH (2012) Effects of anti-diarrhoeal herbs on growth performance, nutrient digestibility, and meat quality in pigs. Asian Austral J Anim 25: 1595.

Frankic T, Voljč M, Salobir J, Rezar V (2009) Use of herbs and spices and their extracts in animal nutrition. Acta Agric Slov 94: 95-102.

MorrisT, Keilty M (2008) Alternative health practices for livestock. John Wiley and Sons.

Rossi R, Pastorelli G, Cannata S, Tavaniello S, Maiorano G, Corino C (2013) Effect of long term dietary supplementation with plant extract on carcass characteristics meat quality and oxidative stability in pork. Meat Sci 95: 542-548.

INTEGRATING TREES IN FARM INCUBATORS TO IMPROVE SUSTAINABILITY AND EFFICIENCY OF PRODUCTION SYSTEMS: A COLLABORATIVE AGROFORESTRY PROJECT

Person S[1*], Leblanc J[2], Aubertin C[2]

(1) Forest Goods Growing – Montpellier – France (2) TERRACOOPA – Montpellier – France

*Corresponding author: forestgoodsgrowing@gmail.com

Abstract

Terracoopa is a business and employment co-operative dedicated to farmers, landscapers and advisors in agriculture and environment. It provides a legal frame and a support to their business, and generates co-operation between those entrepreneurs. Terracoopa also offers to organic vegetables producers a farm incubator near Montpellier in the south of France, designed for 8 producers. Trees are at the heart of many skills and activities within the cooperative. Pursueing an old wish to integrate trees in the farm incubator, exchange meetings, questionnary on line and fields observations with farmers were realized. Main constraints and expectatives about agroforestry project have been identified. Three agroforestry projects were selected: fruit-bearing and windbreak hedges, country mixed hedge and orchards for poultry. The faisablity and oportunities of such arrangements in this specific case, with significant turn-over, short test period, widest diversity of profiles and projects and limitation of the dedicated area, are discussed.

Keywords: farm incubator; collaborative project; organic vegetable; fruit - bearing hedge

Introduction

The cooperative Terracoopa

Terracoopa is a business and employment co-operative dedicated to farmers, landscapers, environmental professionals, consultants and trainers in agriculture and the environment. It supports their installation and creation of activities through a collective dynamic, a legal hosting and pooling of the means of production. Its beginnings are relatively recent (December 2011).

Each project holder after a reception and support phase is invited to test his activity over a few months or several years as part of a business project support contract (in French Contrat d'Accompagnement au Projet d'Entreprise: CAPE). When the activity stabilizes the project holder can be an entrepreneur-employee-associate.

Domaine de Viviers - a farm incubator

The farm incubator is situated in an old farm called domaine de Viviers, near Montpellier in the south of France. Today there are 7 entrepreneurs experimenting in organic vegetable or aromatic plants production. In total the farm has 10 ha of organic farmlands at the entrepreneurs disposal although everyone gets a greenhouse of 400m² and 4500m² of fields.

The cooperative helps non-farm community people who want to start farming as a retraining but who also want to do it as safely as possible. Indeed, the cooperative can provide farmland and equipment in a farm incubator. Everyone can test their activity for up to three years and then look for land available for installation. In a wish to promote a mode of sponsorship and follow-up of the newcomers, the possibility to continue to develop an activity within the site is proposed for one candidate.

Trees at the heart of the businesses and activities of the cooperative

Trees are at the heart of many skills and activities within the cooperative: landscapers, pruners, agricultural producers (tree growers, nurseries...) and consultants / trainers (ecological engineering, agroforestry and forest management, permaculture...). Different types of projects have been proposed by project holders with an agroforestry dimension.

Within the cooperative

The first solicitations date from 2014 for the establishment of an organic market garden orchard and of an orchard for poultry. The first project was not able to materialize following a change in land allocation by the community, preferring a more traditional agricultural project without an agroforestry dimension. The other project was carried out by a pair oriented towards the production of organic eggs in peri-urban (agglomeration of Béziers). Due to significant health problems of the project holder, the project could not be completed.

Within the farm incubator

The question and the opportunity to integrate trees in the farm incubator were requested from the beginning of its creation. However, the very specific status of this space posed many constraints and limitations to the implementation of such arrangements: i)a significant turn-over which limits the follow-up on intraparcellar perennial installations; ii) the test period (<3 years) which does not guarantee a "return on investment" for project promoters; iii) the need to ensure the widest diversity of profiles and projects and therefore test plots; iv) the limitation of the dedicated area especially compared to the many requests.

Added to this are other contextual constraints related to the youth of the test space: "break-in" period of farm incubators in these early years: priorities in terms of development and management that have relegated this issue to the background.

An original initiative was born in 2015 supported by two permaculture trainers and producers with the creation of an edible forest garden.

Materials and methods

Meetings and prior exchanges

Informally, exchanges took place between the market gardeners and other entrepeneurs (consultants and trainers) within the cooperative on the interest and the possibility of agroforestry development on the site (Figure 1). Some market gardeners received training on agroforestry (April 2015). The project has regained interest with the arrival of new farmers sensitized to and trained in agroecology and questioning the desirability and feasibility of installing a vegetable orchard on their plots.

Figure 1: Exchange meetings.

Questionnaire and exchange meetings

An on-line questionnaire was sent to all market gardeners asking them about the main production constraints, main needs and expectations of the latter in terms of possible solutions and agroforestry developments. Two exchange meetings were organized on the basis of the returns of the questionnaire. They have helped to refine and clarify the expectations of each and the means available.

Results

Farmers' observations and expectations

The main constraints and needs are that farmlands are situated in a plain with a small stream flowing in the lower part. The climate is Mediterranean, with rainy winters and dry hot summers. Some of the problems that have been noticed by the farmers are:

i) Strong sunlight and high temperatures that make the work rather hard in the fields during the summer.

ii) Flooding in the lowest part of the fields rendering the land unusable for vegetable production during the rainy season. Participatory mapping of regularly flooded areas and wetlands has been established. There is a significant problem of flooded soils during some periods that can range from 15 days to a month and that strongly limits cultivation. Some areas (wetlands) are particularly affected (Figure 2).

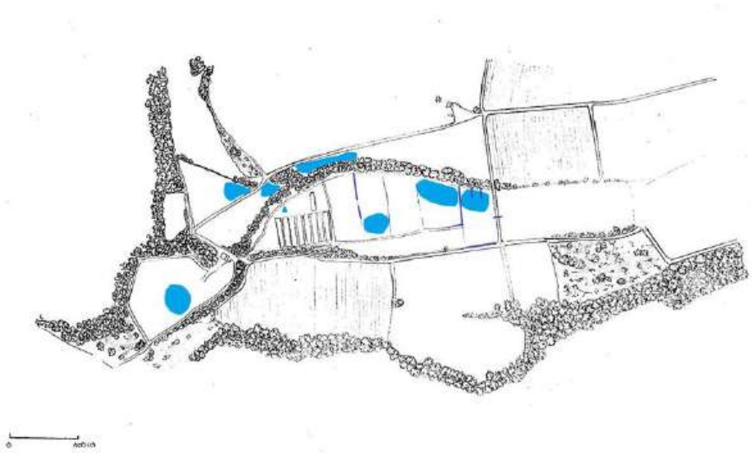


Figure 2: Location of main flooded areas in rainy season.

iii) The wind is troublesome on the plain during seasonal transitions (spring / autumn). It seems to have an impact on crops and dries soil very quickly on the surface, even much faster than when there is strong sunshine. This is particularly the case in the height of the summer period. Watering to compensate for this evapotranspiration can be doubled (according to the farmers).

These are the most important things in the area and they are also sprayed with chemicals that concern the contractors as they can smell it when they are working in their fields.

Beneficial effects of existing hedges on crop auxiliaries (ladybug) maintenance are cited by some of the vegetable growers. Beehives have been set up close to the farmer’s fields, they contribute to a greater pollination of plants.

Farmers are willing to see the establishment of agroforestry plots on the farm. They are all aware of the benefits that it could provide and have some expectations in mind:

i) Some of them would appreciate to be able to harvest some fruits on the farm, such as pears, apples, berries, for autoconsumption or selling. These productions could complement and diversify the basket of vegetables they proposed to their customers.

ii) Some of them would use the wood for different purposes (organic matter for their farmlands, firewood for personal use..).

iii) An orchard could be a favorable environment for the hens they already have in common on the farm.

Main proposals

After these exchange meetings and observations, we can propose these following agroforestry projects (Figure 3):

i) Installation of fruit-bearing and windbreak hedges. These hedges will separate on a line north / south plots in the field of each market gardener with a length ranging from fifty to a hundred meters. They will be installed on the grass strips already present and separating the parcels. The choice of fruit species was focused on species in production outside the peak season of market gardening in late summer and autumn: pear, apple, pomegranate, quince.

ii) Restoration of country mixed hedge : this hedge is planned on the southern part of the space and is intended to separate and protect the vegetable parcels from the neighborhood of vineyards cultivated in a conventional way.

iii) Creation of orchards for poultry: Part of the land is now underused because of the poor quality of its soils. Currently it serves as a course for the ten laying hens raised in common. An orchard for poultry could be set up with local species and pomegranates, fig, almond trees…

Knowing all these parameters, we have to figure out how to design the project together to make it fits everyone's wishes and motivations. We need to think about an effective procedure to make them take decisions together.

Also we should not forget to design something that will not penalize a future entrepreneur joining the co-op, and something that can be sustainable even after the transition period during two entrepreneur's procurement.

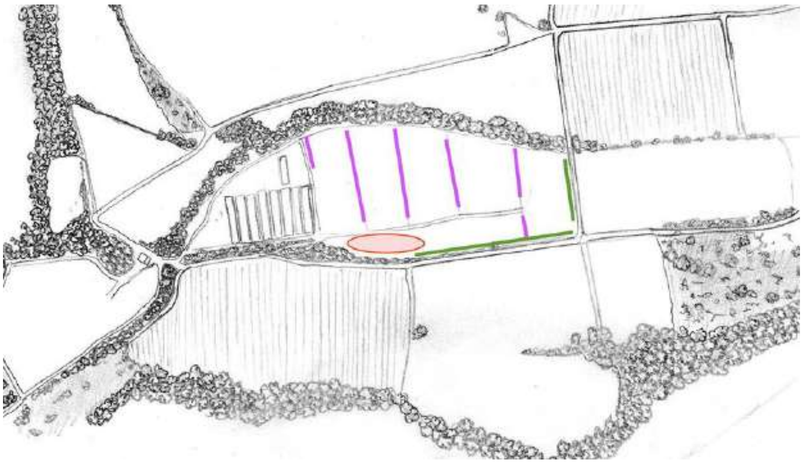


Figure 3 : Location of future agroforestry developments: in green country mixed hedge, in purple fruit-bearing hedge, and in red envisioned location of the futureorchard for poultry

Discussion

Agroforestry management on a farm incubator poses specific problems directly related to the function of such a space, and imposes a compromise between real and precise expectations and the nature of the implications of each actor. Such facilities are also part of a series of equipment and investments intended to improve the efficiency of the test space and the means of production.

Many answers remain to be found concerning the precise division of tasks necessary for the implementation of these facilities, their monitoring and management. If the establishment of fruit-bearing hedges seems to find a compromise in terms of investment, it is in particular thanks to a balance between investment and production expected.

But this first work showed us the relevance of a collective co-construction at different scales and times that can evolve according to the carriers of projects hosted by the test space, and the farm incubator itself. So other future agroforestry developments have been identified, like the establishment of an intraparcellar vegetable orchard2 and could be included in the future.

Finally, such arrangements can be valuable and strategics tools for experimentation, demonstration, promotion, or even training to support future project holders in organic agriculture and especially in peri-urban organic market gardening.

Conclusion

Designing an agroforestry project in a farm incubator leads to the same questions as for every agroforestry project : immediate costs for long-term gains ; competition for natural resources between trees and the other crops, versus positive effects and retroactions ; need for multiple use trees and not only hedges of timberwood. But in the case of a farm incubator, we had to face those questions with a diferent focus : who will pay and work for the plantation, as producers are expected to leave after a few years, before getting the benefits? How to get an adaptable design that still allow new incomers to develop new activities?

In the same time, the advantages of this particular context were taken into account : investing capacity and long term vision of the cooperative, beyond the sum of each of the producers; risk and resources pooling within the cooperative; opportunities for fundraising with the institutional presence of the cooperative. More opportunities have not been used yet, such as the periurban location of the farm that could bring some visitors and pedagogical activities.

It is admitted that agroforestry makes farms more resilient; in the case of farm incubators, resilience and design has to be built at the scale of the whole system.

OOSTWAARD – MULTISTRATA AGROFORESTRY SMALLHOLDING

San Giorgi X[1, 2*]

(1) Oostwaard, Maarssen, The Netherlands (2) Food Forestry Development, Utrecht, The Netherlands

*Corresponding author: Xavier@FoodForestry-Development.nl

Abstract

Oostwaard has changed over the years from a monastery court to a traditional farm, to a diverse multistrata agroforestry system. In 2015 they planted 2.4 ha with over over 225 species with the aim of providing themselves, local markets and restaurants with a wide variety of produce, year-round. Additionally, they have sheep, cows, horses, bees and in the near future they plan to establish a market garden. The project is strongly integrated with the local community. This form of multistrata agro-forestry system is both a forest and a form of agriculture that until recently was an unknow typology for the local planners. By working with the local planners this became the first multistrata agroforestry project, to be legally acknowledged as a form of Agriculture in the Netherlands.

Keywords: Oostwaard; multistrata agroforestry; local land-use plan; local community

Introduction

Oostwaard was known from around 1200 AD to the Reformation as a monastery court of St. Stevens Abbey in Utrecht. Over the centuries it has been through many changes. Currently the 3rd generation of the family Peek lives there, who first started there as farmers. However, due to the expansion of the city a new highway was constructed in the 1990s, cutting off a big part of their agricultural land. Consequently, they stopped their farming practice.

After years of limited use, in 2015 they started to plant a 2.4 ha multistrata agroforestry system, on part of the remaining 8 ha (Figure 1). This consists of over 225 species with the aim of providing themselves, local markets and restaurants with a wide variety of produce year-round. Additionally, they have horses, bees, sheep and cows and in the near future would like to establish a market garden on their farm.

Here we present success and stress factors in the transition into agroforestry.

Figure 1: Bottom picture after the planting the grass grew high and delineates the area of the multistrata agroforestry system. Top picture taken after the second season of growth.

Legislation and multifunctional land use

The transition from a farm to an estate with agricultural land resulted in changes to the way the local government and the province of Utrecht define the land use of the terrain. In order to become an estate, it is obliged by law to have 1/3th of the property as forest or an alternative ecosystem from which wildlife will benefit.

The multistrata agroforestry system is both a forest and a form of agriculture, which up until recently was an unknow typology for the local planners. Due to a change in the municipal land use plan, the opportunity arose to adopt this new typology of farming, which thus far is unknown in land use planning permits in the Netherlands. This makes Oostwaard the first agroforestry project in the Netherlands to be labeled in the local planning as a Food Forest, wherein Food Forest is described as a regenerative farming practice. This is unique since there is currently no official Agroforestry or Food Forestry policy in the Netherlands.

Market potential

Due to the scale and aims of the project, it would not have been commercially viable to grow one type of produce and sell it wholesale. The obvious choice therefore was to grow a diverse array of unique products (Figure 2). Thus, different clusters of plant species were chosen which favor similar ecological and climatic conditions. Where possible they are planted in polycultures to create favorable conditions for each other.

To meet the aim of growing unique crops which could be sold at local farmers markets or to restaurants. Because of this over 225 species have been planted, within which there is a diverse array of cultivars to explore taste and see which cultivars to grow in greater numbers at a later stage of the project.

Figure 2: Example harvest in the second year. Left picture *Pyrus pyrifolia* (Asian pear) and on the right *Prunus dulcis* (Almond).

Social engagement

In addition to the commercial aspect of the project, it also aims to revive local food and also develop knowledge about the produce and maintenance of multi strata agroforestry systems in The Netherlands. For instance, due to the relatively small scale of the system and high diversity it is impossible to have mechanical harvesting. Thus each crop each crop will be harvested by hand. As each crop has its own ripening period, harvesting method and maintenance learning these characteristics and optimizing them is an important aspect of the project.

Social engagement of local people is also very important. The local community has been highly involved in the project, in order to learn and to help out harvesting and maintaining the system. In a way they are ambassadors of the project for the years to come. The success of the project will largely depend on how it will be adopted and embed in the local area.

Therefore the planting of the project has been done together with over 150 volunteers of whom many return and help on volunteering days for maintenance and harvest. These volunteering days start off with an explanation and update on the project, a well-organized lunch and a nice drink at the end of a hard days of work (Figure 3).

Figure 3: Volunteers of the project.

Biodiversity

By changing a large portion of the former grass and maize field into a multistrata agroforestry system there is also a substantial change in habitat. In order to attract new wildlife several elements have been added to the system. For instance a pond was dug to enhance the water habitat, birdboxs for Great tits or Robins were added and also nestboxes for birds of prey such as the screech owl and kerster (Figure 4). The main idea is to increase the biodiversity and therefore create a more balanced ecosystem which will aid pest control.

Figure 4: Pond establishment.

Discussion

It is of great value that the local council has recognized and labeled the multistrata agroforestry system as a sustainable form of agriculture in their municipal land use plan (Figure 5). This is an example and could inspire other municipalities and projects to adopt the same typology in their land plans. However, since each municipality in the Netherlands has one or more unique land use plans it is not yet adopted nationwide. Therefore each unique land use plan would have to be changed in order to have the same typology recognized by other municipalities. Thus other types of policy changes are necessary in order to have Agroforestry recognized as a form of agriculture on nation wide basis and be of value to all farmers. Thus other making it easier for other farms or estates to develop this form of agriculture.

Social engagement is both important for the maintenance and success of the project but also part of a re-education process towards growing and buying our food more locally. Though the multistrata agroforestry system will grow an abundance of food, the harvesting and processing of it will be more labor intensive than mechanized agriculture. Therefore success will depend on how well the community develops around the project which can both support and benefit from it.

Due to the legislation of being an estate increasing the biodiversity in both flora and fauna are important aspects. In the coming years we should see how the increase of plant diversity will impact the local biodiversity of insects, animals and birds.

Figure 5: Design of the multistrata agroforestry system.

SILVOPASTORAL AGROFORESTRY FOR RURAL ENVIRONMENT SUSTAINABILITY AND VALORIZATION OF THE REGION OF GUARDA AND SERRA DA ESTRELA, PORTUGAL

Simões MF[1*], Tomás A[2], Paulo JA[2]

(1) Agronomist Engineer (MSc) – Advisor (2) Centro de Estudos Florestais, Instituto Superior de Agronomia, Universidade de Lisboa

*Corresponding author: manuel.felizes@hotmail.com

Abstract

In the region of Guarda, Portugal, silvopastoral systems play a very relevant part in the local economy. These systems are characterized by an integration of oaks and shrubs, high altitude and permanent semi-natural pastures, and a varied range of livestock production (some of which represent autochthonous species). This communication highlights the fact that the improvement of the production of these systems goods (like meat, milk, cheese) implies a more integrative management. The trees effect over pastures must be acknowledge, in order to have more productive, higher quality and longer availability of pastures. Also, the contribution of fruits (acorns) and leaves (ash branches) to the livestock diet should be further analyzed, alongside the need to consider the introduction of grassland species with soil improvement capabilities and higher nutritional value.

Keywords: silvopastoral systems; livestock management; high altitude pastures; rural development

Introduction

Guarda district is located in the central interior of Portugal. Part of it is enclosed within the Serra da Estrela Natural Park (Figure 1) (ICNB 2009). In this region, agricultural activities are strongly connected with high altitude pastures, where livestock silvopastoral management has a pronounced economic and landscape expression, despite the fact that the land property average size tends to be are very small, fragmented and dispersed. The altitude specificity, which gives a marked differentiation to these systems, has created conditions for a natural improvement of regional breads of sheep, goats and even bovines, and ensures the presence of several endogenous tree species that are not frequently distributed in other regions of the country. This communication describes the silvopastoral systems encountered in the region, and discusses available options for pastures improvement, including the importance of tree fodder has a complement for the farm self-sufficient feeding of the animals. It concludes on the importance of further research on these systems components.

Figure 1: Delimitation of the region of Guarda and Serra da Estrela Natural Park (Portugal).

Wood and shrub pastures

Some of the vegetation types found in Guarda and, particularly, in Serra da Estrela, include cervum and juniper (*Juniperus communis*) communities for the upper zone, several oak species (*Quercus pyrenaica, Quercus rotundifolia* and *Quercus suber*), chestnut (*Castanea sativa*) and ash (*Fraxinus angustifolia*) forests along with shrub areas of *Cytisus* sp., *Lavandula* sp., *Erica* sp. and *Genista* sp. for the intermediate zone, and *Pinus pinaster* plantations in the basal zone (Távora 1985; ICNB 2009). Meshed within these forest and shrubs mosaics are herbaceous clearings that are used as areas of permanent natural or semi-natural pastures (Ribeiro and Monteiro 2014), and serve as the main fodder resource for livestock is this region.

This livestock production consists mainly of pork (Bísaro) and cow (Limousin, Charolais and autochthonous Jarmelista cattle) for meat production, goat (autochthonous Serrana and Jarmelista goats (autochthonous)) and sheep (Lacaune and autochthonous Bordaleira Serra da Estrela and Churra Mondegueira) for production of meat, milk and cheese.

Of particular importance as a tree cover are the oak species that are, generally, found in the higher and more drained areas, and used for wood, biomass and tree fodder (leaf and acorns) collection (Castro and Fernández-Núñez 2016). Acorn, oaks fruit, is a carbohydrate-rich food with a high strategic interest for ruminant feed in this region, as it occurs at a time of the year (after the first autumn rains, usually from October to December) that allows it to value the low nutritional quality of pastures verified at that time. The management of these trees, in particular the promotion of the tree regeneration is of particular relevance for the long term sustainability of the farms, presenting similar challenges to the ones usually found in the *montado* and *dehesa* systems (Paulo et al. 2016).

Valorising trees within permanent semi-natural pastures

“Lameiros” are another traditional system of permanent semi-natural pastures normally located next to water lines. Their contribution to animal grazing and its maintenance is done through direct grazing and cutting for hay production. Despite its local importance, it is difficult to assess their extent area due to lack of official inventory data (Paulo 2015).They involve trees that are included either randomly or in hedges, borders and/or in riparian forests lines (Figure 2). Traditionally placed for field demarcation, these trees are important for fire wood consumption, animal fodder, soil protection from water or wind erosion (Pereira et al. 2004), pasture improvement (Pereira et al. 2005) and for animal welfare, namely, by serving as a natural shelter in defence against rain and wind in winter and by providing shade in summer.

Figure 2: "Lameiro" with pollarded trees in its hedges during summer (left photo) and winter (right photo) seasons (Guarda, Portugal).

High altitude pastures improvement

The main improvement needs are related with the increment of the dry matter production, the increase of the period were natural pastures are available, and the improvement of the pasture quality (Simões and Simões 2014). This can be achieved by studying the existing species adaptability (Moreira 1998), by increasing awareness of farmers about the importance of tree fodder by coppice and pollarding practices, the introduction of other species with soil improvement capabilities and higher nutritional value (like the legume *Trifolium subterraneum* L.) (Pires et al. 1994) and the study of the right timings for grazing (Amaro 2009) and its spatial control (e.g. through the use of fences).

Silvopastoral systems as a way to improve regional development

Silvopastoral agroforestry, as a sustainable system of land use, it is important not only for the production of livestock but also, and consequently, for the human occupation of the territory. Its applicability to marginal land areas, that do not have fitness for another type of activity, prevents them from remaining abandoned and conducive to biomass accumulation (Henriques and Lourenço 2013), potentially combustible under certain adverse climatic conditions (such as those which characterized the year 2017) (Silva 1965a, b; Castro 2008). In addition, the reconciliation of pasture with the native forest allows the recycling of nutrients through direct grazing and the accumulation of organic matter through the foliage fall of the trees, the fixation of atmospheric nitrogen in the soil through the pasture legumes and the reduction of greenhouse gases in the atmosphere through the carbon sequestration.

Agroforestry is therefore essential for sustainable territorial planning, landscape preservation and environmental prevention against climate change and forest fires. Likewise, it's a way against the depopulation of the rural environment by promoting the regional economy, the development of endogenous products and the preservation of noble and characteristic products of the region such as the Queijo da Serra da Estrela, Borrego da Serra da Estrela, Cabrito da Beira, among others.

The farm advisor point-of-view: further research needs

Considering the importance of the mentioned agroforestry systems, there are still voids to be filled when applying them. These systems need some long term studies to determine the interactions between the different system components: pasture, tree, shrub, and livestock. For instance, acorns have nutritional components that seem to help livestock digest some pasture elements. The importance of tree fodder, shrubs, fruits and berries in terms of nutritional content and management practices (best timing to integrate them in the diet) in the livestock feeding is another topic in need of further evaluation and that would lead to the determination of the system's carrying capacity considering all its components. This implies a real need for technical assistance to the small farmer, more rural extension and integration between research, experimentation and application (Simões 2015).

Conclusion

In summary, the importance and potential of silvopastoral agroforestry for this region is very high. Besides the evident need for further pasture improvement, there's clearly also a knowledge gap in the farmer's traditional management plan related with the best ways and techniques to work with the other layers of these kind of systems, such as the tree cover. Not only considering the effects that trees can have on the pasture development and quality (by means of win-win interactions, particularly in terms of microclimate definition) but also as another livestock fodder input (fruit and branches) of the system precisely in times where the pasture is no longer available. This may even mean that investing in trees may actually translate into less expenses for the farmer, since they may delay the pasture senescence and decrease the need for forage buying in times of pasture scarcity.

Along these lines, research is indispensable for the knowledge and potentiation of this region natural resources, as well as for preserving the diversity of its products, for it is in the diversity that lies the richness and the affirmation of a region or a country in a globalizing strategy.

References

Amaro D (2009). Maneio de lameiros. DRAP-N

Castro M (2008) A utilização dos pequenos ruminantes na prevenção dos incêndios rurais: estratégia pró-activa de promoção silvopastoril. In Moreira MB, Coelho IS (eds) A silvopastorícia na prevenção dos fogos rurais. ISA Press. pp 159-175.

Castro M, Fernández-Núñez E (2016) Sistemas silvopastoris em Portugal: componentes, funções e funcionamento. In Fernández-Núñez E, Castro M (eds) Management of agroforestry systems: ecological, social and economic approaches. Instituto Politécnico de Bragança.

Henriques SA, Lourenço L (2013) Incêndios florestais no distrito da Guarda. Fatores desencadeantes e consequências ambientais. Cadernos de Geografia 32: 157-173.

ICNB (2009) Plano de Ordenamento do PNSE – Caracterização.

Moreira N (1998) O melhoramento das pastagens de montanha. Pastagens e Forragens 19. pp. 51-80.

Paulo JA, Crous-Duran J, Palma J (2015) Initial Stakeholder Meeting Report Traditional Agroforestry Systems in Central and Northern Portugal. AGFORWARD.

Paulo JA, Crous-Duran J, Firmino PN, Faias SP, Palma JHN (2016) Report describing the components, structure, ecosystem services, and economic value of selected HNCV agroforestry systems. Deliverable 2.4. AGFORWARD.

Pereira EL, Madeira M, Monteiro ML, Raimundo F (2004) Influence of ash tree (*Fraxinus angustifólia*, Vahl) on soil quality and herbaceous productivity in pastures of the Northeastern Portugal. Revista de Ciências Agrárias. Volume XXVII. 1: 347 – 360.

Pereira EL, Madeira M, Monteiro ML (2005). Assessment of shade and nutrients addition effects on biomass of natural pastures of Northeast Portugal. Revista de Ciências Agrárias. Volume XXVIII. 2: 297-311.

Pires JM, Aguiar Pinto P, Tavares Moreira N (1994) Lameiros de Trás-os-Montes Perspectivas de futuro para estas pastagens de montanha. Instituto Superior Politécnico de Bragança, Portugal.

Ribeiro S, Monteiro A (2014) Pastagens permanentes em zonas de montanha: caracterização, gestão e conservação. Revista de Ciências Agrárias 37: 131-140.

Silva J (1965a) Conceito de Organização Silvo-Pastoril: valorização ecológica de interesse pecuário. DGSFA - Estudos e Informação 209, Lisboa.

Silva J (1965b) Breve análise do problema silvo-pastoril e seus reflexos num plano de fomento pecuário. DGSFA - Estudos e Informação 212.

Simões M, Simões F (2014) Melhoramento de Pastagens Permanentes de Altitude – Projecto PRODER 40490. Jornadas Técnicas Pastagens e Forragens. Agroraia 2014.

Simões M (2015) Melhoramento de pastagens permanentes de altitude. Revista Ingenium nº 150, II Novembro/Dezembro.

Távora J (1985) As pastagens do Parque Natural da Serra da Estrela. Relatório de Estágio do Curso de Engenheiro Silvicultor, ISA.

JANMIEKESHOEVE: AN ORGANIC DAIRY FARM IN TRANSITION TO A BIODIVERSE AGROFORESTRY SYSTEM

Heesakkers J[1*]

(1) Janmiekeshoeve, Mariahout, The Netherlands

*Corresponding author: bio@janmiekeshoeve.nl

Abstract

The Janmiekeshoeve is an organic dairy farm in Noord-Brabant (The Netherlands). The long-term aim of the farm is a sustainable farm, where modern economic challenges are faced from a nature-bases ideology. Agroforestry seems to have the key to our wishes. The farm has just started the transition towards this goal. The design process is in full swing and many ideas have and we have many ideas and possibilities in how to actually design the land. But whether we should go for fruit trees, or nut trees, and what crops to combine them with. This is where we would really appreciate some ideas from you. In order to not only have a long term income but also a short term income, as we have to live from the land, we feel that a good agroforestry design can combine biodiversity, soil restauration, cattle grazing, short term income of short rotation crops and long term income of fruits, nut and timber. However, the exact crops and combinations, we are working on. That is were we would appreciate all suggestions from other participants.

Keywords: cattle; trees; biodiversity; transition; suggestions

Introduction

Janmiekeshoeve is an organic dairy farm in Noord-Brabant, The Netherlands, currently 45 ha on dry sandy slightly loamy soils. We come from a long line of farmers who have been working on the land for at least three centuries, turning age-old barren moorlands into fertile farmlands (Figure 1). Our long-term aim is to have a sustainable farm, where modern economic challenges are faced from a nature-based ideology thus creating a healthy and future-proof business.

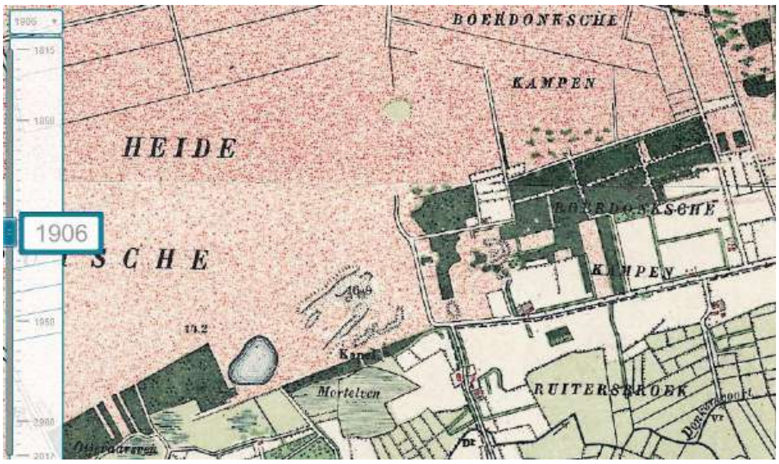


Figure 1: Barren moorlands in the early 20th century.

Because of certain developments around us we are at this point in time given the opportunity to acquire an additional plot of 17 acres bordering on our present farmlands. This provided a natural opportunity to think about the desired transition to a sustainable and future-proof business (Figure 2). Thus we are now in the process of designing plans on this transition and how to incorporate these new lands into our farm and ideology. This new business will preferably, ultimately be run by the younger generation of the family, the family that has been farming here already since 1781.

The field concerned was originally developed by my own grandfather, which adds a sentimental motivation to all other reasons for wanting to buy this piece of land.

Figure 2: Location of future agroforestry.

Materials and methods

First and foremost we are an organic production farm. From an ecology point of view we also want to positively contribute to nature and the environment, whereas at the same time we need our farm to provide us with a stable income.

Implementing restoration agriculture will allow us to participate in an already existing government program of creating extensive natural ‘corridors’ allowing wildlife to roam freely across large areas formerly subdivided into fenced-off fields (Natuurnetwerk Brabant (NNB)).In our case, the to-be-developed agroforestry fields will eventually connect the long stretches of forest West of our farm to those on the North. As a bonus our participation in the above-mentioned larger program will make us candidate for financial aid from the government, compensating for part of the investmentcosts of the whole project.

To fulfill the requirements of NNB we could, of course, simply plant these fields with thousands of trees and create a new belt of biodiverse forest in between the already existing ones. In due time then we could harvest the trees for their timber. This would serve our ecological ideology, but not our need to also now live from the proceeds of our land.

This is why we are attracted the idea of agroforestry. This type of farming will allow us to enhance the development of more nature and biodiversity on the new fields by growing (multipurpose) trees, while at the same time and on these same fields allowing us to grow crops and graze cattle (Figure 3). So through agroforestry we combine the necessary shorter-term harvest and income with a more natural and sustainable aspect. In devising our agroforestry plans (Figure 3) for these new fields we have support from a number of consultants:

- Adviesbureau 5voor1, a financial consultancy bureau on sustainable issues,
- Land&Co, marketing consultancy specialized in advising organic farmers in transition.
- Bosgroep Zuid Nederland, a cooperation of private forest owners, who not only partake and advise in the planning process, but also offer support in several aspects of the actual implementation of the plans.

Figure 3: Cattle on the move (left) and making new plans (right).

Discussion

At the convention, the provisional design for our farm will be presented. This design will be a spatial design, but without the exact species. It will have the outlines of a new way of farming. By presenting our plans, we hope to receive comments, suggestions and hopefully answers to some of our questions, from people already more experienced in agroforestry. Moreover, it would be very helpful if people come up with specific problems we have to be aware of in these kind of processes. We are farmers producing food and we want to combine this in the best possible and ecological way with trees on the farm. Some questions we have; what type of trees would be best to grow on our dry, sandy, slightly loamy soils? We are thinking of fruit-trees and berry-bushes or nuts like chestnuts and walnut as main crops.

- What types or cultivars would be preferable and why? In terms of starting to produce and long term production. Could we in some way anticipate climate changes in these plans? Would certain types of trees e.g. prosper better than others in our changing weather conditions?
- What are other farmers' experiences with manual versus machine harvesting of nuts?
- What are other farmers' experiences in grazing cattle combined with rows of nut trees?

Conclusion

Janmiekes farm is a family farm, an organic cattle farm, with the long term goal to be a sustainable farm, where modern economic challenges are faced from a nature-based ideology Agroforestry seems to be able to offer this: a stable and short-term income from the cattle and additional crops and a long term income from tree produce and additional a growing biodiversity on the farm. At the moment the design process is in full swing and advice, specifically on suitable species for this farm, is very welcome.

Session

Environmental benefits of agroforestry

AGROFORESTRY, GRASS, BIOMASS CROP, AND ROW-CROP MANAGEMENT EFFECTS ON SOIL WATER DYNAMICS FOR CLAYPAN LANDSCAPES

Alagele SM[1]*, Anderson SH[1], Udawatta RP[1, 2], Jose S[1, 2]

(1) School of Natural Resources, University of Missouri, Columbia, MO 65211, USA (2) The Center for Agroforestry, School of Natural Resources, University of Missouri, Columbia, MO 65211, USA

*Corresponding author: smaz22@mail.missouri.edu

Abstract

Soil water use and water storage varies by vegetative management practice and these practices affect land productivity and hydrologic processes. This study investigated the effects of perennial vegetative management systems of agroforestry buffers, grass buffers, and biomass crops, relative to row crop management on water use for a claypan soil in northern Missouri, USA. Results showed significant differences in weekly soil water content among treatments for all four soil depths. Soil water content decreased more rapidly during the summer in agroforestry buffers, grass buffers, and biomass crops compared with the row crop treatment. During recharge periods, a larger increase in soil water content due to better infiltration was observed in the perennial vegetative management practices relative to row crop areas; this can be attributed to enhanced soil pore characteristics (macroporosity) due to changes in soil carbon in agroforestry, grass, and biomass areas. The results showed that vegetative management practices can significantly influence soil water use and storage compared to row crop areas, particularly for eroded claypan landscapes, and these findings can be used to address challenges of soil and water conservation.

Keywords: soil water use; vegetative management practice; claypan soil; recharge periods

Introduction

Vegetative management approaches can help to improve water storage and to reduce transport through the soil profile; these changes can reduce nutrient and pesticide runoff for enhanced sustainable agricultural production (Bharati et al. 2002). A study conducted by Anderson et al. (2009) found that that agroforestry buffers contributed to reduced soil water content compared with row crop areas. Agroforestry practices have also increased water infiltration rates and storage. On the same watersheds, Sahin et al. (2016) showed that agroforestry buffers had lower soil water content than row crop areas during the summer season; however, the infiltration rate was higher within agroforestry buffer practices relative to row crop areas during water recharge periods. Increased water storage under agroforestry and grass buffers has contributed to reductions in surface runoff from row crop areas (Udawatta et al. 2011a). In addition, agroforestry buffers can reduce soil water through enhanced water consumption, and this reduced soil water content will improve water infiltration and may decrease surface runoff, nutrient, and pesticide losses. However, a good understanding of water use within the soil profile is needed to improve water use efficiency under management practices and to design sustainable management practices including agroforestry buffer strips and biomass crops (Anderson et al. 2009; Mulebeke et al. 2010). The objective of this study was to quantify water use, recharge, and storage by perennial vegetative practices and row crops for a claypan soil in northern Missouri, USA.

Materials and methods

The experimental site with three adjacent north-facing watersheds (West, Center, and East) was located at the University of Missouri Greenley Memorial Research Center, Novelty, Knox County, Missouri, USA (Figure 1). Agroforestry buffer (AB), grass buffer (GB), and row crop (RC) treatments were randomly assigned to the watersheds in 1997. The GB (West) and AB (Center) watersheds consisted of 4.5-m wide buffer strips at 36.5-m spacing. The areas between buffers were planted to a corn–soybean rotation with a no-till practice beginning in 1991. In the GB and AB watersheds, birdsfoot trefoil, brome grass, and redtop were planted with pin oak trees, swamp white oak trees, and bur oak trees planted at 3-m apart down the center of the grass-legume strips of the AB watershed in 1997. Biomass crop (BC) was a switchgrass and winter peas mixture which replaced the RC areas in the West and Center watersheds in 2012 between buffers. The dominant soil in this study area was mapped as Putnam silt loam, and it has a drainage restrictive B horizon with a claypan soil. The 30-year average annual precipitation of the experimental site is 920 mm, of which more than 66% falls from April through September.

Volumetric soil water (VSW) content was determined by Campbell CS-616 (Campbell Scientific Inc, Logan, UT) sensors installed at 5-, 10-, 20-, and 40-cm depths with three replications. Sensors were connected to an AM16/32 multiplexer and the multiplexer was connected to a CR23X-4m data logger to record VSW at 10-min intervals (Udawatta et al. 2011b) from the middle of April 2017 to November 2017. VSW were extracted from the datalogger at 12:00 noon each Friday. Sensor readings were calibrated for VSW by regular gravimetric water content determinations and Equation (1) from Udawatta et al. (2011b).

$$\theta v = -0.311 + 0.0193 \times r \qquad (1)$$

Where:

θv: Volumetric water content

r: Period of the signal.

The General Linear Model (GLM) and least significant differences (Duncan's LSD) (P<0.05) procedures in SAS determined statistical significance for VSW among treatments, soil depths, and treatment by depth interactions (SAS Institute 2013).

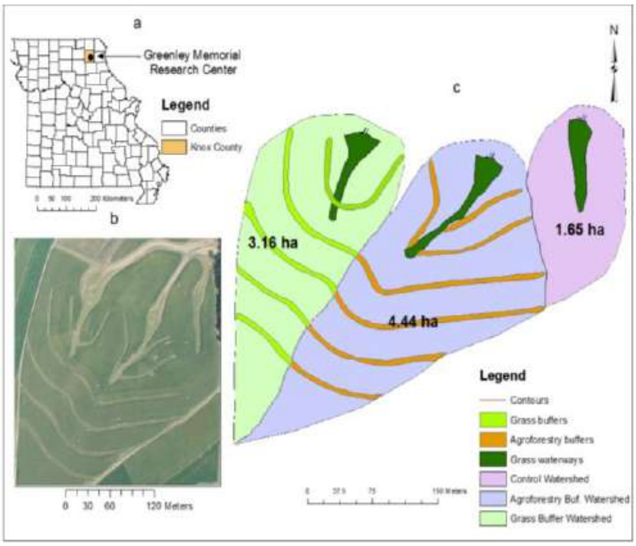


Figure 1: (a) Location of the study site in Missouri, USA (b) Aerial view, and (c) land management maps for the GB (West watershed), AB (Central watershed) and RC (corn-soybean rotation, East watershed) watersheds. All three watersheds have grass waterways at the downslope. Areas between the grass and agroforestry buffers are managed with biomass crops since 2012.

Results and discussion

Significant differences ($P<0.05$) among VWC were found by vegetative management practices, sampling depth, and the interactions between treatment and soil depth. Significant differences also occurred for the three contrasts: 'RC vs others', 'buffers vs BC', and 'GB vs AB'.

Higher VWC occurred during most weeks after May 5 for AB, BC, and RC treatments compared to the GB. Lower VWC occurred during three summer drawdown periods for the AB, GB, and BC treatments compared to the RC; these periods included (i) 2-9 June, (ii) 7 July to 18 August, and (iii) 1-29 September. Soil water content was higher for the RC management compared to AB, GB, and BC treatments in these periods due to more water use by trees, grass, and switchgrass (Anderson et al. 2009). Also, this decrease in VWC for the perennial vegetation may help to reduce nutrient and sediment runoff during subsequent rainfall events after these drawdown periods as well as improve water recharge in the soil profile.

Precipitation events of 50, 92, and 83 mm on 16-17 June, 21-22 August, and 5-6 October, respectively, recharged soil water content, with greater increases in VWC in the buffer and biomass treatments (Figure 2). Higher water content in the perennial management treatments relative to RC can be attributed to better root systems which were created by AB, GB, and BC compared to the annual RC root system (Udawatta et al. 2011a; Zaibon et al. 2017). The BC and RC treatments had higher VWC compared to buffer treatments from 13 October to 17 November, but there were no significant differences among the treatments.

VWC was significantly different among soil depths averaged across the treatments. For 5 cm depth, average soil water content readings ranged from 0.46 m^3 m^{-3} on 14 April to a low of 0.29 m^3 m^{-3} on 9 June, from 0.50 m^3 m^{-3} on 30 June to a low of 0.25 m^3 m^{-3} on 18 August, and from 0.38 m^3 m^{-3} on 1 September to a low of 0.24 m^3 m^{-3} on 29 September. After recharge, VWC values changed to 0.45, 0.42, and 0.45 m^3 m^{-3} on 16 June, 25 August, and 6 October, respectively. Average water content for 10 cm depth followed a similar pattern as the 5 cm depth, but higher water content values occurred within this depth. Generally, the lower and higher water content values pre- and post-recharge periods in the buffers and biomass crops may be attributed to higher root density and greater root decay at the surface (0 – 10 cm). These root system effects improve soil structure by creating deeper root systems which increase the proportion of macropores and add organic matter, and subsequently reduce surface runoff particularly in claypan landscapes (Rachman et al. 2004; Kumar et al. 2008; Zaibon et al. 2017). Also, these researchers have reported that below the 0 – 10 cm depth, the influence of root systems begins to decrease. For the 40 cm sampling depth, water content values were the highest compared to the 5, 10, and 20 soil depths except on 14 April, 28 April, 5 May, 26 May, 16 June, and 30 June. This was probably because bulk density for the 40 soil depth was lower than other depths due to an increase in clay content and subsequent swelling of clays through these subsoil horizons.

Three principle recharge periods occurred on 15 June, 24 August, and 5 October. The water content values in the AB, GB, and BC increased more after recharge periods compared to values for the row crop treatment (Figure 2). These higher water content values in the buffer and biomass treatments were probably due to the long-term perennial vegetative management. These perennial systems have an improved macroporosity which helps water better infiltrate into the soil (Anderson et al. 2009; Sahin et al. 2016). Interestingly, AB, GB, and BC had lower water content in the pre-recharge periods compared to the row crop treatment, but equal or sometimes slightly higher water content in the immediate post-recharge periods compared to the row crop treatment. This was probably due to higher transpiration and more water depletion by trees, grasses, and biomass treatments relative to row crops (Anderson et al. 2009). However, as trees mature root pruning, removing branches, and thinning may be needed to reduce the competition for resources (Senaviratne 2012).

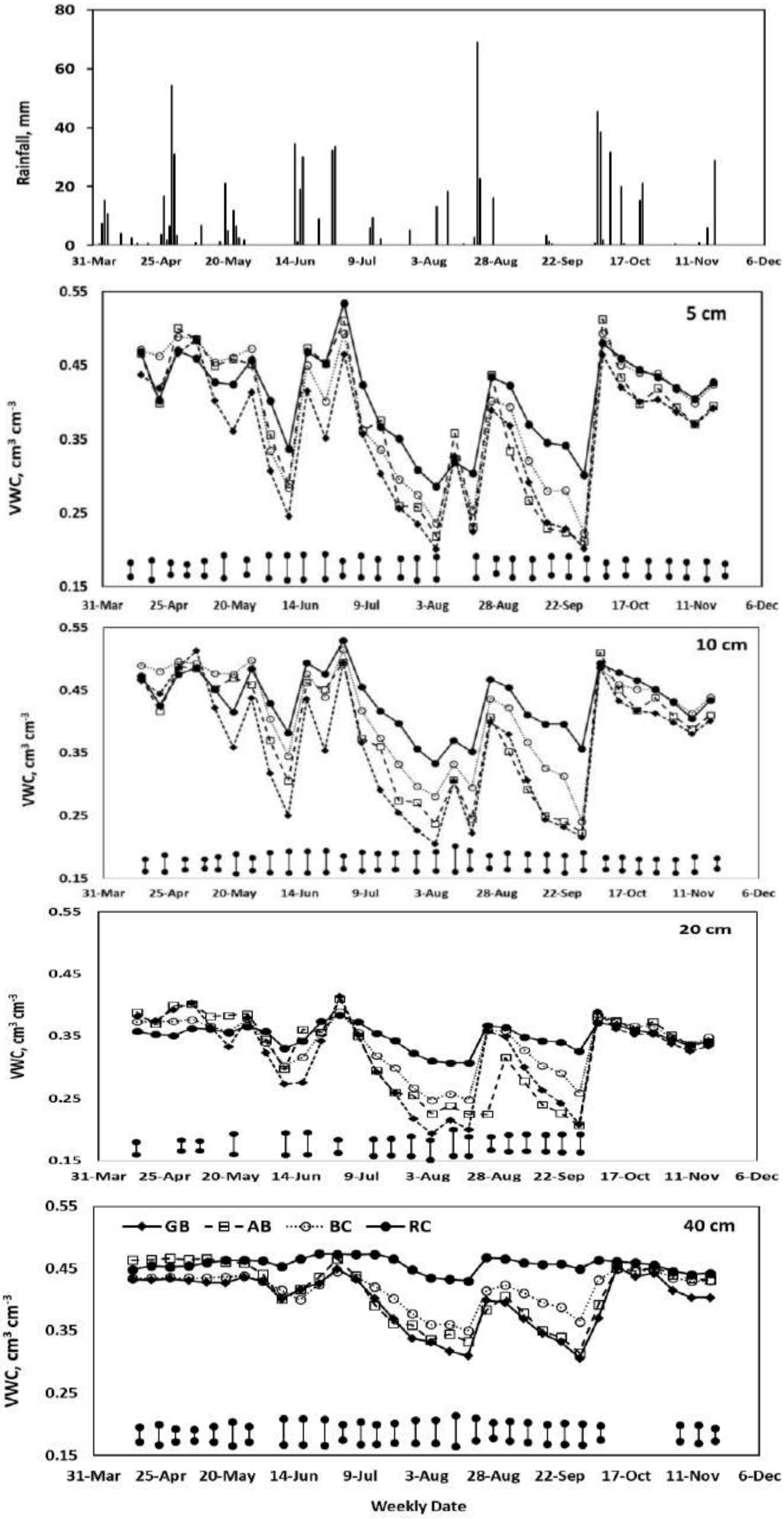


Figure 2: Rainfall distribution and effects of buffer treatments on VWC detected at 12:00 pm each week at 5 cm, 10 cm, 20 cm, and 40 cm depths. Bars indicate the least significant difference.

Conclusion

Results of this study showed that greater profile recharge and more water storage occurred in soils of perennial vegetative areas compared to the row crop management during recharge periods. The lower antecedent soil water content found in the buffer and biomass treatments during pre-recharge periods and the subsequent increased water infiltration and profile recharge during rainfall events will probably reduce surface runoff and soil loss under these perennial vegetative management practices relative to grain crop production. Establishment of agroforestry buffers and biomass crops on strategic locations within row crop watersheds may help reduce non-point source pollution from row crop agriculture. In addition, planting perennial vegetation systems such as trees and grasses may improve soil health parameters and selection of appropriate cultural practices such as selection of soil-site-climate suitable trees and grasses could further enhance water quality benefits and other ecosystem services.

References

Anderson SH, Udawatta RP, Seobi T, Garrett HE (2009) Soil water content and infiltration in agroforestry buffer strips. Agrofor Syst 75: 5-16.

Bharati L, Lee K-H, Isenhart T, Schultz R (2002) Soil-water infiltration under crops, pasture, and established riparian buffer in Midwestern USA. Agrofor Syst 56: 249-257.

Kumar S, Anderson SH, Bricknell LG, Udawatta RP, Gantzer CJ (2008) Soil hydraulic properties influenced by agroforestry and grass buffers for grazed pasture systems. J Soil Water Conserv 63: 224-232.

Mulebeke R, Kironchi G, Tenywa M (2010) Enhancing water use efficiency of cassava and sorghum based cropping systems in drylands. Second Reforum Biennial Meeting, Entebba, Uganda.

Rachman A, Anderson SH, Gantzer CJ, Thompson AL (2004) Influence of stiff-stemmed grass hedge systems on infiltration. Soil Sci Soc Am J 68: 2000–2006.

Sahin H, Anderson SH, Udawatta RP (2016) Water infiltration and soil water content in claypan soils influenced by agroforestry and grass buffers compared to row crop management. Agrofor Syst 90: 839-860.

SAS Institute Inc (2013) SAS User's guide. Statistics. SAS (Statistical Analysis System) Inst., Cary, NC.

Senaviratne GMMM., Udawatta RP, Nelson KA, Shannon K, Shibu S (2012). Temporal and spatial influence of perennial upland buffers on corn and soybean yields. Agron J 104: 1356-1362.

Udawatta RP, Garrett HE, Kallenbach R (2011a) Agroforestry buffers for nonpoint source pollution reductions from agricultural watersheds. J Enviro Qual 40: 800-806.

Udawatta RP, Anderson SH, Motavalli PP, Garrett HE (2011b) Calibration of a water content reflectometer and soil water dynamics for an agroforestry practice. Agrofor Syst 82: 61-75-

Zaibon S, Anderson SH, Thompson AL, Kitchen NR, Haruna, SI (2017) Soil water infiltration affected by topsoil thickness in row crop and switchgrass production systems. Geoderma 286: 46-53.

INVENTORY OF TREE HEDGEROWS IN AN ITALIAN AGROFORESTRY LANDSCAPE BY REMOTE SENSING AND GIS-BASED METHODS

Chiocchini F[1*], Ciolfi M[1], Sarti M[1], Lauteri M[1], Cherubini M[1], Leonardi L[1], Nahm M[2], Morhart C[2], Paris P[1]

(1) Istituto di Biologia Agroambientale e Forestale, Consiglio Nazionale delle Ricerche, Porano, Italy (2) Chair of Forest Growth, Albert-Ludwigs-University, Freiburg, Germany

*Corresponding author: francesca.chiocchini@ibaf.cnr.it

Abstract

Agroforestry denotes land use systems combining trees with agricultural crops and/or livestock. The woody component, consisting of scattered or linear trees, can be located either inside the field or along the field boundaries as tree hedgerows. Such land use approach aims to optimize both ecological interactions and economical revenue and offers a number of ecosystem services, environmental benefits, occurring over a range of spatial and temporal scales. The resulting complexity of the landscape patterns can be detected combining Remote Sensing, GIS spatial analysis and field surveying in order to understand the interactions between woody and crop components, and for assessing, mapping and quantifying the socio-economic values of the agroforestry systems services. In this study, we aimed to map and estimate the extent of Tree Hedge Rows (THR) in an Italian agroforestry landscape and to assess the influence of THRs on the yield of crops at the plot-farm scale.

Keywords: spatial analysis; ecosystem services; Sentinel-2; NDVI; hemispherical canopy photos

Introduction

Agroforestry systems have traditionally been used in different places of Europe employing several types of practices at different levels of intensity (Mosquera-Losada et al. 2009). Agroforestry denotes a land use system in which the woody component (trees/shrubs) is cultivated on the same land unit as agricultural crops and/or animals. Agroforestry is increasingly perceived as providing ecosystem services, environmental benefits, and economic commodities as part of a multifunctional working landscape (Jose 2009). These services and benefits occur over a range of spatial and temporal scales: from the farm/local scale, through the landscape/regional scale up to the global scale (Izac 2003). Thus, the use of GIS technology and the spatial analysis is of major importance for understanding the interactions between biological and physical components and for assessing, mapping and quantifying the socio-economic values of the agroforestry systems services (Mishra and Agarwal 2015).

To slow down the decline of agroforestry practices in Europe that occurred during the 20th century due to agricultural intensification, the European Common Agricultural Policy for Rural Development 2014-2020 is currently supporting the establishment of agroforestry systems, because of their high ecological and socio-economic value. Most of the Italian countryside is naturally suited for agroforestry due to its environmental setting, geomorphological and climatic conditions, as well as for historical and cultural traditions. This study focuses on an agroforestry landscape located in the *Umbria* region in central Italy, with a special focus on “marginal agroforestry systems”. In these systems, trees grow only at the edges of fields, within hedgerows, or on scarps and drainage ditches between fields, and have positive effects on soil erosion, wind protection and ecological as well as aesthetic upgrading of landscapes.

The aims of this work are: i) to map and estimate the extent of Tree Hedge Rows in the study area; ii) to assess the influence of THRs on the yield of crops at the plot scale.

Materials and methods

The study area is located within the municipality of *Castel Giorgio* (TR) in the *Umbria* Region, on the *Vulsini* volcanic hills northeast of *Bolsena* Lake (central Italy). The average elevation is 500 m, average air temperature is 13°C and average annual precipitation is 706 mm. We investigated the farmland owned by the *Faina* Museum Foundation (FMF). This farm manages more than 600 ha of arable land and woods. The main land uses include herbaceous crops (wheat, barley, sunflower, rapeseed, grain legumes, clover and alfalfa), tree hedgerows, shelterbelts and forest belts.

In this study, we combined different methodologies comprising remote sensing, photo interpretation, GIS analyses and field surveys to analyze the spatial distribution of the land cover/use of the area and the spatial interaction between the crop and tree components of the system.

We digitized the land property map from the cadastral map and aerial imagery (Data source: AGEA 2011), then we classified the land use of the study area through photo interpretation.

Basing on the land use classification, we identified two experimental sites (ES) (Figure 1b) to study the continuous or discontinuous THRs along the margins of the cultivated fields. Each site contains a plot of annual crops and a THR along at least one of the borders consisting of oaks (mainly *Quercus pubescens* and *Quercus cerris).*

Basing on the aerial photos (2011) and the Google Earth satellite images (2017), we identified two test areas (TA) of 100 ha (1km x 1km squares) each one containing one of the two ES (Figure 1a).

We tested the following procedure for the GIS inventory of THR over the two TAs:

1) GPS field survey of THRs in the ES; measurement of height (H), diameter at breast height (DBH) for each tree of the THRs; measurement of the distance between adjacent individuals;

2) recognition of THRs by photo interpretation of aerial and satellite images;

3) estimation of the incidence of THRs per hectare of cultivated area over the two TAs and over the whole farmland.

The recognition of THRs was based on photo interpretation of high-resolution multispectral Sentinel-2 (HRS2) images. In particular, evaluating the NDVI (Normalized Difference Vegetation Index, NDVI = (NIR-VIS) / (NIR + VIS)), we could easily discriminate between areas with dense vegetation coverage (0.6 <NDVI <0.9, tree covered areas) and areas with low/zero vegetation cover (cultivated areas or bare soil areas). Starting from the HRS2 images and using the raster algebra of the Sentinel Application Platform (SNAP), the NDVI was derived and the corresponding raster file was generated for the TAs. The 10m spatial resolution of HRS2 scenes, allowed the identification of narrow and long polygons corresponding to the crowns of the tree rows. THRs were identified in the two TAs (Figure 1a) and appropriately validated by comparison with the GPS surveys. This procedure was then applied throughout the study area to estimate the incidence of THRs per hectare.

We collected samples for yield estimations of crops adjacent to the THR, along four transects (25m long) for each ES, two of which being under the influence of tree crowns, at increasing distances from the tree rows. During the summer 2017, we collected five wheat samples from each transect, for 20 plots (each one of 1 m^2) per site (Figure 1b). To assess the shading effect of trees on crops, we used the hemispherical canopy photography technique: 24 hemispherical photos were taken along the four transects of each ES. Using the Gap Light Analyzer software (Frazer et al. 1999), we estimated the light transmission during the growing season in relation to the canopy structure of the tree rows, indirectly evaluating the effect of the trees' shade on crops.

Figure 1: a) Detection of vegetated area and of tree hedgerows in the two test areas. b) Experimental sites with tree codes (Tx) along field margin and sampling transects (orange squares).

Results

We classified about 330ha of arable land out of 628ha of the total surface managed by the farm. Woodlands cover the remaining 298ha of surface with prevalence of mixed broad-leaved woods.

The first ES (Figure 1b) has a surface of 17.8 ha of arable land, and a perimeter of 1992 m. Fifteen oak trees make up a THR oriented N/NE–S/SW, with an average H of 14 m, an average DBH of 50 cm and an average distance between individuals of about 36 m. The second ES (Figure 1b) covers an area of 1.98 ha of arable land, with a perimeter of 791 m. The THR of site 2 is oriented E/NE–W/SW and consists of nine oak trees having an H of 20 m, a DBH of 62 cm and an average distance between individuals of about 15 m.

Through photo interpretation of HRS2 images, we derived polygonal features classified according to the NDVI values. Among these polygons, we selected those with NDVI values between 0.6 and 0.9, corresponding to areas with high density of vegetation coverage (Figure 1a). We estimated 827 m of THR over 5235 m of perimeter of cultivated plots over the TA1. 14% of the margins' length are made up by THRs. For each hectare of cultivated land in TA1, an average of 56m of THRs was found. We estimated that, in TA2, THRs were 16% of the margins length, corresponding to 1273 m out of 9076 m of total perimeter. For each hectare of cultivated land in TA2, an average of 58 m of THRs was found.

A total length of 6241 m of THRs was identified throughout the study area, with respect to a total perimeter of 44885 m of the cultivated plots. These results indicate that THRs correspond to 14% of the total perimeter of the cultivated areas and that for each hectare of cultivated land, there are, on average, 67 m of linear tree rows, along the corresponding boundary (Figure 2). Moreover, the THRs are located mainly along the margins of the cultivations oriented in the direction N-NE/S-SW and NE/SW. The existing THRs along the field boundaries have also an important ecological function, acting as ecological corridors to link fragmented forest patches, thus enhancing connectivity at the landscape level.

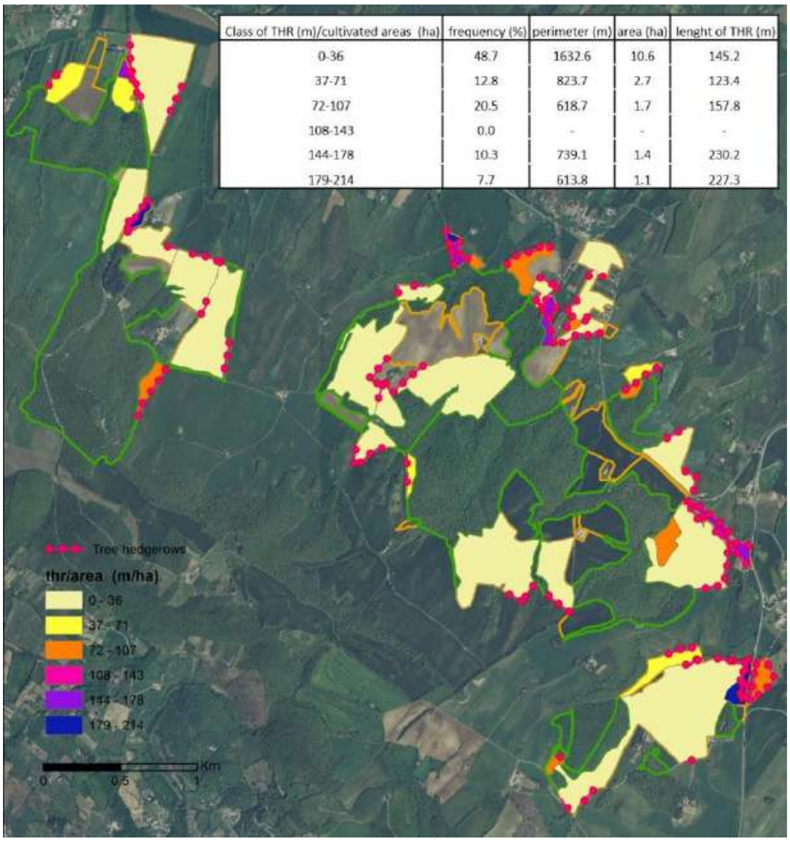


Figure 2: THR incidence per hectare of cultivated land in the study area.

Wheat yields were estimated for ES1 and ES2. The results show average wheat yields of 2 Mg/ha and of 3.4 Mg/ha for ES1 and ES2, respectively (Figure **3**). On ES1, average yields estimated for the plots under tree influence are 1.5±0.2 Mg/ha, while the plots without the influence of trees produced 2.4±0.6 Mg/ha. On site 2, the yields on plots under tree influence are 3.6±0.6 Mg/ha while those on plots without tree influence are 3.1± 0.5 Mg/ha. Crop yield increased with the distance from THR at ES2, where the oak trees' shading affects the crop production. There is no significant relationship between wheat yield and distance from THR at ES1, where oak trees along THR are wider spaced than those of THR at ES2. Tree shading does not affect crop yield at ES1 (Figure 3).

Discussion

Combining methodologies such as remote sensing, photo interpretation, GIS analysis, field survey and hemispherical canopy photos, we quantified the extent of THRs and assessed the effect of THRs on the yield of annual crops at the farm scale in an Italian agroforestry landscape.

In the study area, the 14% of the total fields' perimeter is covered by THRs dominated by oaks, mostly adult trees with a high aesthetic value. The linear density of THRs is variable, amounting to an average value of 67 meters of THR per surrounded hectare. The effects of the trees on the yield of wheat as an adjacent crop were inconclusive, but they indicate that these effects were at least not entirely negative. To assess possible effects of THRs on crops in more detail, further studies with increased numbers of transects should be performed.

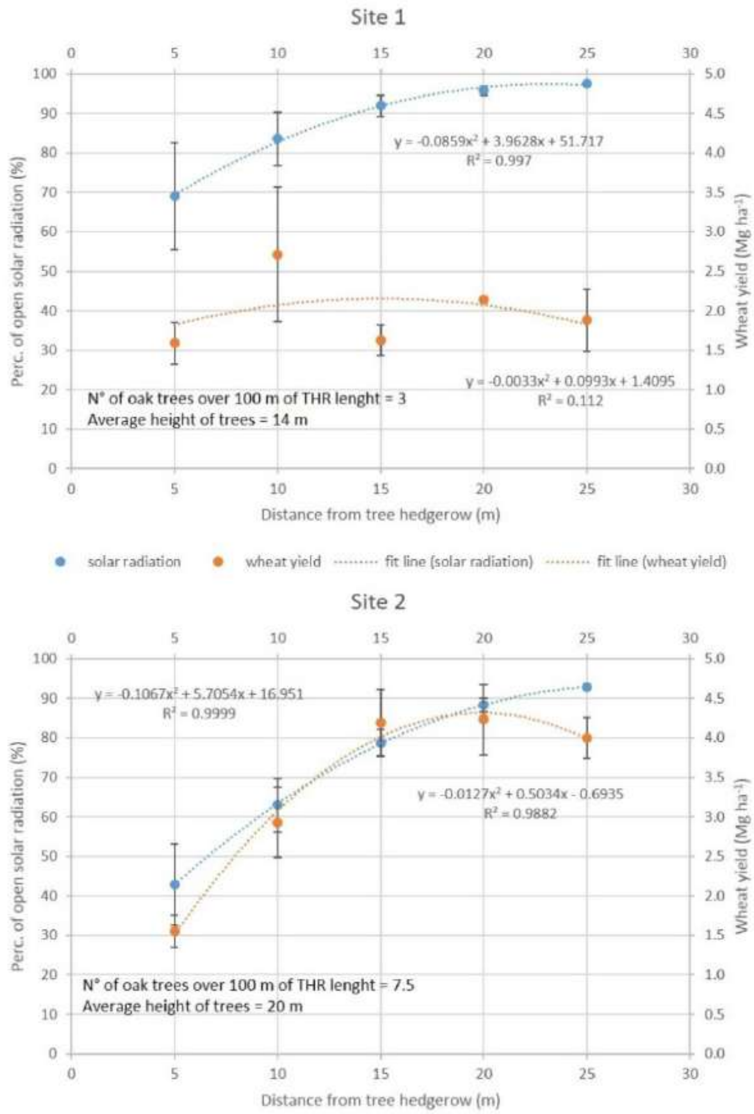


Figure 3: Crop yield and percentage of open solar radiation for Site 1 and Site 2 along sampling transects.

Acknowledgements

Research supported by SidaTim project in the framework of the EU‘s Horizon 2020 research and innovation programme under grant agreement No 652615 (FACCE-JPI) (www.sidatim.eu/en/).

References

Frazer GW, Canham CD, Lertzman KP (1999) Gap Light Analyzer (GLA), Version 2.0: Imaging software to extract canopy structure and gap light transmission indices from true-color fisheye photographs. Copyright 1999: Simon Fraser University, Burnaby, BC, and the Institute of Ecosystem Studies, Millbrook, New York.

Izac AMN (2003) Economic aspects of soil fertility management and agroforestry practices. In: Schroth G, Sinclair F (eds) Trees crops and soil fertility: concepts and research methods. CABI, Wallingford, UK, pp. 13-37.

Jose S (2009) Agroforestry for ecosystem services and environmental benefits: an overview. Agrofor Syst 76: 1–10.

Mishra RK and Agarwal R (2015) Application of information technology and GIS in agroforestry. Trop Plant Res 2: 215–223.

Mosquera-Losada MR, McAdam JH, Romero-Franco R, Santiago-Freijanes JJ, Rigueiro-Rodríguez A (2009) Definitions and Components of Agroforestry Practices in Europe. In Rigueiro-Rodríguez A, McAdam J, Mosqurea-Losada MR (eds) Agroforestry in Europe. Advances in Agroforestry, vol6. Springer, Dordrecht, pp. 3-19.

HOW DO AGROFORESTRY TREES AFFECT THE SUPPLY OF REGULATING ECOSYSTEM SERVICES?

Crous-Duran J[1]*, Graves AR[2], Garcia de Jalón S[2, 4], Kay S[3], Paulo JA[1], Tomé M[1], Palma JHN[1]

(1) Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda, 1349-017, Lisboa, Portugal (2) Cranfield University, Cranfield, Bedfordshire, MK43 0AL, United Kingdom (3) Agroscope, Zurich, Switzerland (4) Basque Center for Climate Change, 48940 Leioa, Spain

*Corresponding author: jcrous@isa.ulisboa.pt

Abstract

Several studies have identified agroforestry systems as suppliers of additional environmental benefits for the society (also called regulating ecosystem services) while maintaining similar levels of productivity compared to agricultural and forestry alternatives. However, no general pattern can be drawn as these studies are very site specific. In order to offer more information on the role of trees in the enhancement of environmental benefits by agroforestry systems, the supply of three regulating ecosystem services (soil erosion, nitrate leaching and carbon sequestration) by four different agroforestry systems in Europe were quantified at: 1) increasing tree densities and 2) compared to its land-use alternatives ranging from agriculture (without trees) to forestry (high tree density). Methods included the use of a biophysical model (Yield-SAFE) where specific methodologies for the quantification of the environmental benefits were previously integrated. First results show different tendencies across Europe even if there was a general improvement of supply linked to an increase of tree density. The methodology also helped to improve management knowledge in order to reduce environmental impact associated to human activities.

Keywords: Yield-SAFE; agroforestry systems; carbon sequestration; soil erosion; nitrate leaching; tree density

Introduction

Agroforestry systems (AFS) are getting attention of land managers as they are able to produce food, energy, and materials in a more efficient way compared to mono-cropping land-use alternatives such as agriculture or forestry (Graves et al. 2007). This is mainly due to the overall higher and more diverse biomass production because of higher use efficiency of solar radiation and water by trees and crops (Cannell et al. 1996). In addition, agroforestry practices are often integrated into strategies for improving natural resources management as they are: 1) linked to less environmental stressful activities and 2) because the multilayer composition makes the system provides more Regulating Ecosystem Services (RES) (Torralba et al. 2016) as it can host more living organisms that can mediate or regulate harmful environment impacts.

The study presented by García de Jalón et al. (2017) showed that, when key actors in the agriculture and forestry sectors (including farmers, landowners, agricultural advisors, researchers and/or environmentalists) are enquired about the potential implementation of agroforestry, the main benefit they see is the reduction of the environmental impacts compared to farming or forestry. In recent years, several studies gave scientific support to this opinion by showing that agroforestry is a practice that can offer similar yields while reducing soil erosion (Nair 2007), nitrate leaching (Jose 2009) net greenhouse gas emissions (Godfray et al. 2012),improve biodiversity conservation (Klaa et al. 2005) and enhance climate change mitigation by sequestering more carbon (Cardinael et al. 2015). However, Moreno et al. (2017) stated that there is evidence that these positive environmental effects are very location specific and that there is a need of a better geographical coverage in order to generalize these patterns at broader scales.

The main objective in this study was to analyze how tree-crop interactions for water and radiation interact with the supply of three Regulating Ecosystem Services: soil erosion, nitrate leaching and carbon sequestration. The study covered four different agroforestry systems in Europe representing diverse biogeographical environments. The Yield-SAFE model described in Palma et al. (2016) was used to predict RES outputs from the four systems. To this end, the model was completed by specific methodologies for the estimation of the three RES. For each system, six different land use alternatives of increasing tree densities were considered: a crop rotation or only pasture (zero tree density); four agroforestry (intermediate tree densities) and forestry (high tree density).

Materials and methods

The integration of methodologies for the assessment of RES into Yield-SAFE allowed to assess the effects of tree density and crop area covered on the supply of RES. A comparison is done to the performance of 4 AFS under increasing tree density alternatives (depending on the system) ranging from agriculture (without trees) to forestry (high tree density). The 3 RES estimated were: 1) soil composition and structure by the estimation the soil eroded by water; 2) water quality through the estimation of the nitrates leached and 3) air composition and climate regulation via the estimation of carbon sequestered by above and belowground biomass and soil carbon storage.

The soil eroded by water was estimated using the revised universal soil loss equation (RUSLE). The equation estimates long-term average annual soil loss by sheet and rill erosion and has been the most frequently used soil erosion model (Panagos et al. 2015). The RUSLE equation was implemented into Yield-SAFE model following the approach used in Palma et al. (2007) with the exception of the cover management factor (C factor) that in this study varies depending on the type and age of vegetation and on the disposition of the trees related to the crop.

For the estimation of the nitrate leached, the approach suggested by Palma et al. (2007) was followed and implemented into the Yield-SAFE model. In this approach it is considered that the quantity of nitrate leached ($kgNO_3^-$ ha^{-1} yr^{--1}) can be estimated depending on the nitrogen balance of the system and the relationship between the flow to groundwater and the soil water content at field capacity. The nitrogen balance considers as nitrogen inputs coming from fertilization, atmospheric deposition, biotic fixation and mineralization and as nitrogen outputs, the processes of denitrification, volatilization, crop and tree uptake and immobilization.

The carbon sequestered by the systems was estimated through the capacity of above and belowground biomass and soil to store carbon. The improved version of Yield-SAFE model (Palma et al. 2017) used integrates a soil carbon model (RothC, Coleman and Jerkinson 2014) that simulates soil organic turnover. The integration focused on the estimation of input plant material from tree and crop into soil including leaf fall and root mortality. For this study products extracted from crops as wheat grain, sugar-beet, or meat (through grass) were not included in the carbon sequestration estimation due to their short durability (timber on the other hand, was included as it immobilizes carbon for many years). For the silvo-pastoral systems (montado and Swiss pastures) the excrements of the livestock grazing were considered to be organic input material for the soil model.

The model was applied to four systems in Europe representing different components and climate regions: 1) Montado wood pastures in Portugal; 2) Grazed cherry tree pastures in Switzerland; 3) Poplar for timber production with cereals alleys in the UK and 4) Poplar short rotation coppice with cereals in Germany. For each system 6 different tree densities were considered including: arable (no trees), forestry (high tree density) and 4 agroforestry alternatives ranging from the arable to the forestry option. The Yield-SAFE model was previously parametrized for all the tree and crop components of the systems and the weather, soil, crop, tree and livestock management inputs required by the model were collected.

The simulation period used was of 80 years. In case of shorter rotation periods (20 years in silvoarable systems in the UK and 4 years in short rotation coppice in Germany), the rotation period was repeated until 80 years were achieved (4 and 20 times respectively).

Results and discussion

First results showed different tendencies across the 4 study regions, even if there was a general improvement of RES supply linked to tree presence. In terms of soil eroded (Figure 1A), most of the parameters included in the RUSLE equations are constant and depend on the physical and weather conditions of the site and just the cover management factor (C_{factor}) varies depending on the growth of the tree, the crop present and the disposition of trees related to crops. The C_{factor} is defined as how crop management causes soil loss compared to bare ground. The higher susceptibility of soil to erode (K_{factor}) presented in Switzerland results in higher values of soil eroded after the simulation period whereas due to the lower rainfall erosivity factor (R_{factor}) in the UK results are the opposite. On the other hand, the lower C_{factor} value presented by natural grasslands in Portugal or Switzerland diminishes the importance of tree presence in avoiding soil erosion. In the UK and Germany, where cereals and sugar beet present higher C_{factor} values, the absence of trees (arable alternatives) lead to higher soil losses.

In Mediterranean areas precipitation rarely exceeds evapotranspiration meaning there is a low flow to groundwater to transport nitrates. In addition, it is assumed that natural grasslands in Switzerland are not fertilized meaning for both systems (montado and Swiss pastures) nitrate leached can be considered negligible (Figure 1B). On the other hand, on the English site there is a clear effect of trees in avoiding nitrate leaching as with the same area and the same amount of fertilization dedicated to crop, the nitrate leached is reduced as tree density increases. Meanwhile no tree effect is initially observed in the German site as nitrate leaching is reduced but also is the crop dedicated area.

Carbon sequestration is estimated as a fixed percentage of living biomass (50%) and its content in soil, that on its turn depends on the inputs provided by the living biomass through root mortality and leaves fall. Therefore, the different levels of carbon sequestration encountered among the four agroforestry system reflect the different edapho-climatic conditions present in the different sites that limit the biomass growth potential of the systems. As expected, pure pastures and arable alternatives remain in an equilibrium state all along the simulation period (Figure 1C). Yet the presence of trees increases carbon sequestration, however this was not linear. Tree competition for water and solar radiation increased with tree density, reducing the quantity of biomass, and therefore the carbon sequestered by each tree. Also the final destination of the products offered by each system influences drastically carbon sequestration estimation. Biomass from German poplar plantations is not considered to sequester carbon as wood chips are burnt to produce energy. Timber from Swiss cherry trees and poplar in the UK are considered to have longer life expectancies as may be used for furniture and cheap wood materials (fruit boxes, pallets) respectively. Portuguese oaks have been also considered to sequester carbon as they remain standing even after the simulation period.

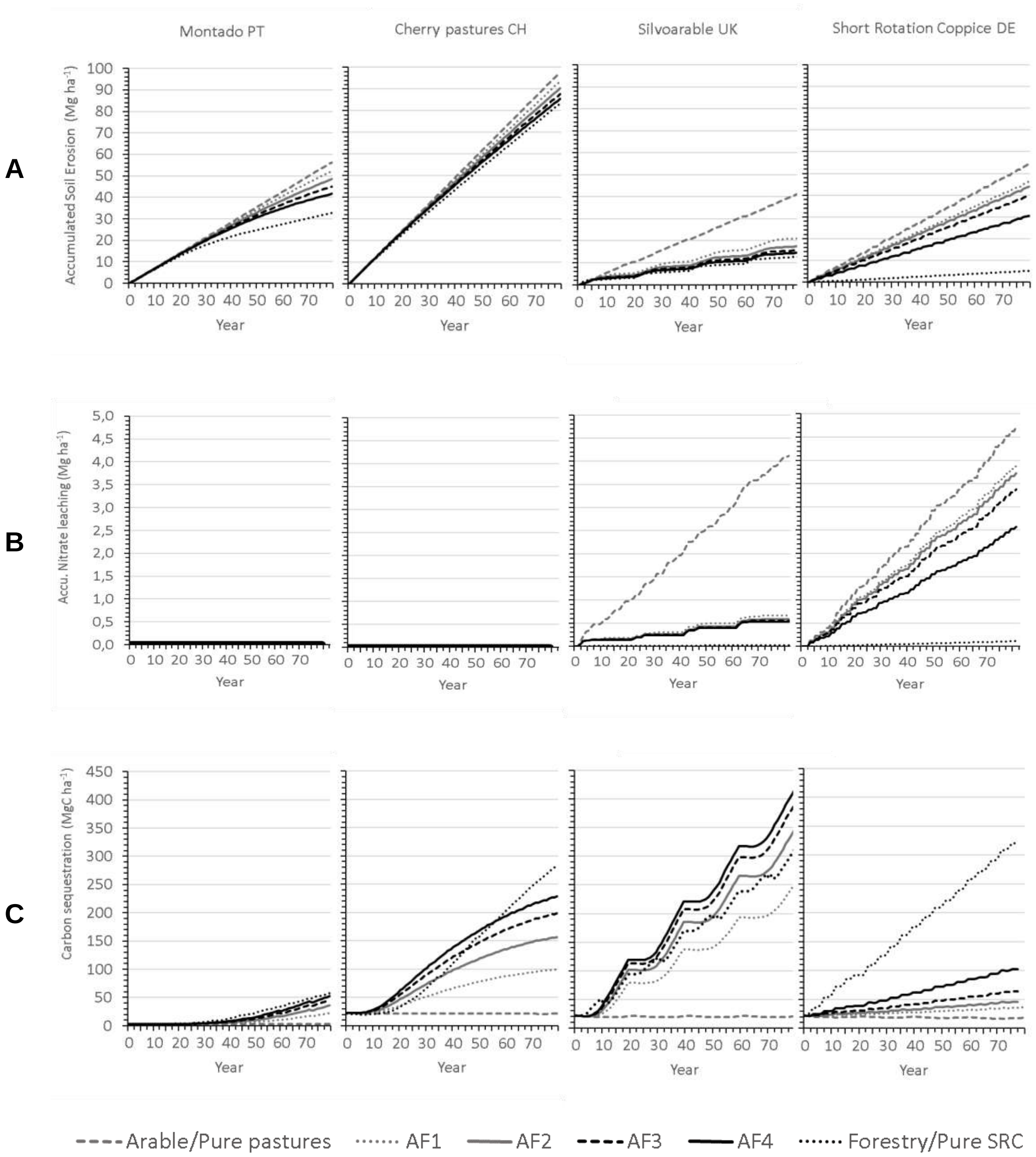


Figure 1: Yield-SAFE predictions of Regulating Ecosystem Services provided (A, soil erosion; B, Nitrate leaching; C, carbon sequestration) in 80 years for 6 different management alternatives in increasing tree densities across Europe. Montado in Portugal (Montado PT): 0 trees ha^{-1} (Pure pastures); 50 trees ha^{-1} (AF1); 100 trees ha^{-1} (AF2); 150 trees ha^{-1} (AF3); 200 trees ha^{-1} (AF4) and Forestry (Forestry/Pure SRC). Cherry tree pastures in Switzerland (Cherry pastures CH): 0 trees ha^{-1} (Pure pastures); 26 trees ha^{-1} (AF1); 52 trees ha^{-1} (AF2); 78 trees ha^{-1} (AF3); 104 trees ha^{-1} (AF4) and Forestry (Forestry). Silvoarable systems in the UK (Silvoarable UK): 0 trees ha^{-1} (Arable); 56 trees ha^{-1} (AF1); 78 trees ha^{-1} (AF2); 104 trees ha^{-1} (AF3); 156 trees ha^{-1} (AF4) and Forestry (Forestry). Short rotation coppice in Germany (Short rotation coppice DE): 0m (Arable); 96m (AF1); 72 m (AF2); 48 m (AF3); 24m (AF4) and pure short rotation coppice (Pure SRC).

References

Cannell MGR, Noordwijk M, Ong CK (1996) The central agroforestry hypothesis: the trees must acquire resources that the crop would not otherwise acquire. Agrofor Syst 34:27–31. doi: 10.1007/BF00129630.

Cardinael R, Chevallier T, Barthès BG, Saby BPA, Parent T, Dupraz C, Bernoux M, Chenu C (2015) Impact of alley cropping agroforestry on stocks, forms and spatial distribution of soil organic carbon - A case study in a Mediterranean context. Geoderma 259–260: 288–299.

Coleman K, Jenkinson D (2014) RothC - A Model for the Turnover of Carbon in Soil - Model description and users guide. Rothamsted Research, Harpenden, UK.

García de Jalón S, Burgess PJ, Graves AR, Moreno G, McAdam J, Pottier E, Novak S, Bondesan V, Mosquera-Losada MR, Crous-Durán J, Palma JHN, Paulo J, Oloveira TS, Cirou E, Hannachi Y, Pantera A, Wartelle R, Kay S, Malignier N, Van Lerberghe P, Tsonkova P, Mirck J, Rois M, Grete Kongsted A, henail C, Luske B, Berg S, Gosme M, Vityi A (2017) How is agroforestry perceived in Europe? An assessment of positive and negative aspects by stakeholders. Agroforst Syst. doi: 10.1007/s10457-017-0116-3.

Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, Robinson S, Thomas SM, Toulmin C (2012) Food Security: the Challenge of Feeding 9 billion. Science 327: 812-818.

Graves AR, Burgess PJ, Palma JHN, Herzog F, Moreno G, Bertomeu M, Dupraz C, Liagre F, Keesman K, van der Werf W, Koeffemande de Nooy A, van den Briel JP (2007) Development and application of bio-economic modelling to compare silvoarable, arable, and forestry systems in three European countries. Ecol Eng 29:434–449. doi: 10.1016/j.ecoleng.2006.09.018.

Jose S (2009) Agroforestry for ecosystem services and environmental benefits: An overview. Agroforst Syst 76: 1–10.

Klaa K, Mill PJ, Incoll LD (2005) Distribution of small mammals in an silvorable agroforestry system in Northern England. Agrofor Syst 63: 101–110.

Moreno G, Aviron S, Berg S, Crous-Duran J, Franca A, García de Jalón S, Hartel T, Mirck J, Pantera A, Palma JHN, Paulo JA, Re GA, Sanna F, Thenail C, Varga A, Viaud V, Burgess PJ (2017) Agroforestry systems of high nature and cultural value in Europe: provision of commercial goods and other ecosystem services. Agrofor Syst. doi: 10.1007/s10457-017-0126-1.

Nair PKR (2007) The coming of age of agroforestry. J Sci Food Agric 87: 1613–1619.

Palma JHN, Graves AR, Burgess PJ, Keesman KJ, van Keulen H, Mayus M, Reisner Y, Herzog F (2007) Methodological approach for the assessment of environmental effects of agroforestry at the landscape scale. Ecol Eng 29: 450–462.

Palma J, Graves A, Crous-Duran J, Upson MA, Paulo JA, Oliveira TS, García de Jalón S, Burgess P (2016) Yield-SAFE Model Improvements. Report for Milestone 29 (6.4) of the AGFORWARD project (Lisboa). http://hdl.handle.net/10400.5/12337 (accessed 24/04/2018).

Palma JHN, Crous-Duran J, Graves AR, García de Jalón S, Upson M, Oliveira TS, Paulo JA, Ferreiro-Domínguez N, Moreno G, Burgess PJ (2017) Integrating belowground carbon dynamics into Yield-SAFE, a parameter sparse agroforestry model. Agrofor Syst https://doi.org/10.1007/s10457-017-0123-4.

Panagos P, Borrelli P, Poesen J, Ballabio C, Lugato E, Meusburger K, Montanarella L, Alewell C (2015) The new assessment of soil loss by water erosion in Europe. Environ Sci Policy 54: 438–447.

Torralba M, Fagerholm N, Burgess PJ, Moreno G, Plieninger T (2016) Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. Agr Ecosyst Environ 230: 150-161.

THE IMPACT OF SOIL AND VEGETATION MANAGEMENT ON ECOSYSTEM SERVICES IN EUROPEAN ALMOND ORCHARDS

Leijster V[1*], Santos MJ[1, 2], Diaz M[1], Wassen MJ[1],Belen AB[3], Ramos ME[3], Verweij PA[1]

(1) Copernicus Institute of Sustainable Development, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, Netherlands (2) URPP GCB Global Change and Biodiversity, University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland (3) Estación experimental del Zaidín (CSIC), C/Profesor Albareda, 1, 18008 Granada, Spain

*Corresponding author: v.deleijster@uu.nl

Abstract

This study examines the use of green manure, no-tillage and compost to improve nutrient cycling and plant species richness. Therefore we conducted a full factorial design with four treatments in five almond plantations. The treatments include the business as usual management, conventional tillage (CT) and no-tillage (NT), compost (CM) and green manure (GM). Soil enzymatic activity was used as a proxy for nutrient cycling and plant richness and cover for habitat provisioning. Phosphatase activity increased with 50% in the alternative treatments, and the activity of glucosidase was twice as high in CM compared to CT. Plant species richness was highest in NT, but the vegetation cover was found to be equal in GM and NT. To conclude, implementing green manure, no-tillage and compost application on a monoculture almond farm appear to be effective strategies to improve ecosystem services provided on the farm, such as nutrient cycling and plant species conservation.

Keywords: ecosystem services; agroecology; conservation agriculture; tree-crop; nutrient cycling; habitat provisioning

Introduction

Over 30% of Mediterranean Europe is experiencing degradation of biophysical processes on land (Zdruli 2014). Within Europe, Spain has the largest issues related to land degradation as an estimated 12.5 % of the total territory is degraded (Bai et al. 2008), moreover other authors are even estimating that the extent of the problem is reaching 28 – 54 % of the territory (Dregne 2002). Tree-crop systems play an important role in the reduction of ecosystem services due to the widespread conventional management. In this conventional management, clean sweeping is a common practice whereby soils are frequently tilled to assure that understory vegetation is permanently removed (Meerkerk et al. 2008). This management results in a loss of soil of 5.70-10.5 Mg ha-1 yr-1 and runoff of 10.9-58.1 mm ha^{-1} (Durán Zuazo and Rodríguez Pleguezuelo 2008). Additionally, the removal of understory vegetation in almond orchards is estimated to reduce the abundance of pollinators by 64.3-86.8 % (Norfolk et al. 2016; Saunders et al. 2013). Moreover, the frequent tillage practices are driving the breakage of soil aggregates and the loss of 20 – 30 % soil organic carbon pool (West and Post 2002). This physical degradation of the soil negatively affects the abundance and activity of soil biota that play a crucial role in belowground ecosystem processes (Barrios 2007). Nonetheless, recent evidence is mounting to show that alternative land management practices, such as cover crops or natural vegetation covers, reduced or no-tillage and organic soil amendments, can contribute to the rehabilitation of biophysical and ecological processes in almond orchards (Ramos et al. 2010; Almagro et al. 2013; Saunders et al. 2013; Ramos et al. 2011; Duran Zuazo et al. 2008; Martínez Raya et al. 2006; Macci et al. 2010). However, all these studies have been conducted on just a single, or in some cases two experimental sites making it difficult to draw conclusions related to best management practices. Therefore, this study experimentally tested the use of green manure, no-tillage and compost applications in five farms, to assess their impact on nutrient cycling and on habitat provisioning for plant species.

Enzymatic activity was assessed as a proxy for nutrient cycling service in the soil. Soil enzymatic activities have been proven to be a powerful tool to assess soil quality as they respond rapidly to changes in soil management (Burns et al. 2002). For this study, the enzymes β-Glucosidase, Phosphatase, Urease and Dehydrogenase were chosen because they catalyse the hydrolysis of organic compounds. They give an indication for the decomposition processes in the soil, as they are indicators for the breakdown of cellulose (β-Glucosidase) and the P-cycle (Phosphatase), N-cycle (Urease) and C-cycle (Dehydrogenase) (Das and Varma 2011).

Materials and methods

The research was conducted in the high planes of the provinces Granada and Almeria in the East of Andalusia, SE Spain.

Experimental design

We conducted a full factorial design with four treatments in five existing almond plantations. On each farm a homogeneous site was chosen where the four treatments were randomly implemented, a treatment within a farm is hereafter referred to as a 'plot'. Each plot corresponded to a rectangular area of at least four by eight trees, but only the inner two rows with almond trees were included in the research, to optimize the effect of the treatment and exclude the influence of adjacent management. The dimensions of the research plots were then 14 m x 56 m = 784 m^2 (7m average distance between trees), and included a minimum of 15 trees (Figure 1).

In each farm, the four plots were implemented as follows:

CT – Conventional tillage: the plot is tilled 2-3 times a year to remove the understorey vegetation using a cultivator.

NT – No-tillage: the plot is not tilled and has spontaneous understory vegetation.

GM –Green Manure: Common vetch (*Vicia sativa*; 50 kg ha^{-1}), Bitter vetch (*Vicia ervilia*; 50 kg ha^{-1}) and Barley (*Hordeum vulgare*; 20 kg ha^{-1}) were sown in the plots. Seeds were mixed in a ratio of 5:5:2 and were sown by hand in December 2016 in a quantity of 120 kg ha^{-1}. After sowing, a cultivator passed to incorporate the seeds into the soil. In addition, after the ground cover sampling, between the end of May and the beginning of June, the ground cover was plowed into the soil with a cultivator.

CMP – Compost, type Bokashi: the plot is fertilized with compost, which was purchased from a local vendor (Moreno Basura - Maria, Alméria). The compost was applied in December with a quantity of approximately 6 m^3 ha^{-1} and incorporated in the soil with a cultivator. During the rest of the year, the plot was tilled 1-2 times to remove weeds.

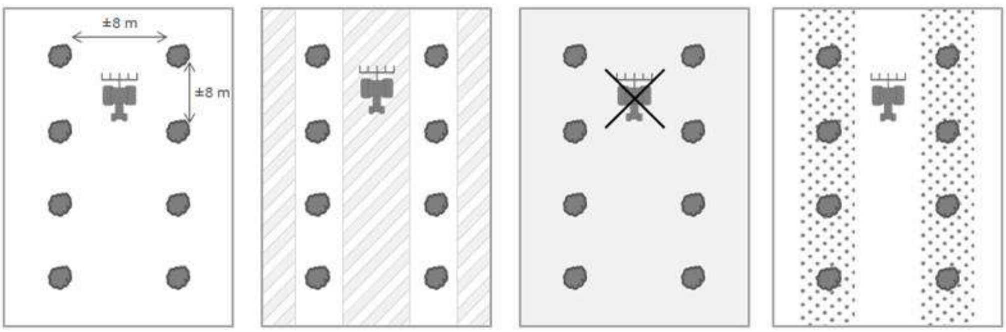


Figure 1: Schematic overview of the four treatment plots. a) tillage (CT), b) green manure (RTGM), c) no-tillage (NT), d) compost (CM). White soil color indicates bare soil, grey indicates permanent vegetation, white/grey stripes indicate inpermanent vegetation (green manure seed mixture), dots indicate that compost is applied.

Soil sampling

In each plot three soil samples of 1-2 kg were taken in April 2017, each consisted of ten sub-samples that were randomly taken from the 0-20 cm soil layer from the plot. Soil samples were sieved at field moisture through a 2 mm sieve. The samples were stored at 4°C until lab analyses.

Enzymatic activity

Dehydrogenase activity was measured according to the methodology described by García et al. (1997). To assess the Phosphatase activity and β-glucosidase we used the methodology of Ramos et al. (2011). Urease activity was determined according to Nannipieri et al. (1982).

Vegetation sampling

The ground cover vegetation composition was assessed in May 2017 using the point-intercept method, modified as proposed by Ruiz-Mirazo and Belén (2012). In each treatment plot, six 10 m long transects were randomly laid out, and each consisted of one hundred points measured at a distance of 10 cm. At each point of the transect, a needle of 30 cm was put in the ground and all plants that touched the needle were identified to the species level. When there was no plant touching the needle, we recorded bare soil. From these data, we calculated vegetation cover (%) and plant species richness (number of species per unit area).

Statistical analysis

Data was analysed with a generalized linear mixed model to test the effect of the treatments on enzymatic activity, vegetation cover and plant species richness by using the lme4 package in R. In this analysis the treatments were taken as a fixed factor and the farms were taken as a random factor.

Results

We found a significant effect of treatment on soil enzymatic activities (Table 1), especially for the enzyme phosphatase, where CT (conventional tillage) was related to a lower enzymatic activity than the three other treatments, NT (no tillage), GM (green manure) and CM (compost). We found that urease in NT was twice as high than CT, however this was not significant, also the activity of this enzyme in CM and GM was higher than CT. Glucosidase enzymatic activity was higher in CM than CT, however, GM and NT did not statistically differ from the other treatments, but had on average higher activity than CT. Dehydrogenase activity was not influenced by the treatments.

Both vegetation parameters turned out to be significantly affected by the implemented management regimes (Table 1). The plant species richness was significantly higher for NT treatment, followed by GM treatment. CM and CT had on average lower plant species richness. Vegetation cover was significantly lower in CT than in all other treatments, except for CM. This was mainly due to the large variation in cover in the compost treatment.

Table 1: Mean values ± standard error of the activity of dehydrogenase (mgr INTF h^{-1}), glucosidase (mgr PNP h^{-1}), phosphatase (mgr PHO h^{-1}), Urease (mgr NH4 h^{-1}), and vegetation cover (%) and plant species richness (# species $transect^{-1}$), for the treatments conventional tillage (CT), no-tillage (NT), green manure (GM) and compost (CM).

ES indicator	p-value	CT		NT		GM		CM	
Nutrient cycling									
Dehydrogenase	0.7	2.1 ± 1.4		2.7 ± 1.9		2.5 ± 1.9		2.7 ± 1.5	
Glucosidase	0.01	140 ± 78	b	365 ± 215	ab	270 ± 97	ab	330 ± 140	a
Phosphatase	0.001	102 ± 72	b	157 ± 59	a	150 ± 59	a	159 ± 67	a
Urease	0.6	33 ± 32		65 ± 50		51 ± 30		55 ± 35	
Habitat provisioning									
Vegetation cover	1E-07	25 ± 25	b	72 ± 27	a	72 ± 18	a	34 ± 43	b
Plant species richness	1E-07	6.3 ± 5.1	b	11.2 ± 2.9	a	7.4 ± 3.0	ab	5.3 ± 4.6	b

Discussion

In this study we found that improved management practices, such as green manure, no-tillage and compost application, played a significant role in the rehabilitation of soil services provisioning and plant species conservation. The enhancement of phosphatase activity in all treatments compared to conventional tillage shows that the capacity to release organically-bound phosphorus may be increased with improved management practices leading to a boost in the P-cycle for the benefit of all plants present including the almond trees. Additionally, we found that dehydrogenase, an enzyme that plays a role in the decomposition process within the C-cycle, is not sensitive to changes in these soil and vegetation management practices. The other enzymatic activities, that play roles in the N-cycle and P-cycle and in the breakdown of cellulose, have shown to be enhanced after implementation of these management practices. To improve plant species richness, no-tillage management is most effective. However, for increasing vegetation green manure is just as effective.

To conclude, implementing green manure, no-tillage and compost application on a monoculture almond farm appear to be effective strategies to improve and rehabilitate ecosystem services provided on the farm, such as nutrient cycling and plant species conservation.

References

Almagro M, de Vente J, Boix-Fayos C, García-Franco N, Melgares de Aguilar J, González D, Martínez-Mena M (2013) Sustainable land management practices as providers of several ecosystem services under rainfed Mediterranean agroecosystems. Mitig Adapt Strateg Gl 21: 1029-1043.

Bai ZG, Dent DL, Olsson L, Schaepman ME (2008) Proxy global assessment of land degradation. Soil Use Manag *3*: 223–234.

Barrios E (2007). Soil biota, ecosystem services and land productivity. Ecol Econ 64: 269–285.

Burns RG, Nannipieri P, Kandeler E, Ruggiero P (2002) Enzymes in the Environment± Activity, Ecology, and Applications. Marcek Dekker.

Das SK, Varma A (2011). Role of Enzymes in Maintaining Soil Health. Soil Biol 22: 25–42.

Dregne HE (2002) Land Degradation in the Drylands. Arid Land Res Manag 16: 99–132.

Durán Zuazo VH, Rodríguez Pleguezuelo CM (2008). Review article Soil-erosion and runo ff prevention by plant covers . A review. Agron Sustain Dev 28: 65–86.

Duran Zuazo VH, Rodriguez Pleguezuelo CR, Marinez-Raya A, Francia Martinez JR, Panadero LA, Rodriguez BC (2008) Environmental and Agronomic Benefits of Aromatic and Medicinal Plant Strips for Rainfed Almond Orchards in Semiarid Slopes (SE, Spain). Open Agr J 2: 15–21.

García C, Hernández T, Cota F (1997) Potential Use of Dehydrogenase Activity as an Index of Microbial Activity in Degraded Soils. Commun Soil Sci Plant Anal 28:123-134

Macci C, Doni S, Peruzzi E, Masciandaro G, Mennone C, and Ceccanti B (2010). Almond tree and organic fertilization for soil quality improvement in southern Italy. J Environ Manag 95: 215–222.

Martínez Raya A, Durán Zuazo VH, Francia Martínez JR (2006) Soil erosion and runoff response to plant-cover strips on semiarid slopes (SE Spain). Land Degrad Dev 17: 1–11.

Meerkerk A, van Wesemael B, Cammeraat E (2008) Water availability in almond orchards on marl soils in southeast Spain: The role of evaporation and runoff. J Arid Environ 72: 2168–2178.

Nannipieri P, Ceccanti B, Cervelli S, Conti C (1982) Hydrolases extracted from soil: Kinetic parameters of several enzymes catalysing the same reaction. Soil Biol Biochem 5: 429-432.

Norfolk O, Eichhorn MP, Gilbert F (2016) Flowering ground vegetation benefits wild pollinators and fruit set of almond

within arid smallholder orchards. Insect Conserv Diver 9: 236–243.
Ramos ME, Benítez E, García PA, Robles AB (2010) Cover crops under different managements vs. frequent tillage in almond orchards in semiarid conditions: Effects on soil quality. Appl Soil Ecol 44: 6–14.
Ramos ME, Robles AB, Sánchez-Navarro A, González-Rebollar JL (2011) Soil responses to different management practices in rainfed orchards in semiarid environments. Soil Till Res 112: 85–91.
Ruiz-Mirazo J, Belén AB (2012) Impact of targeted sheep grazing on herbage and holm oak saplings in a silvopastoral wildfire system in south-eastern Spain. Agrofor Syst 86: 477-491.
Saunders ME, Luck GW, Mayfield MM (2013) Almond orchards with living ground cover host more wild insect pollinators. J Insect Conserv 17: 1011–1025.
West OW, Post WM (2002) Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation : A Global Data Analysis Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation : A Global Data Analysis. Soil Sci Soc Am J 66: 1930–1946.
Zdruli P (2014) Land resources of the Mediterranean: Status, pressures, trends and impact on future regional development. Land Degrad Dev 384: 373–384.

AGROFORESTRY COMPONENT IN FORMATION AND FUNCTIONING OF CURRENT AGRICULTURAL LANDSCAPES

Yukhnovskyi V[1]*, Gladun G[2], Lobchenko G[3], Khryk V[4]

(1) Forest Restoration & Meliorations, National University of Life and Environmental Sciences, Kyiv, Ukraine (2) Woodworking Technologies and System Engineering in Forestry, National Technical University of Agriculture named after Peter Vasylenko, Kharkiv, Ukraine (3) Forest Restoration & Meliorations, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine (4) Forestry, Botany and Physiology of Plants, National Agricultural University, Bila Tserkva, Ukraine

*Corresponding author: yukhnov@ukr.net

Abstract

The purpose of this research is to justify the agroforestry component in the formation and functioning of current agricultural landscapes. We analyzed the structure of agro-landscapes within of natural zones of Ukraine. Our results suggest that 52% of the territory belongs to the state of destruction, and the proportions of unstable, medium-stable and stable landscapes are 12.8% and 4.0%, respectively. The agro-landscapes with ecological balance and sustained fertility growth occupy only 4.0% of the total area. We have assessed the ecological stabilization of agro-landscapes in the zonal aspect. The ecological stability factor for the entire territory is 0.38. The values of an environmental sustainability factor calculated using optimization of the structure of agro-landscapes for Steppe, Forest-Steppe and Polissia are 0.41; 0.45 and 0.61 respectively. This indicator for the whole territory is 0.47. Achieving favorable environmental conditions depends on the use of the optimal composition of land uses in various elements of agro-landscape.

Keywords: agro-landscape; protective stand; natural and anthropogenic impacts; environmental sustainability factor.

Introduction

Scientific principles of forest amelioration at the landscape level were developed at the turn of the nineteenth and twentieth centuries based on the fundamental research of domestic and foreign scientists including the founder of the doctrine of forest amelioration V. Dokuchaev and his followers – G. Vysotskyi, L. Berg, Ye. Pavlovskyi (Vysotskyi 1950; Gladun et al. 2007). The large-scale experiments using different systems of protective forest stands were conducted by "Special Expedition" under the leadership of V. Dokuchaev in 1897. Dokuchaev’s doctrine of the application of forest amelioration at the landscape level inspired investigations of anthropogenic-modified landscape complexes (Bayllovich 1938). One of the most important components of assessing the state of natural-territorial complexes is estimating the degree of their anthropogenic transformation. Anthropogenic transformation of a natural-territorial complex is the change in its structural and dynamic features as a result of functional use (Grodzinskyi and Shishchenko 1993). It is used to develop the system of ecological management of the region, to balance regional environmental policy, and to optimize the use of natural resources. This analysis reveals regional patterns of anthropogenic transformation of the territories, which allows classification and assessment of the degree of environmental stress as well as the development of the adequate measures for its improvement.

The purpose and tasks of the research

The purpose of this research is to justify the agroforestry component in the formation and functioning of current agricultural landscapes and to develop the scientific basis for the provision of the forest-melioration component of sustainable agro-landscapes. To achieve this goal, we set three research objectives. First, we substantiate landscape-ecological principles of application of forest amelioration on a zonal-regional basis. Second we determine the degree of violation of the ecological situation in the modern agro-landscapes. Finally we assess the resilience of agro-landscapes to anthropogenic impacts and develop the integral structure of the ecological framework for the agricultural landscapes.

Materials and methods

The theoretical and methodological basis of the research is a systematic approach to the study of the processes of conservation of agro-landscapes from the action of a complex of negative factors using forest plantations. We analyzed the current state and structure of agro-landscapes using the method of statistical generalization, comparison, analysis and synthesis. The parameters of the field-protection forest cover were justified using method of forming the ecological framework of agro-landscapes using the abstract-logical method (Gladun 2007).

The current state of agrolandscapes was analyzed using the methodology of optimal correlation of land (Grodzinskyi 1995), which is based on the ratio of destabilizing and ecologically stabilizing land uses (forests, meadows, pastures, orchards, riparian, water bodies).

To determine the degree of environmental degradation of current agrolandscapes of the regions of Ukraine, we conducted an assessment of their stability over the range of areas of arable land and ecologically stabilizing land uses according to the methodology of Postolov and Kryukova, (2010). We used land-use data by natural-climatic zones of Ukraine for 2014.

Optimization of the interaction of agricultural production and the environment was conducted taking into account the concept of "Ecological and economic balance" (Kochurov 1999) which implies solving of land-ecological problems by improving the structure of land use.

Results and discussion

The resilience of the agrolandscape to negative anthropogenic and natural impacts can be achieved using concept of ecological framework (Nikolaev 1992). This concept of ecological framework is similar to other concpets such as ecological network, nature conservation geosystem (Preobrazhensky and Alexandrova 1988), ecological texture of agro-landscape (Grodzinskyi 1995), territorial system of ecological stability of the landscape (Ruzicka and Miklos 1990), landscape-ecological skeleton (Rodin and Rodin 2003), the system of protected areas (Selyedets 1987) and others.The main rule in the adding new areas to agricultural use or in the optimization of established agricultural landscapes must be preserving and maintenance of in the effective state of natural elements of space-time environmental infrastructure (Kotlayrova et al. 2013). Prevention of adverse impacts on landscapes can be achieved through systematic structural measures, which will be discussed later.

We have developed a basic scheme of the ecological framework for a region, which may be the basis for ensuring the stability of the lands of current agro-landscapes (Figure 1).

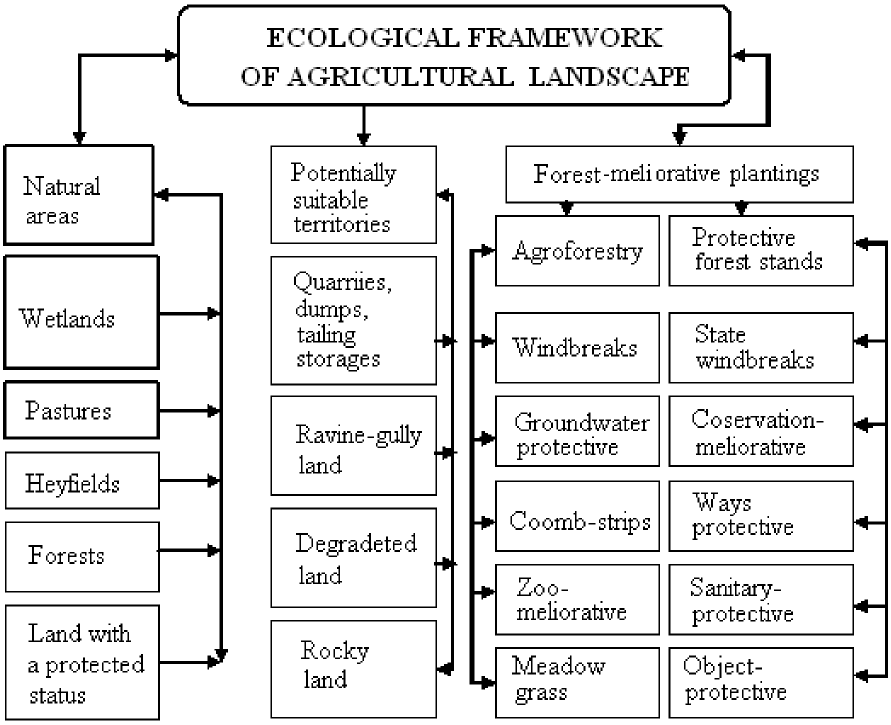


Figure 1: Scheme of the ecological framework of agro-landscape.

The choice of the elements of the ecological framework, as well as the placement of agricultural land, should be based on the principle of adaptability. All newly created elements of the ecological structure, such as forest strips, windbreaks, buffer strips of hayfields, pastures and perennial grasses, ponds, etc., should fit into the natural morphology of agro-landscapes. This fit is mainly determined by the features of the meso - and micro-topography (Yukhnovskyi 2003). In general, the regional structure of agro-landscapes must be adaptive-constructive in its content.

The optimal composition of land uses of the region depends on the adaptability of agricultural production while taking into account environmental factors.

To determine the degree of environmental degradation of current agro-landscapes, we conducted an assessment of their resilience at different levels arable lands, and ecologically stabilizing land uses. Our results indicate that 52% of the territory of Ukraine is assessed as being at the state of destruction. The landscapes assessed as unstable, average stability and resilient occupy 12%, 8% and 4% respectively. Agricultural landscapes with ecological balance with stable fertility growth occupy only 4% of Ukraine's territory.

The main reasons for the current state of landscape resilience are: a high level of cultivation of agricultural lands (over 80%), the spontaneity in changing land uses, the absence of national, regional and local soil conservation programs, the low level of financial support for soil erosion protection measures, and deficiencies in the implementation of land reform. The causes of increase in soil erosion processes are the violations of the organization of the territory, the decline of forest amelioration, the deterioration of the state of the windbreaks, the neglect of the basic rules of erosion-safe land use and the inadequate use of effective contouring-melioration erosion control measures in the agriculture.

To estimate the degree of ecological balance of agro-landscapes, we calculate the ratio of the main land uses: arable land – native pastures – forests. For Ukraine overall, this ratio should be equal to 1:1.6:3.6 (Sozinov et al. 1998). The observed ratio is 1:0.23:0.3, indicating a violation of the ecological balance in agro-landscapes. The ecological stability of the region is estimated using the of ecological stability factor (CES). The coefficient of ecological stability of agro-landscape is calculated using equation 1:

$$CES = \frac{\sum K \times S_i}{\sum S}, \quad (1)$$

where K_i is the coefficient of ecological stability of land use *i*; S_i – area of *i*-th land use.

The region is considered environmentally unstable when CES is less than 0.33. When CES varies from 0.34 to 0.50, the region belongs to stable instability, when CES is in the range from 0.51 to 0.66, the region is beyond the average stability, and when CES exceeds 0.67, the region is environmentally stable.

The average value of CES calculated for the Steppe, Forest-Steppe and Polissia is 0.29, 0.36 and 0.55 respectively. For the whole territory of Ukraine, CES is 0.38. Optimal values of CES for the mentioned zones are calculated as 0.41; 0.45; 0.61 respectively and for whole Ukraine, it is 0.47.

The coefficient of anthropogenic impact (CAI) characterizes the adverse phenomena in agro-landscapes and reflects the zonal-regional particularities of land use. The coefficient of anthropogenic impact is calculated by the formula 2:

$$CAI = \frac{\sum P_i \times S_i}{\sum S}, \quad (2)$$

where P_i – an anthropogenic impact on *i*-th land use in the agro-landscape; S_i – an area of *i*-th land use.

The values of CAI indicator calculated for the Steppe, Forest-Steppe and Polissia are 3.63; 3.50 and 3.06 respectively. The value of CAI for the territory of Ukraine is 3.44. The proposed changes to optimize the structure of the abovementioned zones are 3.34; 3.26; 2.93 respectively. In general, the CAI for Ukraine was calculated in 3.21.

The organizational basis for improving the management of forest meliorations should be the use of the principles of placing various categories of protective plantings on landscape-ecological and catchment basis. Landscape-ecological principles of the use of forest meliorations in current agro-landscapes include a number of measures of different content, but the basis is the optimization of the composition and the ratio of lands of agro-landscapes by removing from the warehouse arable land degraded and unproductive lands, the afforestation of rocky and damaged ravines steep slopes, sands and parts of riparian strips.

Conclusion

The analysis of the current structure of agro-landscapes found that 52% of the territory of Ukraine belongs to the state of destruction, and the proportion of unstable, medium-stable and stable territories is 12.8 and 4.0%, respectively. The agro-landscapes with ecological balance and sustained fertility growth occupy only 4.0% of the total area.

Estimation of the ecological stability of the territory showed that ecological stability factor for the Steppe, Forest-Steppe and Polissia zones is 0.29; 0.36 and 0.55 respectively. In general, for the territory of the country,, the CES reaches 0.38. As a result of optimization of the structure of agricultural lands CES can reach 0.41; 0.45; 0.61 for the climatic zones, respectively. It can reach the value of 0.47 for whole Ukraine.

The values of the coefficient of anthropogenic impact for the Steppe, Forest-steppe and Polissia zones are 3.63; 3.50 and 3.06 respectively. For the territory of Ukraine, CAI reaches 3.44. We have calculated optimal values of CAI for the optimized structure of the land use of agricultural landscapes. The values of CAI for the climatic zones are determined as 3.34; 3.26 and 2.93, respectively, and for the whole territory of Ukraine it is determined as 3.21.

We have developed the basic scheme of the ecological framework of the territory, which may be the basis for ensuring the stability of the lands of current agro-landscapes.

The application of the landscape-ecological methodology of forest amelioration enabled to substantiate the principles of the formation of a spatial geometry of current agro-landscapes, in which the predominant and system-forming element of land protection is a combination of field-protection afforestation and agroforestry.

References

Bayllovich Y (1938) On the theory of phytocultural landscapes. News of All-Union geographic society 70: 559-587.
Gladun G, Lokhmatov M (2007) Dokuchaev V. and forest meliorations. Kharkiv, Nove slovo publ, 574 p.
Grodzinskyi M, Shishchenko K (1993) Landscape-ecological analysis in land reclamation. Kyiv. Lybid, 225 p.
Grodzinskyi M (1995). Stability of geosystems to anthropogenic impacts. Kyiv. Lickey, 233 p.
Kochurov B (1999). Geoecology: ecodiagnostics, ecological and economic balance of the territory. Smolensk. Smolensk State University publ, 154 p.
Kotlayrova E, Cherniavskih V, Dumacheva E (2013) Ecologically Safe Architecture of Agrolandscape is Basis for Sustainable Development. Sustainable Agriculture Research 2: 12-23.
Nikolaev V (1992) Basics of the doctrine on agrolandscapes. Agricultural Landscape Research. Methodology, methods, regional problems. Moscow. Moscow State University publ, pp. 4-57.
Postolov V, Kryukova N (2010) On the need to move from traditional land management to landscape-ecological one under the conditions of soil degradation. Proceedings of Voronezh State Agrarian University 1 (24): 86-94.
Preobrazhensky V, Alexandrova T (1988). Fundamentals of landscape analysis. Moscow, 192 p.
Rodin A, Rodin S (2003) Formation of the ecological framework in Steppe and Forest-Steppe. Forest Management Journal 5: 9-10.
Ruzicka M, Miklos L (1990) Basic premises and methods in landscape-ecological planning and optimization. Changing Landscapes: An Ecological Perspective. New York. Springer–Verlag, pp. 233–257.
Seledets V (1987) Principles of organization of nature protection complexes. Geography and Natural Resources Journal 4: 38-43.
Sozinov O, Kozlov M, Serduk A et al. (1998) Current degradation processes, ecological-agronomic status and assessment of the suitability of agricultural land for the creation of environmentally friendly raw material zones and farms. Kyiv. Agroecol Biotechnol J 2: 54-65.
Vysotskyi G (1950). The doctrine of the forest impact on the change of the environment of its growth and on the surrounding space (the doctrine of forestry persistence). Moscow. Goslesbum publ, 102 p.
Yukhnovskyi V (2003) Forest-agrolandscapes of plain Ukraine: optimization, standards, and ecological aspects. Kyiv. Publ. of the Institute of Agricultural Economy, 273 p.

AGROFORESTRY SYSTEM BENEFITS TO ENVIRONMENT: CARBON STOCK, BIOMASS PRODUCTION BETWEEN ROWS AND SOIL ATTRIBUTES

Abdo MTVN[1]*, Siqueira CCZ[2], Chiba MK[2], Santos GXL[1], Rotta M[3], Rosa JM[3], Martins ALM[1], Pissarra TCT[4], Fabri EG[2], Chaves TH[1]

(1) Polo Centro Norte-Agencia Paulista de Tecnologia dos Agronegócios (APTA), Pindorama, SP, Brazil; (2) Instituto Agronômico de Campinas, Agencia Paulista de Tecnologia dos Agronegócios (APTA), Campinas, SP, Brazil; (3) Instituto Municipal de Ensino Superior IMES, Catanduva, SP, Brazil, (4) Departamento de Engenharia Rural, UNESP, Campus de Jaboticabal,SP, Brasil

*Corresponding author: mtvilela@terra.com.br

Abstract

Gully erosion stabilization started in 1997 to restore water flow and control soil erosion with four ponds construction. In 2011 an agroforestry system was planted in the edges under four treatments: T1-Mower, trees planted in hollows, spacing 3 x 2m, no plantation between rows; T2-herbicide, trees in hollows, 3.5 x 2 m, maize between; T3-Plough, harrow, scarifier, trees in furrows, 3.5 x 2 m, maize between; T4-Plough, harrow, scarifier, trees in furrows, 3.5 x 2 m, nothing between rows. Treatments influenced biomass between rows, trees carbon stock and soil properties. Trees C stock in 2015 was T1-6.4 t ha^{-1}, T2-8.31 t ha^{-1}, T3-4.84 t ha^{-1} and T4-4.41 t ha^{-1}. In 2017 C stock was T1-104.21 t ha^{-1}, T2-44.91 t ha^{-1}, T3-39.2 t ha^{-1} and T4-29.54 t ha^{-1}, vegetation between rows C stock was: T1-103.56 g ha^{-1},T2-199.11 g ha^{-1}, T3-147.77 g ha^{-1} and T4-85.14 g ha^{-1}. Also soil OM, K, P, Mg, Ca, sum of bases, CEC, pH, and base saturation at 0-20 cm increased.

Keywords: no tillage, carbon stock, tropical trees, soil attributes, *Bixa orellana*

Introduction

Agroforestry Systems (AFS) are important tools to restore degraded areas once they can induce the restoring process of vegetation and soil including trees to agricultural production ensuring biodiversity of the ecosystem and optimizing land use. Integrating forestry with food production and minimizing intensive land use compared to monoculture it also generates income and food production (Abdo et al. 2008). Siqueira (2017) also agrees that AFS generates extra income and allows diversified production in reforested area due to use of agricultural crops, shrub and tree species in the same physical space, with the possibility of including animal husbandry. According to the author species consortium can improve soil conditions, water quality, increase biodiversity and carbon sequestration. This crop diversification leads to a significant improvement of the physical, chemical and biological properties of the soil through nutrient cycling and erosion control. Also the use of trees can contribute significantly to reduce carbon emissions and mitigate climate change since their maintenance reduces emission of carbon as CO2 dioxide, the main source of emissions of greenhouse gases in tropical countries. According to Paixão et al. (2006) Brazil is a privileged country to reverse global climate change process by carbon sequestration through reforestation since it has climatic and technological conditions suitable for forest production but projects that measure forest related to carbon sequestration are necessary. The annatto (*Bixa orellana* L.) is a Bixaceae family plan, originally from tropical America, widely cultivated as a monoculture in Brazil and was used in this agroforestry system as part of the semi-arboreal component. Its seeds are valuable for producing pigments that are used as natural colorant in food, pharmaceutical and cosmetic industries with commercial value (Mendes et al. 2005). So this specie was chosen in order to optimize land and generate extra income (Fabri et al. 2015).

This restoration project took place at the Polo Regional Centro Norte-APTA a research center, located in the municipality of Pindorama, São Paulo state, Brazil. The area had no soil conservation practices and excess of runoff due to cattle tracks depth towards the water in the lower part of the area resulted in a gully with approximately 700 meters long and in some places up to 15 meters deep. To stop the erosion, four dams and four sunken ponds were built perpendicular to the erosion direction in 1997 and 1998. Each pond was connected to the next one by concrete overflows channels to prevent channel erosion and stabilize the area.

The following step to control erosion process and establish environmental sustainability was to restore the vegetation cover what was done with the implantation of a Agroforestry System in the edges of the pounds and a reforestation with native tree species in the spring.

Materials and methods

Characterization of the study area

The AFS area is in Polo Centro Norte- APTA, Pindorama, SP, Brazil. An agricultural research center with total 532 ha and 144 ha of forest. The coordinates are 48 55 'W and 21 13' S, Koeppen Aw climate (tropical rainy), altitudes from 498 to 594 m (Lepsch and Valadares 1976). It is a transition between Cerrado and Atlantic Forest biomes (IBGE 2013). The predominant land use are cane sugar, citrus, mango, guava, tomato and pasture (Cavichioli et al. 2008) and with ultisols very susceptible to erosion (Vieira et al. 1999). The restoration of riparian vegetation on the edges of the ponds was done with an agroforestry system under different managements from a minimum interference on the soil (T1) to intensive tillage and no vegetation protection (T4), planted in 2011 with four parcels with 10 rows and 7 plants. Treatments were: T1 (Mower coupled to the tractor, trees planted in hollows, spacing 3 x 2 m without cultivated or fertilization between lines); T2 (herbicide, planting in hollows, 3.5 x 2 m spacing, maize cultivated between lines); T3 (Plough, Harrow, scarifier, planting trees in furrows, 3.5 x 2 m spacing, with maize between lines); T4 (Plough, Harrow, scarifier, planting trees in furrows, 3.5 x 2 m spacing, with no plantation between lines).

Trees survey

All trees were measured in January 2015 and in 2017.The annatto also in 2014. Height was measured with graduated wooden ruler and circumference at breast height (CBH) with a graduated tape. To estimate above tree biomass an indirect method developed by ICRAF (Arevalo et al. 2002) was used and results are in tons of carbon per hectare (C t ha^{-1}).

Biomass between rows

To determine plant biomass between rows 4 samples were taken for each treatment plot using a sample square metal with an area of 0.25 m^2, randomly launched in the area. All vegetation above ground was collected and the samples were oven dried at 60°C with forced air circulation to constant mass according to Pitelli (2000).

Soil analysis: fertility

In 2011 before plantation soil fertility attributes were evaluated in the 0-20 cm depth layer and two samples were composed by treatment (AFS1, AFS2 and AFS3). Samples were conditioned in plastic bags, identified and sent for determination, according to Raij et al.(2001): phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), active acidity (pH in calcium chloride), potential acidity (H + Al), sum of bases (SB), cation exchange capacity (CEC) and base saturation (V%). In 2016, four samples composed of 20 sub-samples were obtained at soil depths of 0-20 cm and 0-40 cm in each treatment for determination of the same chemical parameters analyzed in 2011.

Carbon and nitrogen levels

A composed sample consisting of 10 simple samples was obtained at depths of 0-5, 5-10, 10-20, 20-30, 30-40, 40-60, 60-80 and 80-100 cm (four replicates per treatment). C stocks (Mg ha^{-}

[1]) were calculated for each layer by multiplying carbon content (%), soil densities (g cm^{-3}) and layer thickness (cm), and were corrected by the Carvalho et al. (2009) method.

Results

The carbon stock for all live trees of the agroforestry system (AFS) in 2015 and 2017, the carbon stock of vegetation between trees rows in 2017 in all treatments and the value for soil carbon stock in 2017, for treatments 1, 2 and 3 are shown in Figure 1. All data is shown in tons per hectare (t ha^{-1}).

The carbon stock of trees and soil carbon in the native forest (t ha^{-1}) were also calculated so it can be compared to trees carbon stock from 2015 and 2017.

By September 2015 the soil organic matter and sum of bases had increased in all treatments from 2011. It was observed that soil attributes such as soil organic matter (SOM), potassium, sum of bases, phosphorus, magnesium, cation exchange capacity (CEC), pH, calcium and base saturation at the 0-20 cm depth layer also increased from the year of plantation 2011 to 2016 (Figure 2).

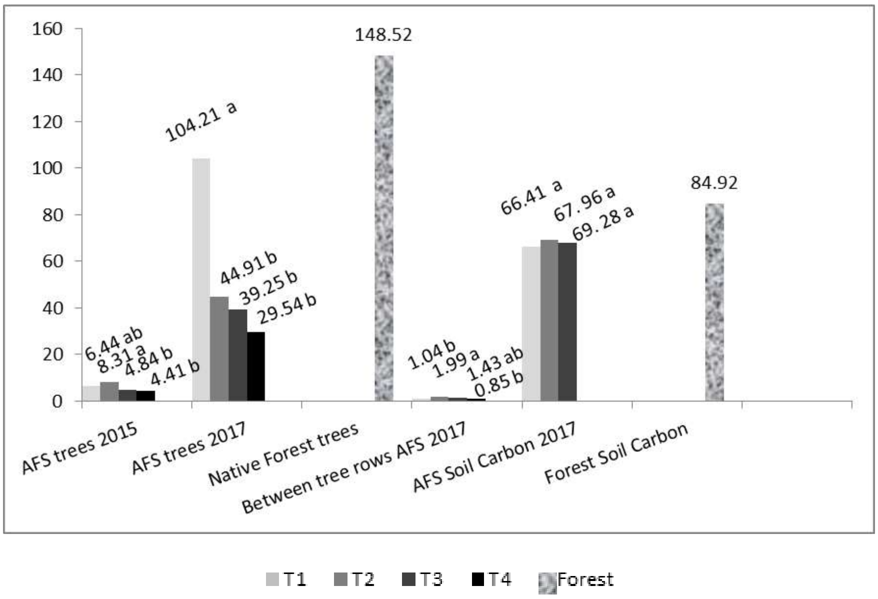


Figure 1: Carbon stock of trees in 2015 and 2017, carbon stock of vegetation between AFS trees rows in tons per hectare (t ha^{-1}) in four treatments of the Agroforestry System (AFS) compared to carbon stock of native forest trees in 2017 and AFS soil carbon (t ha^{-1}) in treatments 1, 2 and 3 compared to Forest Soil Carbon (t ha^{-1}).

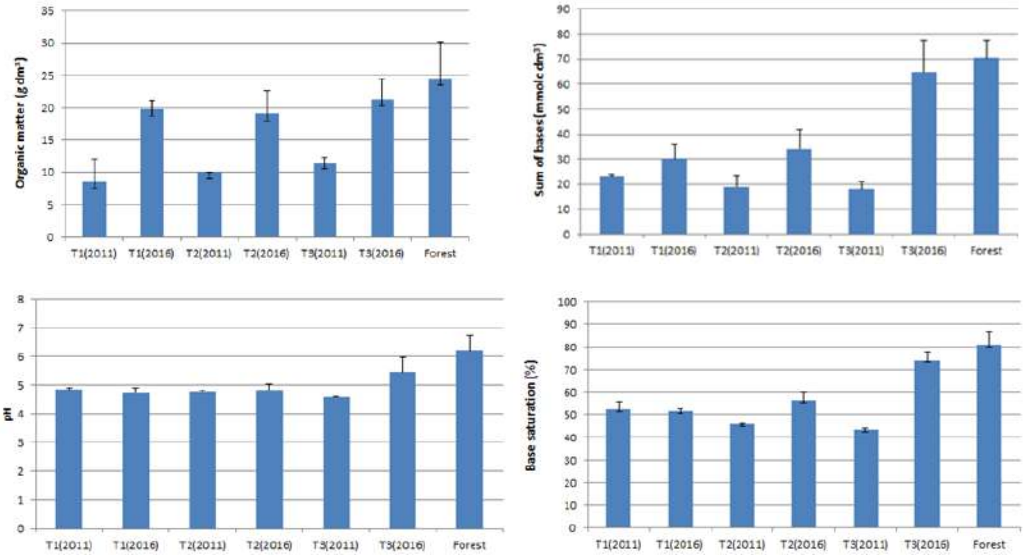


Figure 2: Soil attributes in 2011 before AFS and in 2016, compared to forest soil (Siqueira 2017).

The annatto (*Bixa orellana)* was also influenced by plantation techniques. Table 1 shows production and carbon stock of the specie in 2012 and 2014.

Table 1: Seeds weight (SW) in g, productive trees (PT) and total fruits (TF) in 2012, and2014 and total of living trees (LT) and Carbon stock (CS) in 2014 under four different treatments (T1, T2, T3 and T4), Variation Coefficient (VC) and General Mean (GM).

Var	SW2012	SW 2014	PT 2012	PT 2014	TF 2012	TF 2014	L T 2014	C S 2014
VC%	77.04	74.53	44.71	39.33	80.56	83.96	23.53	47.07
GM	0.13	5.17	2.43	6.56	216.43	6507.53	14.41	1.46
T1	0.01b	8.2ª	0.62c	7.87a	20.00b	11347.5a	16.01 a	0.31 a
T2	0.14ab	5.76ab	2.37b	6.37ab	258.62a	6468.37ab	14.20 ab	0.54 a
T3	0.24ª	4.8ab	4.50a	8.37a	362.25a	5534ab	17.16 a	0.28 a
T4	0.13ab	1.93b	2.25b	3.62b	224.87ab	2680.25b	10.29 b	0.36 a

*Averages followed by the same letter in Colum are not statistically different (Tukey- p>0.05)

Discussion and conclusions

The agroforestry system improved soil and vegetation in the area contributing to environmental preservation. The data confirm the expectations that management of each treatment influenced the soil and vegetation. The annatto, the commercial crop that is already producing is a good option for extra income for small farmers reducing costs of reforestation and attracting new agroforestry projects. The soil improvement can be observed in all attributes evaluated and carbon stock of living trees confirm that agroforestry systems are one of the most important tool to mitigate climate change problems and can be very attractive to farmers.

References

Abdo MTVN, Vieira SR, Martins ALM, Silveira LCP (2008) Estabilização de uma voçoroca no Pólo Apta Centro Norte-Pindorama-SP. Tecnologia & Inovação Agropecuária 1: 135-141.

Arevalo LA, Alegre JC, Vilcahuaman JM (2002) Methodology for Estimating Carbon Stocks in Different Land Use Systems. Colombo. EMBRAPA, p.38.

Carvalho JLN, Cerri CEP, Feigel B J, Piccolo MC, Godinho VP, Cerri CC (2009) Carbon sequestration in agricultural soils in the Cerrado region of the Brazil Amazon. Soil Till Res 103: 342-349.
Cavichioli FA et al. (2008) Avaliação do uso e ocupação do solo em propriedadesrurais para implantação de práticas conservacionistas. XII Encontro Latino Americano de Iniciação Científica, Jaboticabal. http://www.cpa.unicamp.br/outras-informacoes/ clima_muni_431.html (accessed 01/06/2013).
Fabri EG, Abdo MTVN, Salazar FF, Cordeiro Junior PSC, Martins ALM, Finoto EL, Bieras AC (2016) Production and carbon stock of annatto tree in agroforestsystem, Pindorama, SP. Anais: XIV World Forestry Congress, Durban, South Africa.
IBGE (2013) IBGE Cidades. http://www.ibge.gov.br/cidadesat/painel/ painel.php?codmun=353810 (accessed 02/06/2013).
Lepsch IF, Valadares JMAS (1976) Levantamento pedológico detalhado da Estação Experimental de Pindorama, SP. Bragantia. Campinas 35: 13-40.
Mendes MAS, Figueiredo AF, Silva J F (2005) Crescimento e maturação dos frutos e sementes de urucum. Revista Brasileira de Sementes 27: 25-34.
Paixão FA, Soares CPB, Jacovine LAG, Silva ML, Leite LG, Silva GF (2006) Quantification of carbon stock and economic evaluation of management alternatives in a eucalypt plantation. Revista Árvore 30: 411-420.
Pitelli RA (2000) Estudos fitossociológicos em comunidades infestantes de agroecossistemas. Jornal Conserb 1: 1-7.
Raij B, Andrade JC, Cantarella H, Quaggio JA (2001) Análise Química para Avaliação da Fertilidade de Solos Tropicais. Campinas: Instituto Agronômico.
Siqueira CCZ (2017) Atributos do solo e estoques de carbono em sistemas agroflorestais na restauração de áreas degradadas. Dissertação de Mestrado. Campinas, IAC.
Vieira SR (1999) Relatório de projeto de recuperação ambiental da Estação Experimental de Pindorama. Pindorama, Brazil.

HEDGEROWS AS FORM OF AGROFORESTRY TO SEQUESTER AND STORE CARBON IN AGRICULTURAL LANDSCAPES: A REVIEW

Blair J[1,2*], Olave R[1], McAdam J[3]

(1) Agri-Food and Biosciences Institute (AFBI), Large Park, Hillsborough, BT26 6DR, UK (2) School of Biological Sciences, Queen's University Belfast, MBC, 97 Lisburn Road, Belfast, BT9 7BL, UK (3) Agri-Food and Biosciences Institute (AFBI), Newforge Lane, Belfast, BT4 3SD, UK

*Corresponding author: jonathan.blair@afbini.gov.uk

Abstract

Hedgerows are an intrinsic part of the agricultural landscape in Europe. As an anthropogenic feature it is difficult to ascertain the carbon storage potential. We performed a systematic literature review on the potential of hedgerows to take in and store carbon. Results show two emerging trends to consider. Aboveground biomass storage estimates range from 5 t C ha^{-1} to 131 t C ha^{-1}. Maintenance of hedges is ascribed as leading to differences in estimation as a result of continually trimming and shaping. .There has also been a decline in hedge length across Europe over the past decades leading to losses of biomass. Soil organic carbon stocks below hedgerows range from 5 t C ha^{-1} to 360 t C ha^{-1}. Hedgerows can thicken soil horizons, prevent erosion and interact with soil water and nutrients. The hedgerow ecosystem is highly localised with differing levels of material input and decomposition. Therefore it is needed to ascertain carbon assimilation and storage to improve estimates for national GHG inventories.

Keywords: hedgerow carbon; hedge carbon; carbon storage; landscape carbon; soil carbon

Introduction

Hedgerows, as an agroforestry system, combine trees/shrubs and agriculture on the same land. This epitomises a land sharing approach to reap multiple benefits; traditionally multiple food or food plus wood crops. In terms of environmental benefits hedgerows present an option for climate mitigation, absorbing and storing carbon on the same land while still producing food or other agricultural outputs.

Hedgerows are lines of woody material on agricultural land used primarily for the division of land parcels. A distinction must be made between the word 'hedgerow' (which incorporates all biomass material and the associated land, banks, ditches and soils) and the word 'hedge' (which is simply the vegetation associated with hedgerows) (Black et al. 2014; Barr and Gillespie 2000).They must be >20m long. They can be viewed similarly to shelter belts or alley cropping, lines of trees with crops growing in-between. Hedges form a network across the landscape and account for large amounts of land, e.g. approx. 3% land in Northern Ireland is under hedge (McCann 2007). Hedgerows have been extensively studied for their ecological benefit however they have rarely been studied for carbon sequestration and storage potential. In the UK landscape scale models of carbon sequestration fail to incorporate hedgerows into GHG inventories, missing a potentially large sink for atmospheric CO_2 (Moxley et al. 2014).

Hedges are anthropogenic in nature and as such must be continually trimmed, shaped and maintained making measurement difficult. Aboveground storage of carbon is greatly influenced by species composition and position in the landscape. Management is also a concern, incorporation of large machinery into the farming landscape in the 1960's lead to declines in hedge length in England and Wales of ~43% (Carey 2008). This has been replicated in other European countries. It has been estimated that the EU-27 can incorporate 17 million km of hedgerow (Aertsens et al. 2013).

Materials and methods

A systematic literature review relating to information on hedge carbon storage and sequestration rates was utilised to search for and gather publications for review. This method was chosen as the most appropriate approach to minimize bias towards particular publication journals, authors or study type and to ensure searches captured as many relevant publications as possible. Information was extracted and trends identified to gain an understanding of current work. No restrictions were placed on geographic location or time of publication. A further search of grey literature was conducted including information from government reports, conference proceedings and contact with authors.These formed the basis of the search terms to be utilized in gathering publications for assessment. General themes from review are presented here.

Results

Two main areas for consideration emerged from literature review, aboveground and belowground.

Aboveground

Carbon storage is not easily quantifiable with variations across location and species composition. Our search estimates carbon storage in the range 5 t C ha^{-1} to 131 t C ha^{-1} and carbon input rates from 0.37 t C ha^{-1} yr^{-1} to 45.78 t C ha^{-1} yr^{-1}. Discrepancies arise due to maintenance. As an anthropogenic feature of the landscape hedges are continually trimmed and shaped. Maintenance consists of either trimming, using a mechanical flail, laying, where the hedge is cut back shaped and allowed to regrow, or coppiced, where the majority of aboveground biomass is removed and regrowth occurs from the little material left. Maintenance has impacts on hedge regrowth, affecting both storage and input rates. In a coppiced system hedge biomass fell to 21% (Blackthorn) and 27% (Hawthorn) of previous storage capacity (Crossland 2015). Regrowth potentials also differ, Hazel (*Corylus avellana*) showed the best re-growth after one year at >200cm shoot growth, Hawthorn (*Crataegus monogyna*) approx. 125cm and Blackthorn (*Prunus spinosa*) showed the least re-growth at approx. 40cm (Westaway et al. 2016). Carbon storage is highly dependent on the use of hedge biomass. Trimmed material that is subsequently burnt returns CO_2 to the atmosphere, thus limiting potential sequestration.

Declining hedge length leads to declines in biomass and thus carbon storage. In Britain between the 1950's and 2000's there was a decline of approx. 43% in hedge length. This pattern is repeated in other countries such as Germany (Poschlod and Braun-Reichert 2017). The EU-27 could potentially introduce 17.8 million km of hedge incorporating 18 million tonnes C annually (at a rate of 0.366 t CO_2-eq ha^{-1} yr^{-1}) (Aertsens et al. 2013). Reasons for hedge loss are largely social, with removal dependent on the surrounding land use. A trade-off exists, where hedges provide ecosystem services, such as carbon storage; they can be seen as an interruption to production limiting access of large machinery and can be expensive to establish. These declines in hedge length can have negative impacts on landscapes ability to store carbon.

Belowground

Soil plays an important role in the functioning of agroecosystems, including sequestration of carbon. A paucity of data exists on the effects hedgerows have on soil organic carbon (SOC) stocks. We suggest SOC stocks under hedge range from 5t C ha^{-1} to 360t C ha^{-1}. Carbon stocks are higher under a hedge than the surrounding cropped land area. Hedgerow soils are usually undisturbed, where humification processes show similar patterns to those in a forested soil (Sitzia et al. 2014). Hedgerows increased carbon stocks by up to 114% compared to treeless areas (Van Vooren et al. 2017). SOC contents were higher adjacent to a hedge structure, dissipating with distance (median value 16.6 kg C m^{-2} hedge side vs 13.3 kg C m^{-2} landscape value) and depth in a hedged landscape (Follain et al. 2007). SOC contents are also affected at depth under hedgerow. Mean carbon content increased from the 0-10cm layer and declined again from the 10-30cm layer (Follain et al. 2007) SOC stocks in a silvoarable system were also higher in the upper layers however the situation was reversed for lower layers

(>150cm) (Upson and Burgess 2013). Fractionation of soil under silvopastroral systems showed a significant increase in C pools at the micro-aggregate, silt and clay sizes, leading in the long term to increases in recalcitrant fractions (Fornara et al. 2017). Hedgerow influence can extend beyond the reach of the branches, with a zone showing higher concentrations of major ions, dissolved oxygen, a deeper water table and higher hydraulic conductivity.

There is a pronounced barrier effect when hedgerows are placed across a sloping plane. Up to 60m upslope from a hedgerow in such a situation soil 'A' horizon was thicker and more developed with significantly higher levels of carbon compared to the downslope (Walter et al. 2003). This thickening was observed for the higher levels of soil only and not at lower levels. This prevention of erosion was not observed by Chaowen et al. (2007) however who observed soil particles eroding laterally. Their study was conducted with hedge strips, highlighting the importance of the interconnectedness of the hedgerow network in the landscape. Thickening was found to remain in the landscape decades after removal of hedgerow (Follain et al. 2009) Hedgerows therefore also display a significant temporal effect.

Previously researchers have used estimates from agroforestry to model sequestration rates. Using information from short rotation Poplar, (Taylor et al. 2010) estimated that hedges would sequester enough carbon to offset 5% of on farm emissions. Hedges have been incorporated into process based models such as RothC and Landsoil (Lacoste et al. 2014). Accurate information about specific hedge species should be gathered and used. Allometry for example has been applied to many forestry and agroforestry systems. Such destructive sampling would provide the information necessary to complement models and provide more accurate assessments. To our knowledge they have yet to be applied to the hedgerow system.

Conclusions

Hedges are lines of woody material, however as an anthropogenic feature of the landscape it is difficult to ascertain the carbon storage potential. Estimates range from 5 to 131 t C ha^{-1}. Belowground hedgerow soils store between 5 and 360 t C ha^{-1}. Discrepancies arise due to differing management and surrounding land use. They exhibit influence on nutrient levels and help in prevention of erosion and thickening of soils, increasing carbon stocks relative to adjacent cropped land. Potential sequestration relating to hedges is highly dependent on the use of biomass material. More work is needed to ascertain carbon assimilation and storage to improve estimates from modelled situations having impacts for national GHG inventories.

References

Aertsens J, De Nocker L, Gobin A (2013) Valuing the carbon sequestration potential for European agriculture. Land Use Policy 31: 584-594.

Barr CJ, Gillespie MK (2000) Estimating hedgerow length and pattern characteristics in Great Britain using Countryside Survey data. J Environ Manag 60: 23-32.

Black K, Green S, Mullooley G, Poveda A (2014) Carbon Sequestration by Hedgerows in the Irish Landscape: Towards a National Hedgerow Biomass Inventory for the LULUCF Sector Using LiDAR Remote Sensing. EPA Climate Change Research Programme 2007–2013.

Carey PD, Wallis S, Chamberlin PM, Cooper A, Emmett BA, Maskell LC, Mccann T, Murphy J, Norton LR, Reynolds B, Scott WA, Simpson IC, Smart SS, Ullyett JM (2008) Countryside Survey; UK Results from 2007. CEH Report.

Chaowen L, Shihua T, Jingjing H, Ybing C (2007) Effects of plant hedgerows on soil erosion and soil fertility on sloping farmland in the purple soil area. Acta Ecologica Sinica 27: 2191-2198.

Crossland M (2015) The Carbon Sequestration Potential of Hedges Managed for Woodfule. A report of the Organic Research Centre, 45.

Follain S, Walter C, Legout A, Lemercier B, Dutin G (2007) Induced effects of hedgerow networks on soil organic carbon storage within an agricultural landscape. Geoderma, 142: 80-95.

Follain S, Walter C, Bonté P, Marguerie D, Lefevre I (2009) A-horizon dynamics in a historical hedged landscape. Geoderma 150: 334-343.

Fornara DA, Olave R, Burgess P, Delmer A, Upson M, McAdam J (2017) Land use change and soil carbon pools: evidence from a long-term silvopastoral experiment. Agrofor Syst https://doi.org/10.1007/s10457-017-0124-3

Lacoste M, Michot D, Viaud V, Evrard O, Walter C (2014) Combining 137Cs measurements and a spatially distributed erosion model to assess soil redistribution in a hedgerow landscape in northwestern France (1960–2010). CATENA 119: 78-89.

Mccann T (2007) Northern Ireland Countryside Survey 2007 Field Boundaries summary. https://www.daera-ni.gov.uk/publications/northern-ireland-countryside-survey-2007-field-boundaries-summary (accessed 04/05/2018).

Moxley J, Anthony S, Begum K, Bhogal A, Buckingham S, Christie P, Datta A, Dragosits U, Fitton N, Higgins A, Myrgiotis V, Kuhnert M, Laidlaw S, Malcolm H, Rees B, Smith P, Tomlinson S, Topp K, Watterson J, Webb J, Yeluripati J (2014) Capturing Cropland and Grassland Management Impacts on Soil Carbon in the UK LULUCF Inventory. Contract Report prepared for the Department for Environment, Food and Rural Affairs.

Poschlod P, Braun-Reichert R (2017) Small natural features with large ecological roles in ancient agricultural landscapes of Central Europe - history, value, status, and conservation. Biol Conserv 211: 60-68.

Sitzia T, Pizzeghello D, Dainese M, Ertani A, Carletti P, Semenzato P, Nardi S, Cattaneo D (2014) Topsoil organic matter properties in contrasted hedgerow vegetation types. Plant Soil 383: 337-348.

Taylor R, Jones A, Edwards-Jones G (2010) Measuring holistic carbon footprints for lamb and beef farms in the Cambrian Mountains initiative. CCW Policy Research Report No. 10/8, 57.

Upson MA, Burgess PJ (2013) Soil organic carbon and root distribution in a temperate arable agroforestry system. Plant Soil 373: 43-58.

Van Vooren L, Bert R, Steven B, Pieter DF, Victoria N, Paul P, Kris V (2017) Ecosystem service delivery of agri-environment measures: A synthesis for hedgerows and grass strips on arable land. Agr Ecosyst Environ 244: 32-51.

Walter C, Merot P, Layer B, Dutin G (2003) The effect of hedgerows on soil organic carbon storage in hillslopes. Soil Use Manag 19: 201-207.

Westaway S, Chambers M, Crossland M, Wolton R, Smith J (2016) Managing traditional hedges for biofuel. 12th European International Farming Systems Association Symposium 'Social and technological transformation of farming systems: Diverging and converging pathways'. Harper Adams, UK

AGROFORESTRY SYSTEMS AS ALTERNATIVE FOR CONSERVING NATIVE PLANT SPECIES AND IMPROVING AGRO-ECOLOGICAL KNOWLEDGE

Cadena González AL[1]*, Buttschardt T[1]

(1) Institute of Landscape Ecology, Westfälische Wilhems University of Münster, Münster, Germany

*Corresponding author: a_cade01@uni-muenster.de

Abstract

Depletion and displacement of native plant species by exotics is reported worldwide, including tropics and temperate areas. Agroforestry systems (AFS) may help to conserve native plant species. Therefore, the aim of the project is to analyze local factors that determine if farmers cultivate native species in AFS or not in the tropics and temperate regions, and to find out if lack of agro-ecological knowledge is a significant factor. The study comprises literature review, case studies with implementation of questionnaires and interviews of farmers in the tropics and temperate regions. Results from a case study in La Vega municipality, Colombia, include a characterization of plant species reported to be cultivated locally in AFS. We will complete an analysis of local social factors that determine plant cultivation, including the analysis of the role of agro-ecological knowledge at local level.

Keywords: native species; agroforestry systems; plant conservation; conservation and benefits

Introduction

Native plant species have been displaced by exotic plant species in several regions, including tropics and temperate areas (Gómez et al. 2011). One of the reasons is expansion of modern agricultural land use which has led to disruption of natural habitats and loss of biodiversity (Douglas et al. 2014). Productivity of exotic species has been the most frequent reason supporting the introduction of exotic species into agricultural systems. For example, tree species that require low inputs, but offer high potential of adaptation and fast growth, are frequently planted in the central area of the Colombian Andes (Pacheco 2004) and in the south-east of Brazil, in Minas Gerais (Couto et al. 1994), where local markets focused on wood are established and, similarly, small-scale farmers are interested in inexpensive sources of wood. These species include, e.g., *Eucalyptus*, well industrialized in Brazil and Colombia where also Acacias and Pines are popular (Escobedo et al. 2015). However, in spite of the high productivity of these species, they have not brought positive returns to the environment as a whole. Rather they seem to have deteriorated the soil and to have rendered land in agricultural regions unproductive (personal communication). Another example is *Acacia melanoxylon*, an exotic species to Spain which was introduced and officially established by laws of forestation in various localities in Spain in past decades (Swagemakers and Dominguez 2015). It has invaded woodlands and affected natural habitats (Jose 2011). Such ecological impacts also entail social problems because in several cases small-scale farmers, although getting the right to cultivate the land, are not able to restore the degraded soils due to various difficulties. Furthermore, in a number of localities worldwide native species have disappeared or are endangered due to overuse or lack of cultivation and failed restoration of resources (Van Andel and Aronson 2012; Cadena et al. 2013). As an alternative to monocultures of trees or crops, agroforestry systems (AFS) are integrated forms of land use that besides high production also have potential to reduce adverse environmental impacts, such as land degradation, reduced food production, and climate change (Smith et al. 2012; Leakey 2014; Morhart et al. 2014). Further, they may help to recover and maintain native plant species (Barrios et al. 2018). A key element for the conservation of native species in AFS is the recovery and improving of traditional agroecological knowledge and the attention to the reasons that farmers have for not investing in cultivation and protection of these species.

Project description

The project comprises literature review; case studies in the tropics and temperate regions; statistical analyses of data; identification of local factors that determine cultivation of plant species; characterization of plant species reported to be cultivated among local agroforestry systems, this characterization includes agro-ecological requirements of the plant species.

So far, a case study in the Eastern Andean range in Colombia, municipality of La Vega, department of Cundinamarca, has been completed. This case study aimed at (i) identifying local factors that influence farmers' decisions to cultivate native species or not, at (ii) studying the traditional structure of AFS, and at (iii) assessing gaps in agro-ecological knowledge at local level. The municipality of La Vega comprises a wide elevational range between 1,100–2,700 meters and, consequently, a marked climatic gradient and a diverse geographical structure which allows for cultivation of a high diversity of crops and tree species. In spite of the benign characteristics of the natural environment and high quality of soils, many local farmers, especially subsistence farmers, struggle to gain some income to support their families. This situation is becoming worse due to effects of climate change. Thus, farmers need support to ensure food production, to diversify their income sources, and to improve agro-ecological knowledge. Regarding protection of native plant species, effective programs are needed that motivate locals to conserve local genetic material, e.g., via collection of seeds and seedlings found in the wild. Five representative villages were selected in order to carry out the field work. Data were obtained via qualitative and quantitative methods, namely community meetings, questionnaires, semi-structured and structured interviews with farmers, expert interviews, open talks, and visits to farms. A total of 71 farmers participated in the study.

Based on the plant species cultivated and described by the farmers, further research was done in order to characterize the agro-ecological requirements of these species. The results included in this paper comprise information of the structure that farmers give to their AFS and detailed ecological and botanical characterizations of the crops and trees cultivated in the locality, including information on characteristics such as origin of the species, drought tolerance, life cycle, red list status, and ecological requirements.

To date, we have characterized a total of 152 species including crops and trees. One hundred and three species of this list have been identified as perennials, and 20 species belong to the group of annuals and biennials. Among these species, 50 are exotic and 71 natives; 22 are nitrogen-fixers, 17 species are resistant to drought, some of them with clear limits of resistance as they can only survive droughts of maximum three months. The most popular agroforestry systems in the locality are homegardens and intercropping systems represented by approximately 60 % and 10% respectively.

Until now, the results show that the cultivation of exotic woody species is greatly intensified, and farmers are mainly depending on few crops (*Coffea arabica* and *Thebroma cacao*) (Figure1). Other popular exotic woody species are *Persea Americana, Citrus nobilis* and *Citrus aurantium,* Additionally, another popular and non-timber exotic plant species is *Musa paradisiaca.*

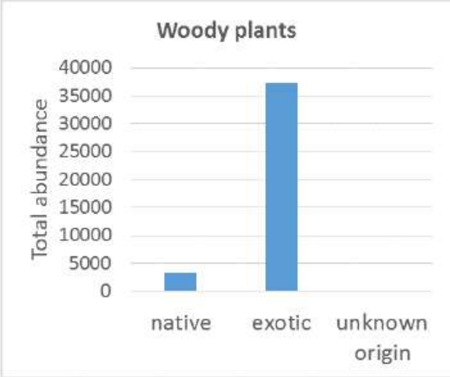


Figure 1: Cumulative number of woody plants species on 26 farms in La Vega, Cundinamarca, Colombia, according to their place of origin.

In the case of herbaceous plants, the inclusion of native species in AFS is more popular than exotics species (Figure 2).

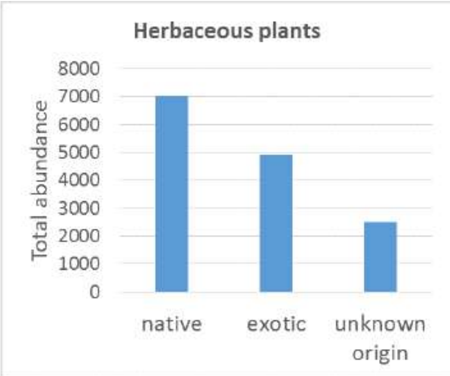


Figure 2: Total cover (m²) of herbaceous plants species on 26 farms in La Vega, Cundinamarca, Colombia, according to their origin.

By the end of the project, approximately end of 2019, we expect to contribute significantly at local level to: (i) the improvement of design and structure of AFS based on the potentials of local plant species and agro-ecological knowledge –the results obtained during the characterization of the species mentioned during interviews, will guide the elaboration of proposals for designing and structuring AFS – (ii) the promotion of diversification, (iii) the conservation of native plant species that will be achieved during the visits, talks and interviews with farmers, and (iv) the process of communication of results and transfer of knowledge which is expected to be achieved by the elaboration of a report and direct communication with farmers.

References

Barrios E, Valencia V, Jonsson M, Brauman A, Hairiah K, Mortimer PE, Okubo S (2018) Contribution of trees to the conservation of biodiversity and ecosystem services in agricultural landscapes. Int J Biodivers Sci Ecosys Serv Manag 14: 1-16.

Cadena González AL, Sørensen M, Theilade I (2013) Use and valuation of native and introduced medicinal plant species in Campo Hermoso and Zetaquira, Boyacá, Colombia. J Ethnobiol Ethnomed 9: 23.

Couto L, Binkley D, Betters DR, Moniz CVD (1994) Intercropping Eucalypts with maize in Minas Gerais, Brazil. Agrofor Syst 26: 147–156.

Douglas DJT, Nalwanga D, Katebaka R, Atkinson PW, Pomeroy DE, Nkuutu D, Vickery JA (2014) The importance of native trees for forest bird conservation in tropical farmland. Anim Conserv 17: 256–264

Escobedo FJ, Clerici N, Staudhammer CL, Tovar CG (2015) Socio-ecological dynamics and inequality in Bogotá, Colombia's public urban forests and their ecosystem services. Urban For Urban Gree 14: 1040-1053.

Gómez H, Díaz F, Franco L, Mercado J, Guzmán J, Medina J, Gaitán R (2011) Folk medicine in the northern coast of Colombia: an overview. J Ethnobiol Ethnomed 7: 27.

Jose S (2011) Managing native and non-native plants in agroforestry systems. Agrofor Syst 83: 101-105.

Leakey Roger RB (2014) The Role of Trees in Agroecology and sustainable agriculture in the Tropics. Annu Rev Phytopathol 52: 133-33

Morhart CD, Douglas GC, Dupraz C, Graves AR, Nahm M, Paris P, Sauter UH, Sheppard J, Spiecker H (2014) Alley coppice –a new system with ancient roots. Ann For Sci 71: 527–542.
Pacheco Fonseca P. (2004) Plan de Desarrollo Municipal de Zetaquira Boyacá 2004–2007. Desarrollo Municipal con Participación Ciudadana.
Smith J, Pearce BD, Wolfe MS (2012) A European perspective for developing modern multifunctional agroforestry systems for sustainable intensification. Renew Agr Food Syst 27: 323–332.
Swagemakers P, Dominguez G MD (2015) How to move on? Collective action and environmental protection in the city-region of Vigo, Spain. Proceedings from International Conference Meanings of the Rural-between social representations, consumptions and rural development strategies 28–29 September 2015, University of Aveiro, Portugal.
Van Andel J, Aronson J (2012) Restoration Ecology. The New Frontier. Wiley-Blackwell, Chichester.

IMPACT OF TREES ON SOIL NITROGEN DYNAMICS IN TEMPERATE SILVOARABLE AGROFORESTRY SYSTEMS

Coussement T[1*], Janssens P[1], Elsen A[1], Pardon P[3,4,5], Nelissen V[3], Reubens B[3], Vandendriessche H[1,2]

(1) Soil Service of Belgium, Heverlee, Belgium (2) Division of Crop Biotechnics, KU Leuven, Heverlee, Belgium (3) Flanders Research Institute for Agriculture, Fisheries and Food, Merelbeke, Belgium (4) Department of Plant Production, Ghent University, Ghent, Belgium (5) Department of Forest and Water Management, Ghent University, Gontrode, Belgium

*Corresponding author: tcoussement@bdb.be

Abstract

By introducing trees on an arable field, agroforestry systems will have a strong impact on many aspects of the soil nitrogen dynamic, with important agronomic and environmental consequences. In the temperature region of Europe, these consequences are still poorly understood and quantified. This research focuses on the way mature poplar trees (*Populus x canadensis*) affect the soil nitrogen dynamic on six arable fields in Flanders (Belgium), with the aim to quantify the impact and to identify its spatial and temporal extent. Preliminary results show a significant impact of the trees on the soil mineral nitrogen content, spatially as well as temporally, with significant differences between fields with maize and winter grains. These results indicate that nitrogen uptake by the tree roots could play an important role in the late growing season of maize, and result in lower residual soil nitrogen after maize harvest.

Keywords: nitrate leaching; belowground competition; nutrient competition; temperate agroforestry; tree-crop interactions

Introduction

Nitrogen (N) is one of the most important plant nutrients in agricultural soils, however N fertilization often causes environmental problems in regions with intensive agriculture, such as Western Europe, mainly due to leaching into surface and subsurface waters (Allen et al. 2004). Agroforestry systems are considered to have the potential to mitigate these problems, because the deep root system of the trees can capture N that is leached below the crop root zone (Allen et al. 2004). The presence of trees on an arable field however will possibly have a strong impact on the whole soil nitrogen dynamics. These effects range from direct uptake of soil N by the tree roots and input of N from tree leaves and roots, to subtler effects, such as an alteration of the mineralization of soil organic matter due to changes in soil temperature and water content. Additionally, competition for light, water and nutrients may affect the biomass production of the arable crop close to the tree line, and consequently the residual N left in the soil after harvest (Allen et al. 2005; Jose et al. 2000a; Jose et al. 2000b; Fernández et al. 2008; Ishikawa and Bledsoe 2000).

The impact of trees on the soil nitrogen dynamics in arable fields in the temperate region of Europe is still poorly understood and quantified (Jose et al. 2000a; Allen et al. 2005). This research focuses on the way mature poplar trees (*Populus x canadensis*) affect the soil nitrogen dynamics on arable fields in Flanders (Belgium). For the studied fields, significantly increased soil organic carbon and soil nutrient concentrations (P, K, Mg, Na, and total N) in the topsoil close to the trees were already observed (Pardon et al. 2017). The study aims to quantify the impact of mature poplar trees on the soil nitrogen dynamics in the field, and to identify the spatial and temporal extent of the impact.

Materials and methods

Today there are still very few arable alley cropping systems in Flanders, and the existing systems are exclusively of young age. Therefore, a set of six arable fields partially bordered by a row of high-pruned poplar trees (*Populus x canadensis*) of moderate to older age (15–47 years) was selected as a proxy. An overview of the location of the fields and their characteristics is provided in Table 1. In order to compare the boundary planted zone of the field with a conventional arable field, the part of the field without tree border was selected as a reference situation.

Table 1: Characteristics of the boundary planted fields: climatic data (“Temp.”: annual average air temperature in C° near surface, “Precip.”: annual average precipitation in mm yr−1) for the period 1990–2015; soil type according to field measurements; DBH: the tree diameter at breast height.

Location	Temp. [°C]	Precip. [mm yr^{-1}]	Soil texture	Year of plantation	Height [m]	DBH [m]
Ieper	10.1	679.4	Loam	1969	31.2	0.88
Ieper	10.1	679.4	Loam	1985	27.0	0.73
Sint-Pieters-Leeuw	10.3	787.9	Silt	2001	16.7	0.29
Geraardsbergen	10.2	775.5	Silt	1988	33.1	0.70
Tongeren	9.5	842.3	Silt	1998	26.7	0.60
Landen	9.8	814.1	Silt	1994	32.3	0.60

On each field, measurements were carried out along transects perpendicular to the tree row (3 transects) and the treeless field border (2 transects), at 5 sampling plots per transect. Sampling plots were rectangular (1.5 m by 6 m), the centre of which was located at 2, 5, 10, 20 and 30 meter distance from the field edge. A schematic overview of the trial layout is shown in Figure 1.

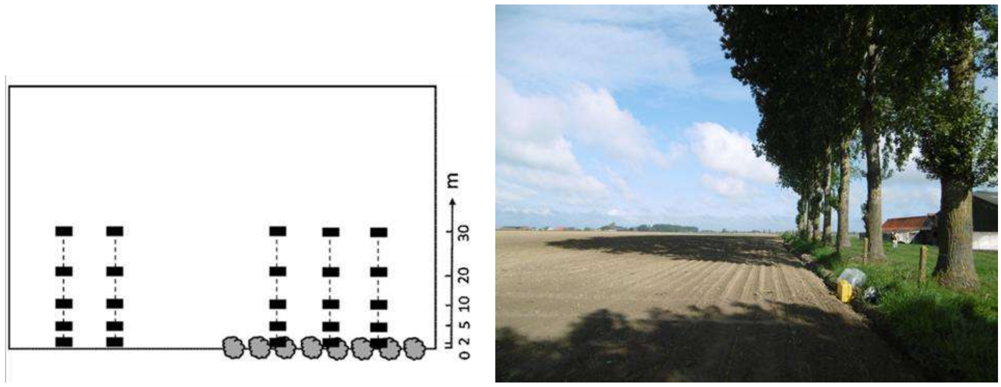


Figure 1: Left: overview of the trial setup: sampling plots are shown as black rectangles, the trees as grey polygons. Right: example of one of the studied fields.

The crop rotation included winter barley, winter wheat, grain maize, silage maize and hemp as main crops, and various types of cover crops during the winter (Table 2). On each field on all 25 plots, soil samples (composite samples composed of 8 individual augurings) were taken three times a year in 2015 and 2016, and once in 2017 before the start of the growing season. Date of sampling in 2015 and 2016 depended on the type of main crop. Samples were taken at the start of the growing season (before the application of manure), at harvest, and at the end of the year (period October - November). If the harvest happened in October or November (such as for grain and silage maize), an additional sampling moment was added during the growing season of the crop. In each plot the soil mineral nitrogen content (ammonium-N and nitrate-N) was determined for the soil layers 0-30 cm, 30-60 cm and 60-90 cm (extraction with KCl and determination using continuous flow, ISO 14256-2). Initially, the soil organic carbon content (sulphochromic oxidation, ISO 14235) and pH-KCl were also determined for each plot in de topsoil (0-30 cm).

Table 2: Crop rotation on the studied fields in 2015 and 2016.

Location	Main crop 2015	Cover crop 2015-2016	Main crop 2016
Ieper	Winter barley	Mixture	Grain maize
Ieper	Grain maize	Gras	Grain maize
Sint-Pieters-Leeuw	Winter wheat	Mustard	Silage maize
Geraardsbergen	Grain maize	(Winter wheat)	Winter wheat
Tongeren	Winter wheat	White mustard	Grain maize
Landen	Winter wheat	Yellow mustard	Hemp

To explain observed differences in soil nitrogen content, additional measurements are available for all six fields of the crop yield and quality for 2015, 2016 and 2017 for all sampling plots (results to be published), and of the soil organic carbon content and availability of other plant nutrients (P, K, Mg, Na, and total N, published in Pardon et al. 2017). Furthermore, on one of the fields, a more detailed experimental setup is carried out which includes a barrier between the tree roots and the field (analogous to Jose et al. 2000b). This setup allows a more close look at the competition for water (and nutrients) in the root zone.

Due to the nested, hierarchical structure of the data (measuring point nested in transects nested in fields), the soil mineral nitrogen content could be modelled using a linear-mixed effect model (LMM). The LMM analysis was carried out seperately for the 3 sampling moments: early season (March 2015, 2016, and 2017), mid season (late June/early August 2015 and 2016) and late season (October/November 2015 and 2016). Fixed effects were the logarithm of the distance from the tree row and the main crop. The statistical analysis was carried in R (R Development Core Team 2016) using the *lme4* package.

Preliminary results and outlook

Preliminary results show a significant impact of the trees on the mineral nitrogen content of the soil at 0-90 cm depth, spatially as well as temporally. In Table 3 the results from the linear mixed model are summarized, and Figure 2 shows both the results from the LMM and individual measurements upon which the model is based.

Table 3: Linear mixed model results. Model: Y = a*ln(distance in m) + b. Bold characters indicate significant effect (P-value < 0.05).

	Fixed effects		
	Main crop	Distance from the tree row	Interaction
Early season	p = 0.2399	**p = 0.0061**	p = 0.2135
Mid season	**p < 0.0001**	p = 0.6780	p = 0.4021
Late season	**p < 0.0001**	**p = 0.0275**	**p = 0.0404**

Measurements taken in the early season show no significant difference between the different crops on the field at that time (varying between winter wheat, winter grain, and various types of green manure), but do show a significant impact of the distance from the tree row, with plots close to the tree row having a lower nitrogen content (13 kg N/ha lower compared to the plots at 30 meter from the tree row). In the mid season, the two main crops maize and winter grain (both winter wheat and winter barley) differed significantly, but on the other hand no significant differences based on the distance from the tree row were found. Measurements from the late season show again a significant difference between maize and winter grains, and also a significant effect of the distance from the tree row. For maize, the linear-mixed model showed a nitrogen content which was 30 kg N/ha lower at 2 meter from the tree rows, compared to 30 meter. For winter grains the effect of the distance was negligible.

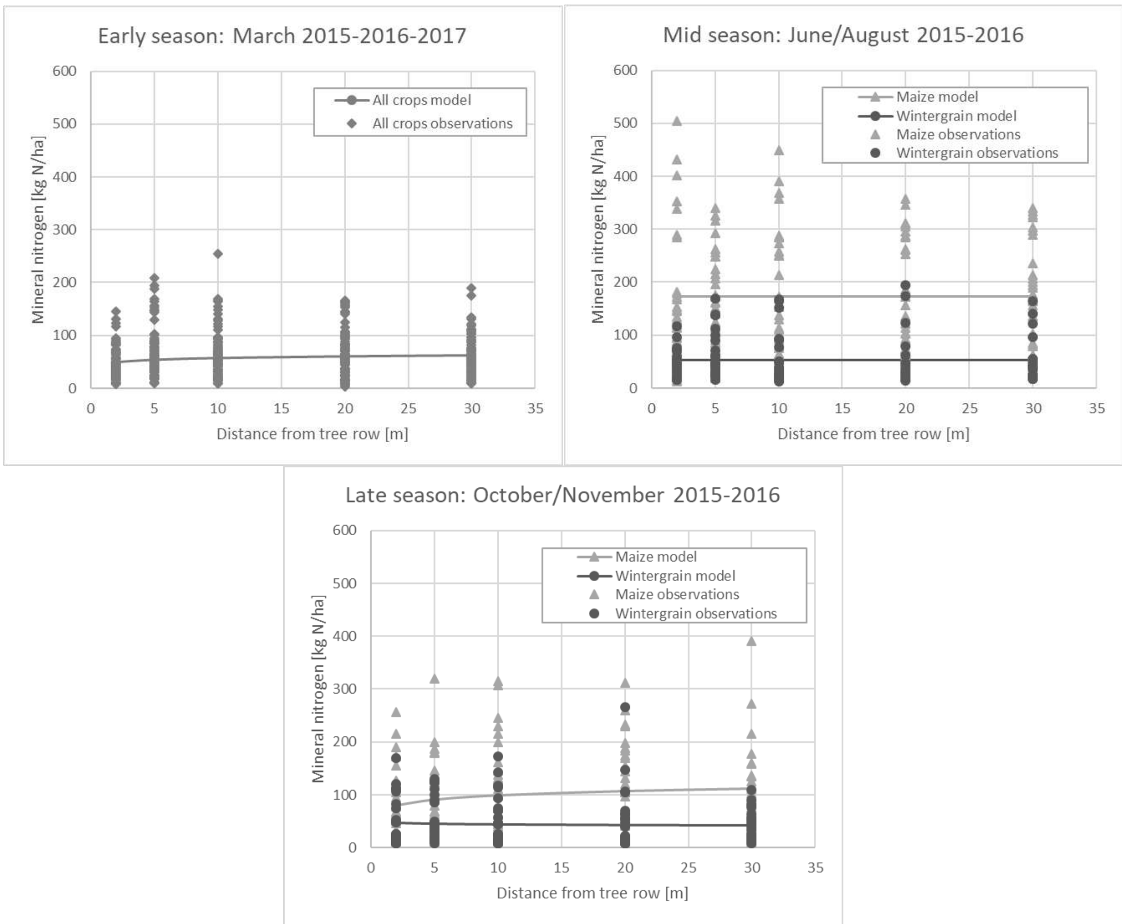


Figure 2: Mineral nitrogen in the soil at 0-90 cm depth as a function of distance from the tree row. Lines represent the result of the LMM analysis, dots represent the individual soil measurements.

Lower soil nitrogen levels close to the tree row can have several causes, such as nitrogen uptake by the tree roots, lower nitrogen uptake by the crop due to a reduction in crop growth, and less (solid) fertilizer received due to non-overlapping fertilizer application patterns at the field edge. Trial harvests carried out at the field plots show a reduction in crop yield close to the tree rows, which was very severe for maize. This, coupled with the fact that in the mid season soil nitrogen levels for maize seem to be unaffected by the distance from the tree row (Figure 2, mid season), indicates that tree uptake of soil nitrogen plays an important role during the late growing season. These results will be further analyzed together with crop yield data and soil water measurements to shed further light on the mechanisms at work.

References

Allen SC, Jose S, Nair PKR, Brecke BJ, Nkedi-Kizza P, Ramsey CL (2004) Safety-net role of tree roots: evidence from a pecan (Carya illinoensis K. Koch) -cotton (Gossypium hirsutum L) alley cropping system in the southern United States. Forest Ecol Manag 192: 395–407.

Allen SC, Jose S, Nair PKR, Brecke BJ, Nair VD, Graetz DA, Ramsey CL (2005) Nitrogen mineralization in a pecan (Carya illinoensis K. Koch) - cotton (Gossypium hirsutum L.) alley cropping system in the southern United States. Biol Fertil Soils 41: 28–37.

Fernández ME, Gyenge J, Licata J, Schlichter T, Bond BJ (2008) Belowground interactions for water between trees and grasses in a temperate semiarid agroforestry system. Agrofor Syst 74: 185-197.

Jose S, Gillespie AR, Seifert JR, Mengel DB, Pope PE (2000a) Defining competition vectors in a temperate alley cropping system in the midwestern USA; 3. Competition for nitrogen and litter decomposition dynamics. Agrofor Syst 48: 61–77.

Jose S, Gillespie, AR, Seifert JR, Biehle DJ (2000b) Defining competition vectors in a temperate alley cropping system in the midwestern USA; 2. Competition for water. Agrofor Syst 48: 41–59.

Ishikawa CM and Bledsoe CS (2000) Seasonal and diurnal patterns of soil water potential in the rhizosphere of blue oaks: evidence for hydraulic lift. Oecologia 125: 459-465.

Pardon P, Reubens B, Reheul D, Mertens J, De Frenne P, Coussement T, Janssens P, Verheyen K (2017) Trees increase soil organic carbon and nutrient availability in temperate agroforestry systems. Agr Ecosyst Environ 247: 98-111.
R Development Core Team (2016) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing.

TIME AND CROPS INFLUENCES ON CARABIDS TAXONOMIC AND FUNCTIONAL DIVERSITIES WITHIN A PESTICIDE-FREE AGROFORESTRY CROPPING SYSTEM

Lagier C[1], Garcia E[2], BenSarsa L[3], Vannieuwenhuyse A[2], Seyed-Esmaïl A[2], Oheix S[3], Simon L[3], Mercadal AM[3], Grandgirard D[3*]

(1) Université de Normandie, Rouen, France (2) Université Picardie - Jules Vernes, Amiens, France (3) UniLaSalle Polytechnic Institute, Beauvais, France

*Corresponding author: david.grandgirard@unilasalle.fr

Abstract

Within a pesticide-free agroforestry cropping system, carabids' communities are trapped once over years and, over weeks for one given year in order to test (1) the ageing of the cropping system, (2) the impacts of the presence of different crops and of their related agricultural practices. Main results shown that the carabids communities are different between years but no progressive diversity increase was observed. Conversely, annual climatic conditions showed significant effect on carabids abundance and limited the observation of any longitudinal trend. Then, significant differences between habitats, crops and cropping systems were observed. If diversity between closed and open-habitats was significantly different, no effect was observed between open-habitats despite the presence/absence of specific carabids species in each one. Altogether, results suggest that the SCA0PEST platform is still too young to demonstrate of the ecological connectivity enhancement potential of agroforestry, if exist.

Keywords: SCA0PEST; pesticide-free system; carabids 'communities; NMDS; IPM

Introduction

Very frequently, farmers argue that decision towards adoption of agroforestry systems is supported by the possibility to obtain benefits i.e. ecosystemic services from the system set up. Among others, these benefits concern the potential control of pests by their natural enemies (Fagerholm et al. 2016). By reintroducing linear tree-based plants association around or directly within agricultural parcels, agroforestry reinforce the number and surface of transitional zones in-between landscape units, potentially prolonging one habitat within the adjacent ones. In the same time agroforestry increases the transition zone area all around or within the cultivated parcel, enhancing abiotic edge effect (Murcia 1995) that have in return - (i) direct impact onto the local species abundance and taxonomical diversity and again – (ii) indirect impact on functional diversity by changing species interactions. Among others, ground beetles (Carabidae) answer to the modification of the transitional zones such as habitats fragmentation. In the SCA0PEST pesticide-free agroforestry platform (Grandgirard et al. 2014) part of the work concern carabids; they are surveyed in order to analyze and testify of the potential of the biological control of certain pests.

More precisely, main goals are (i) to identify the taxonomic and functional carabids communities' evolution along time, (ii) to assess the potential effect of crop rotation and associated agricultural practices in order to (iii) produce and share biological pest control references with agroforestry farmers, advisers and students in agroecology.

Materials and methods

Concerning ground beetles, assumptions are several and organized in two groups:

(1) **along time**, we assumed that annual carabids communities would progressively evolve from "open space" community to more rich community with new species or diversification of the carabids functional traits reflecting the ageing of the trees' matrix or of the whole system;

(2) **for one given year**, if carabids communities are relatively unique at the whole parcel scale we assumed that each one of the six experimental parcels composing SCA0PEST should present differences regarding taxonomic and functional diversities reflecting the potential influence of annual crop and practices choices.

To verify the assumptions above, two protocols were conducted within the SCA0PEST platform (see N 49.47458 E 2.06341):

• Protocol n.1: from 2014 up to 2017, in each one of the 6 experimental parcel of SCA0PEST (Figure 1(a)), ground beetles were sampled by pitfall traps at 8 sites (n°1 to 8). Every site was 16 m², at a distance of 4 up to 12m of the tree lines, 20 m apart from each other. It hosted one pitfall trap centered within the site. The first site was 50 m from the forest edge. Trapping period duration was 8 days and started annually approximately on May15th.

• Protocol n.2: in 2017 only, in 3 of the 6 experimental parcels of SCA0PEST (P2-winter wheat, P4- 2-years old alfalfa, P6-field bean), at sites n°2, 4 and 6 (respectively at 50, 70 and 90m from the forest edge), pitfall traps were 3, at 1m apart from each other, respecting a triangle shape (Figure 1(b)). Close to the SCA0PEST platform, 3 groups of 3 pitfall traps were positioned within (a) the contiguous 70 years-old forest "Fo", (b) within an 8-years old forestry control "FC" located within the parcel at 35m from the SCA0PEST platform and hosting a high density ($600m^{-2}$) of the same agroforestry trees species, (c) within the non-agroforestry reference cropping system "RCS"; respecting the 50/70/90m distance range and the 1m triangle shape. Ground beetles were sampled from May 15th up to mid-July, every 10 days.

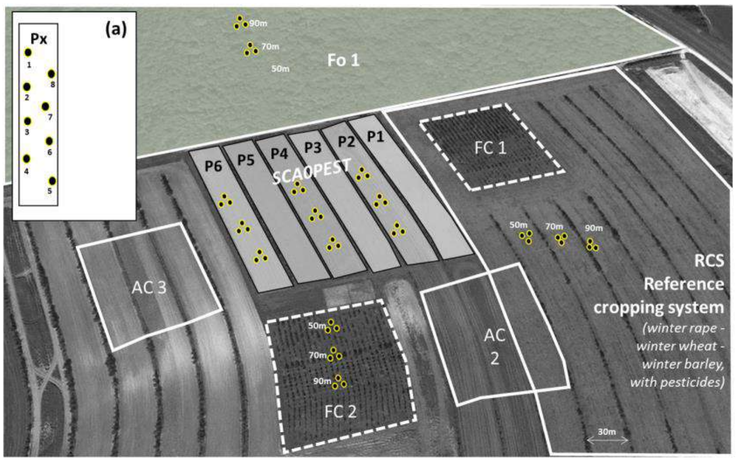


Figure 1: Map of the different conditions present within or around the SCA0PEST platform; (a) pitfall traps position at 8 sites per experimental parcel from 2014 to 2017- protocol n.1; (b) triangular pitfall traps positioning in 2017 - protocol n.2 (AC= agricultural control meaning grassy strips without trees and conventional cropping system; FC= forest control meaning uncultivated area with trees at $600ha^{-1}$ high density; Fo= Forest meaning 70 years-old forest; RCS= reference cropping system meaning grassy strips with trees and conventional cropping system).

All carabids caught were identified to species using standard keys (Roger at al. 2013). Functional traits were selected a priori and were related to morphology (individual length), reproduction (reproduction period), dispersal (wing morphology) and the resource use (diet). Moreover, Shannon-Wiener and Simpson α-diversity index were performed (Magura 2017). Statistical analyses were performed using R. Non parametric Kruskal-Wallis, Friedman and Mann-Whitney tests were performed (p-value<0.05) and communities were described using

NMDS; community resemblance were tested using ANOSIM and most influential ground beetles species were identified using SIMPER in Past 2.17 (Hammer et al. 2001).

Results

Over the 4 first years of the experimentation, 886 carabids and 29 different species were trapped. Most of them were trapped in 2015 (41%) then in 2017 (31%); only 9% were trapped in 2015 due to heavily rainy spring (results not shown). In the same time, we observed large differences of the specific abundance between experimental parcels suggesting that crops (and related agricultural practices) at a given year would partly condition the ground beetles assemblages. More precisely, statistical tests showed that carabids significantly prefer cereals and rapeseed or again field bean than alfalfa (results not shown). Even if true, the year effect remained higher than the crop effect. Because of this first results, carabids' assemblages were studied independently every year.

For instance, *Amara similata* and *Poecilus cupreus* were related to rapeseed when *Pseudophonus rufipes* was mainly found in field bean and alfalfa. *Harpalus affinis* was related to pesticide-free wheat when *Anchomenus dorsalis* was related to the reference one. In the other hand, *Brachinus sclopeta*, *Notiophilus quadripunctus* or *Demetrias atricapillus* were found in the SCA0PEST wheat where lines of trees and grass strips are present and where they can alternate between habitats, within the transition zone. Whereas they were not found in the reference wheat located in the agricultural control i.e. without lines of trees. Concerning functional traits, the number of generalist species was higher in agricultural control (open-habitat as RCS and SCA0PEST) and forestry "FC" control. Conversely, predatory ground beetles were mainly found in the forest "Fo" habitat.

Assemblages were then analyzed through NMDS. In 2014, supplementary ANOSIM (r=0.54; p-value=0.001) showed that carabids assemblage were different between experimental parcels i.e. between crops and related agricultural practices. Then, the SIMPER function identified major species those explaining this assemblage's differences: when *Pterostichus melanarius* is frequently present in cereals, *Nebria salina* is generally trapped in alfalfa and *Poecilus cupreus* was more present in field bean. However these results were not constant over years as crops are changing according to the crop rotation in place and as some species seemed strongly related to some crops and crops conditions e.g. *Amara sp.* in rapeseed or *Ophonus azureus* in alfalfa. This result was also due to the early apparition of new carabids' species such as *Amara aulica* or *Badister sodali*. Over the 2014-17 period, results showed that the carabids' assemblage tend to become uniform as the ANOSIM R test was decreasing (R=0.44, p-value =0.001 in 2015; R=0.32, p-value =0.001 in 2017).

From protocol n.2, in 2017, 2185 carabids were trapped. Preliminary statistics showed that the distance to the forest edge effect was not significant, whatever the sampling date. Mean daily catches at the three distances (50, 70 and 90m) were then summed and NMDS was mobilized to describe the habitat effect. ANOSIM and SIMPER were then performed: forest's assemblage (Fo) is significantly different from others (RCS, FC and SCA0PEST's assemblages). These habitats have very closed communities but few supplementary carabids species were sampled in very specific cropping conditions (Figure 2) and made significant the multivariate tests performed.

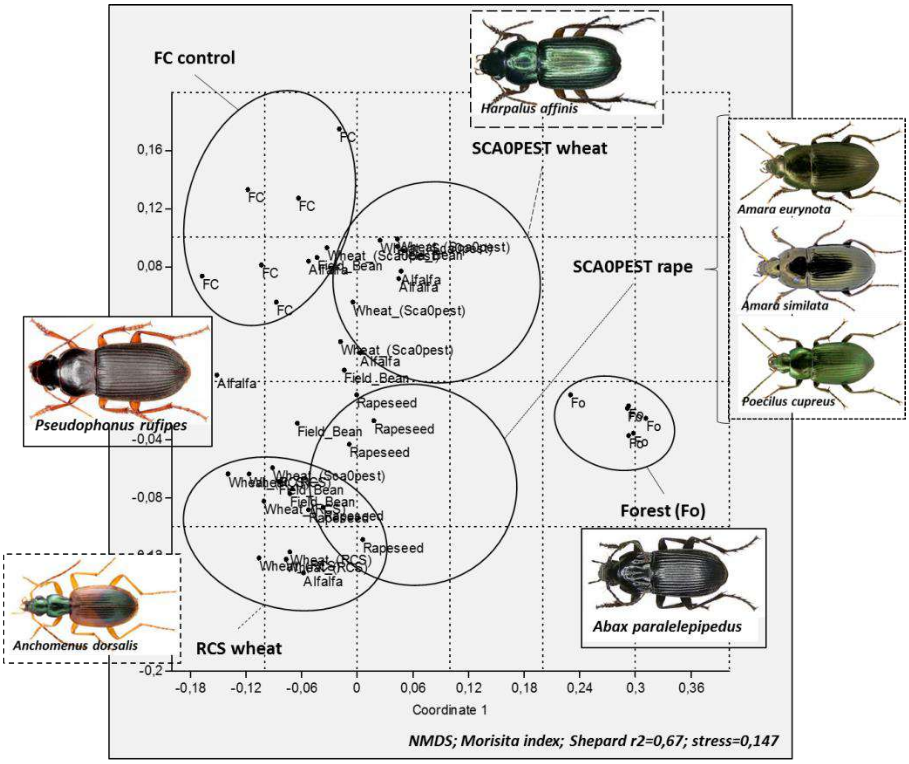


Figure 2: NMDS results of the mean daily catches per habitat in 2017 (carabids.day^{-1}) over the sampling period.

Discussion

If the communities of Carabids appeared significantly different in some extreme conditions met within the SCA0PEST landscape, they stayed relatively closed from each other's because of the omnipresence of five carabids species in each modalities. However, communities of less perturbed habitats such as forest or again forestry control appeared more stable over time. At the opposite, in open-habitats such as agricultural control, some species appeared early in spring and disappeared before summer time, making the communities less stable. Regarding functional diversity, it also appeared different between closed and open-habitats. Moreover if crops and associated agricultural practices have non negligible impact, results showed that rainfall and temperature conditions were major determinant of the carabids assemblages caught. These first results could be as positive as carabids communities has been enriched of new species adapted to transition zone and having corresponding functional life traits. It could be the first signs of the installation of a biological control potential in SCA0PEST. However, SCA0PEST is still very young and the observed trends remain insufficient to conclude of the potential ecosystemic services carabids could provide. In the literature most of the time effects on assemblages are rapidly observed as forest carabids could appear during the 1st year, but when we speak about functional communities and eco-systemic services (ES) time needed generally increase up to 10-15 years (soil fertility and fauna, integrated pests management) or even more depending of the ES considered (water quality, CO_2 sequestration …).

References

Fagerholm N, Torralba M, Burgess, PJ, Plieninger, T (2016) A systematic map of ecosystem services assessments around European agroforestry. Ecol Indic 62: 47-65.

Grandgirard D, Oheix S, Leclercq C, Lançon L, Liagre F, Dupraz C, Mézière D, Poulain JL, Wartelle R (2014) SCA0PEST, a pesticide-free agroforestry cropping system: ex-ante performances evaluation. 2nd EURAF conference, Cottbus, Germany.

Hammer O, Harper DAT, Ryan PD (2001) PAST: paleontological statistics software package for education and data analysis. Palaeontol Electron 4. http://palaeo-electronica.org/2001_1/past/past.pdf (accessed 24/04/2018).

Magura T (2017) Ignoring functional and phylogenetic features masks the edge influence on ground beetle diversity across forest-grassland gradient. Forest Ecol and Manag 384: 371-377.
Murcia C (1995) Edge effects in fragmented forests – implications for conservation. Trends Ecol Evol 10: 58-62.
Roger JL, Jambon O, Bouger G (2013) Clé de détermination des carabides. Paysages agricoles du Nord-Ouest de la France. INRA SAD.

EXPLORING THE RELATIONSHIPS AMONG BIO-PHYSICAL AND SOCIO-CULTURAL ECOSYSTEM SERVICES OF AGROFORESTRY SYSTEMS ACROSS EUROPE

Roces-Diaz JV[1]*, Rolo V[2], Kay S[1], Moreno G[2], Szerencsits E[2], Fagerholm N[3, 4], Plieninger T[3], Torralba M[3], Graves A[5], Giannitsopoulos M[5], Palma J[6], Herzog[1]

(1) Agroscope, Department of Agroecology and Environment, Zurich, Switzerland (2) Forestry Research Group, Universidad de Extremadura, Plasencia, Spain (3) Department of Geosciences and Natural Resource Management, University of Copenhagen, Copenhagen, Denmark (4) Department of Geography and Geology, University of Turku, Turku, Finland (5) Cranfield University, Bedfordshire, United Kingdom (6) Forest Research Centre, School of Agriculture, University of Lisbon, Lisbon, Portugal

*Corresponding author: jvroces@gmail.com

Abstract

Agroforestry systems are often highlighted for their multifunctional role, the different goods and services provided, but also for their social-relevance in different European rural landscapes. However the connections among the bio-physical ecosystem services (ES) and the socio-cultural values of these landscapes are still underexplored. With the aim of to assess if perceived ES are related to measured and modelled biophysical ES and land use types, we combined seven spatially explicit models of ES and a dataset with more than 2,300 records of public participatory GIS for 12 European landscapes. We found that biophysical ES had variable relevance in predicting socio-cultural ES. In addition, when we analyzed relationships among ES, we found that, in general, biophysical ES values were negatively related to the occurrence of socio-cultural ES. Thus, further research should be developed to explore these potential connections among ES.

Keywords: agroforestry systems; European rural landscapes; PPGIS; ecosystem services modelling

Introduction

The multifunctional role of traditional European agricultural landscapes, but also their general decline during the last decades, has been highlighted by e.g. Jongman (2002) and Antrop (2005). These landscapes involve different types of ecosystems, including forest patches and (semi-)natural vegetation (only a small part of European landscapes involves natural vegetation *sensu stricto*). Most of these landscapes also have notorious presence of agroforestry patches - as pastures, arable lands, etc. – with variable density of wood elements (den Herder et al. 2017). Different typologies of European landscapes show different types of agroforestry systems (AFS) (Eichhorn et al. 2006) adapted to different climatic and socio-ecological conditions. Most of them have been part of these landscapes since hundreds of years.

From the beginning, these AFS have provided a wide range of ecosystem services (ES), including for example firewood or food as provisioning services and erosion control or soil fertility regulation (Torralba et al. 2016; Pardon et al. 2017) as regulating ES. These services were usually studied by using bio-physical measurements and modelling (Kay et al. 2017).

More recently, the socio-cultural ES provided by AFS have also attracted attention (Fagerholm et al. 2016). People´s perception of these services can be evaluated by several approaches. At the landscape scale, the spatial location of the areas relevant for specific ES with Public

Participatory Geographic Information Systems (PPGIS) has grown in relevance during last years (Brown and Fagerholm 2015).

Until now, only few authors have studied the interactions between the different categories of ES (Garcia-Llorente et al. 2015), and only at a sub-regional/local scale. We therefore investigated the relationships between provisioning, regulating and socio-cultural ES by combining biophysical measurements and modelling with PPGIS interviews in twelve case study areas across European agroforestry landscapes (Figure 1). Here, we explore a methodology that can lead to an integrated analysis along a broad geographical gradient and combining different scientific disciplines (bio-physical and socio-cultural research methods).

Materials and methods

Study area

We studied twelve study cases which represent different European rural landscapes from four biogeographical regions including Mediterranean (4 cases), Continental (4), Atlantic (3) and Boreal (1) shown in Figure 1.

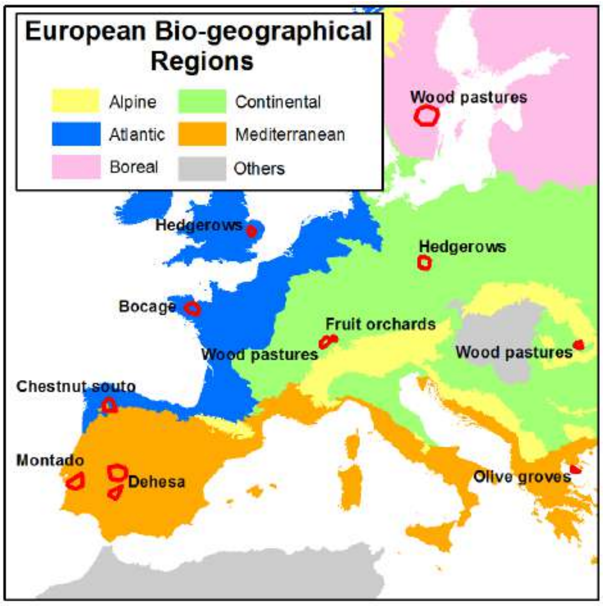


Figure 1: Location of the agroforestry system study cases.

Cartographic data sources

We produced a specific map of habitat types derived from existing information, namely land use maps (Corine Land Cover –CLC-; EEA 2012), forest cover (Tree Cover Density –TCD; EEA 2016) and a semi-automatic aerial photograph interpretation. Combining these sources of spatial information, we classified our study areas into the following broad land cover classes:

1. Forest and semi-natural habitats
2. Agroforestry areas
3. Agricultural areas
4. Artificial and bare soil areas
5. Water-related habitats

Bio-physical ES models

We used a series of spatially explicit models that reflect different provisioning and regulating ES for our study areas. To this end, in the case study regions the agroforestry areas, the agricultural areas and the forestry areas (if applicable) of the study regions, four 1 km squares per study region and land cover type were randomly sampled and mapped (habitats). Biophysical ES were then evaluated with appropriate models (Kay et al. 2017). In order to expand these ES models from the 1 km squares to the study area limits, values representing average results for each of the five classes of land use were used. Table 1 shows the different bio-physical ES assessed.

Table 1: Different types of biophysical and socio-cultural ecosystem services (ES) assessed.

Approach	ES category	ES type
Bio-physical	Provisioning	Biomass yield
		Biomass stock
	Regulating and support	Carbon sequestration
		Carbon stock
		Water regulation (ground water recharge)
		Soil fertility (nutrient retention)
		Erosion control
Socio-cultural	Provisioning	Farmland products
		Freely harvested wild products
	Regulating and support	Appreciation of environmental capacity to produce, preserve, clean, and renew air, soil and/or water
		Habitat and biodiversity
	Cultural	Outdoor activities
		Social interactions
		Aesthetic values
		Cultural heritage
		Inspiration value
		Existence value

Socio-cultural ES assessment

In each study case, PPGIS were conducted and the results assembled in a database, which provides a series of points (between 1,000-2,500 per study region). These points were identified by local inhabitants as relevant in relation with different socio-cultural ES. The socio-cultural ES were aggregated to 10 types as shown in Table 1.

Spatial analysis and general results

To each study case, we applied a 100x100 meter grid. For each cell average values of bio-physical socio-cultural ES were calculated. Using the combined bio-physical and socio-cultural ES database we analysed the relationships among different types of ES, as well as the effect of AFS on these relationships. To analyse how biophysical ES can help to predict socio-cultural ES, we run a Redundancy Analysis (RDA) using socio-cultural ES as response variables and biophysical ES as predictors (Figure 2).

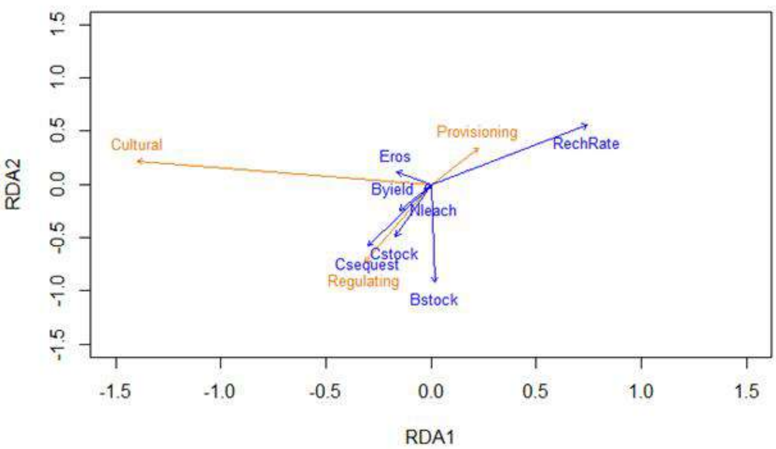


Figure 2: Redundancy analysis (RDA) showing the relationship between the three general types of surveyed ES (yellow) and seven modelled biophysical ES predictors (blue).

Our results showed that surveyed provisioning and regulating ES were negatively related, having socio-cultural ES no relationship with any of them (Figure 2). Surveyed regulating ES were positively related to model regulating ES, particularly to Cstock and Csequest. By contrast, surveyed provisioning ES were positively related to recharge rate, confirming the positive association between modelled and surveyed ES.

We then ran individual GLM models with a bionomial distribution for each socio-cultural ES to assess how bio-physical ES affected the probability of occurrence of socio-cultural ES. We expected significant relationships among those ES from both types tested (bio-physical and socio-cultural), which were thematically similar. Thus for example, we expected that those areas with high values of supply of ES would be also identified by the PPGIS process as relevant for provisioning ES. However, we observed that, in general, biophysical ES values were negatively related to the occurrence of socio-cultural ES, indicating that PPGIS points were located in places with low values of biophysical ES (mainly in artificial land use types).In addition, we did not observed a positive role of AFS, although positive effects of AFS as ES providers in agricultural landscapes is accepted (Jose 2009; Torralba et al. 2016; Pardon et al. 2017).

Acknowledgments

We acknowledge funding through Grant 613520 from the European Commission (Project AGFORWARD, 7th Framework Program). JVRD was supported by the Government of Asturias and the FP7-Marie Curie-COFUND program of the European Commission (Grant 'Clarín' ACA17- 02).

References

Antrop M (2005) Why landscapes of the past are important for the future. Lands Urban Plan 70: 31-34.

Brown G, Fagerholm N (2015) Empirical PPGIS/PGIS mapping of ecosystem services: A review and evaluation. Ecosyst Serv 13: 119-133.

den Herder M, Moreno G, Mosquera-Losada MR, Palma JHN, Sidiropoulou A, Santiago Freijanes JJ, Crous-Duran J, Paulo J, Tomé M, Pantera A, Papanastasis V, Mantzanas K, Pachana P, Papadopoulos A, Plieninger T, Burgess PJ (2017) Current extent and trends of agroforestry in the EU27. Agriculture Ecosyst Environ 241: 121–132.

EEA, European Environmental Agency (2012) CORINE Land Cover 2012. http://land.copernicus.eu/pan-european/corine-land-cover/clc-2012/view (accessed 12/10/2017).

EEA, European Environmental Agency (2012) Tree Cover Density. http://land.copernicus.eu/pan-european/high-resolution-layers/forests/tree-cover-density/view (accessed 12/10/2017).

Eichhorn MP, Paris P, Herzog F, Incoll LD, Liagre F, Mantzanas K, Mayus M, Moreno G, Panastasis VP, Pilbeam DJ, Pisanelli A, Dupraz C (2006) Silvoarable systems in Europe – past , present and future prospects. Agroforst Syst 67: 29–50.

Fagerholm N, Torralba M, Burgess PJ, Plieninger T (2016) A systematic map of ecosystem services assessments around European agroforestry. Ecol Indicat 62: 47-65.
Garcia-Llorente M, Iniesta-Arandia I, Willaarts BA, Harrison PA, Berry P, Bayo MM, Castro AJ, Montes C, Martín-López B (2015) Biophysical and sociocultural factors underlying spatial trade-offs of ecosystem services in semiarid watersheds. Ecol Soc 20: 39.
Jongman RHG (2002) Homogenisation and fragmentation of the European landscape: ecological consequences and solutions. Landsc Urban Plan 58: 211–221.
Jose S (2009) Agroforestry for ecosystem services and environmental benefits: An overview. Agrofor Syst 76: 1-10.
Kay S, Crous-Duran J, Ferreiro-Domínguez N, García de JAlón S, Graves A, Moreno G, Mosquera-Losada MR, Palma JHN, Roces-Díaz JV, Santiago-Freijanes JJ, Szerencsits E, Weiberl R, Herzog F (2017) Spatial similarities between European agroforestry systems and ecosystem services at the landscape scale. Agroforst Syst doi.org/10.1007/s10457-017-0132-3
Pardon P, Reubens B, Reheul D, Mertens J, De Frenne P, Coussement T, Janssens P (2017) Trees increase soil organic carbon and nutrient availability in temperate agroforestry system. Agriculture Ecosyst Environ 247: 98-111.
Torralba M, Fagerholm N, Burgess PJ, Moreno G, Plieninger T (2016) Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. Agriculture Ecosyst Environ 230: 150–161.

A MULTI-FACTORIAL SUSTAINABILITY ASSESSMENT OF FIVE EUROPEAN AGROFORESTRY FARMS

Smith LG[1*], Smith J[1], Wolfe M[2], Ghaley BB[3], Pisanelli A[4], Russo G[4], Sandor M[5], Gliga A[5], Wawer R[6], Borek R[6]*

(1) The Progressive Farming Trust Ltd. t/a the Organic Research Centre, Hamstead Marshall, Berkshire, UK (2) Wakelyns Agroforestry, Suffolk, United Kingdom (3) Department of Plant and Environmental Sciences, University of Copenhagen, Denmark (4) National Research Council, Institute of Agro-environmental and Forest Biology, Italy (5) University of Agricultural Sciences and Veterinary Medicine Cluj Napoca, Romania (6) Institute of Soil Science and Plant Cultivation – State Research Institute, Puławy, Poland

*Corresponding authors: laurence.s@organicresearchcentre.com, rborek@iung.pulawy.pl

Abstract

Within the European project SustainFARM researchers from five countries (Denmark, UK, Italy, Poland, Romania) have adapted an established sustainability assessment to allow for its application within a range of agroforestry systems. The Public Goods Tool assesses the agriculture-related “public goods” that are provided by a farm, covering a number of ‘spurs’ or dimensions of sustainability. Results from an initial pilot assessment of seven agroforestry farms from the five countries with the updated tool have revealed that it can provide a useful learning framework; however further improvements are needed to capture the future aspirations of the farm-manger and introducing a weighting factor to account for region/system specificity. The results from the assessment itself have also revealed the benefits that diverse agroforestry systems can provide across a range of sustainability criteria. Future research in this area will investigate the potential for adapting the PGT to allow for self-assessments.

Keywords: public goods; silvopastoral; silvoarable; olives; alley cropping

Introduction

In recent years there has been a growing interest in the development and application of sustainability assessment tools within agriculture. As a result a number of approaches have been established to provide an overview of farm performance against a range of environmental, economic and social criteria and to identify trade-offs between multiple dimensions. Despite considerable developments in this area, few tools address the sustainability of agroforestry systems, with most approaches focusing on the sustainability of agricultural products (crops, meat, dairy), or occasionally forestry/other non-food products in isolation, rather than in combined systems.

Within the European project SustainFARM (FACCE-JPI www.sustainfarm.eu) a group of researchers from five countries (Denmark, UK, Italy, Poland, Romania) have therefore adapted an established sustainability assessment to allow for its application within a range of agroforestry systems (willow and hazel alley cropping systems, olive silvopastoral system, wooded pasture, intercropped orchard), to identify areas of stronger/weaker performance and to seek feedback on the assessment process.

Materials and methods

The Public Goods Tool (PGT) provided the framework for the analysis. The PGT was originally developed by the Organic Research Centre in 2011 and has been updated within recent projects such as Sustainable Organic and Low Input Dairying (SOLID), Towards Eco-energetic Communities (TWECOM) and a recent PhD that compared the performance of a range of tools (Gerrard et al. 2012; Marchand et al. 2014).

The PGT assesses the agriculture-related “public goods” that are provided by a farm. A number of ‘spurs’ or dimensions of sustainability are covered. These dimensions include soil management, agri-environmental management, landscape and heritage, water management, fertiliser management and nutrients, energy and carbon, food security, agricultural systems diversity, social capital, farm business resilience, animal health and welfare management and governance. Each spur is assessed on a 1-5 scale by asking questions to farmers based on a number of key “activities”. Each activity has at least one corresponding question, mostly about farm management practices, and these allow a researcher or advisor to evaluate the detailed ways in which the farm provides each public good. The choice of activities to be included was influenced by a desire for the data collected to be of a type that a farmer would already have in their farm records, i.e. not requiring any further surveys to be carried out. The PGT assessment takes two to four hours to complete, depending on the size and complexity of the farm.

Within the SustainFARM project, a new version of the PGT was produced through the incorporation of assessment criteria with particular relevance to studied agroforestry systems (Table 1). Individual criteria and their associated indicators were identified through a comprehensive literature review carried out in the summer of 2016. In a second stage of work the new assessment criteria identified through the review were subjected to a series of online surveys and workshops with national stakeholders from Denmark, Italy, Poland, Romania and the UK. The workshops aimed to identify the criteria and indicators that were the most “appropriate” for an assessment of agroforestry systems in Europe, with “appropriateness” defined in terms of each indicator’s relevance, comprehensiveness, interpretability, data quality, efficiency and the degree of overlap with existing criteria within the PGT. Through this process the list of 91 indicators was narrowed down to around 50. The narrowed down list was incorporated within the PGT to produce a new version of the tool for the SustainFARM project, and assessments carried out on seven agroforestry farms (Table 1).

Table 1: Agroforestry farms within the study (numbers corresponding to the figure below).

No.	Agroforestry farm	Study location	Size
1	Organic farm: hazel and willow alley cropping systems, mixed species timber and apple system, hedgerows	Wakelyns Farm, Suffolk, UK	22 ha
2	Experimental farm: alley cropping system (willow and cereals)	Taastrup, Denmark	11 ha
3	Organic farm with intercropped orchard with vegetables and forest	Opolskie Voivodship, Poland	45 ha
4	Livestock farm with wooded grasslands and forest	Beskin Mountains, Poland	200 ha
5	Organic farm: olive orchard with natural weed between the tree rows, fruit orchard and forest	Orvieto Municipality, Italy	7 ha
6	Conventional farm, of which 22 ha are managed as olive orchards with periodical soil harrowing	Orvieto Municipality, Italy	207 ha
7	Livestock silvopastoral system with wooded grasslands	Petrova Municipality, Romania	94 ha

Results and discussion

The results from the PGT assessment of studied agroforestry farms are provided in Figure 1 below.

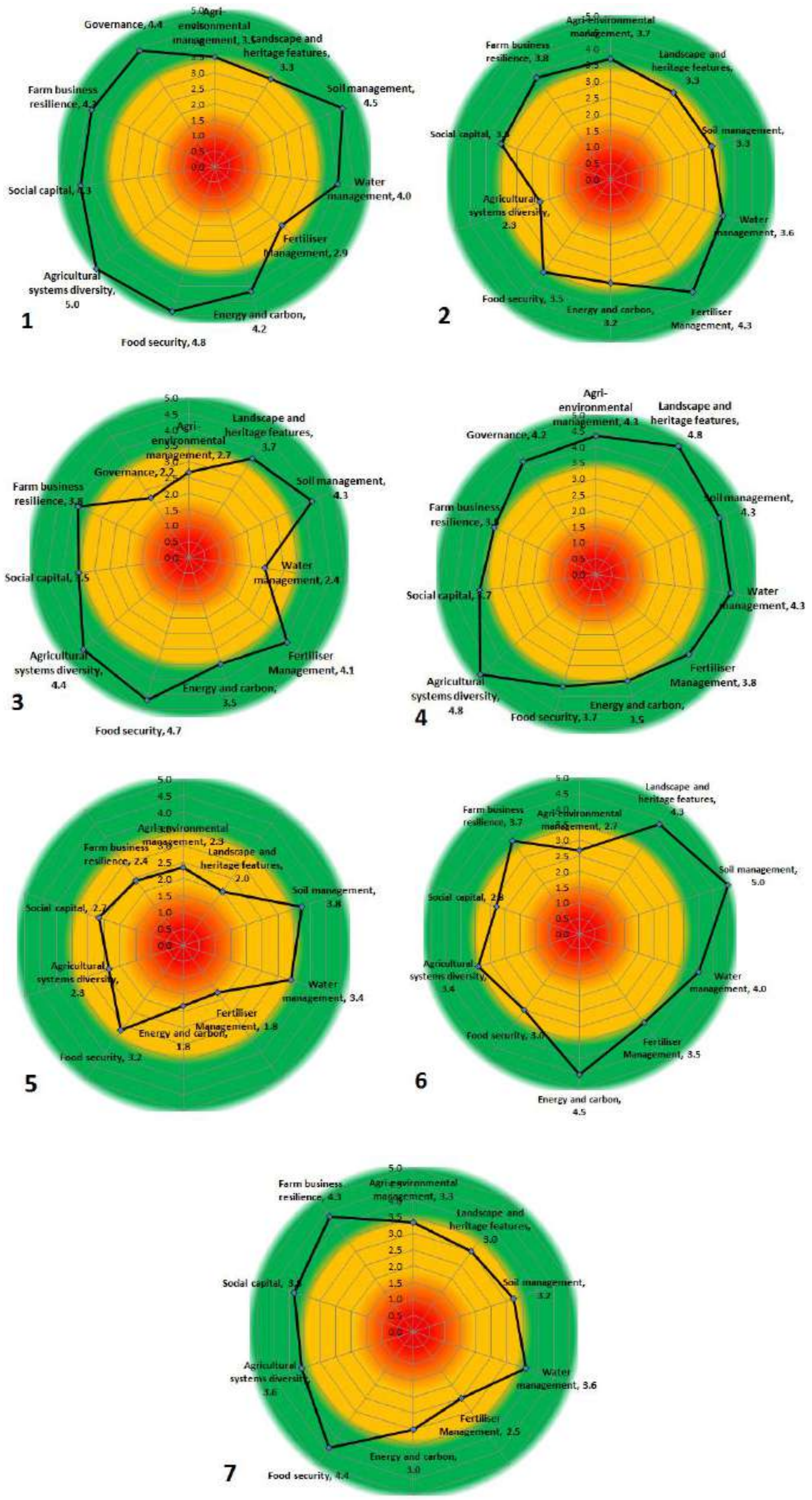


Figure 1: PGT assessment results for SustainFARM agroforestry farms (explanations of the numbers in the table 1).

The PGT assessment revealed diversified range of scores across most of the 11 spurs (Figure 1). Farms Business Resilience, Social Capital, Systems diversity, Food Security, and Soil Management were particularly strong areas as a result of the diversity in marketing outlets, the high species / varietal diversity, importance of the farm for social involvement, local sales and a range of measures for enhanced soil protection. Weaker areas of performance were fertiliser management and agri-environmental management due to an absence of written plans for nutrient/water management and conservation.

Feedback on the assessment process itself highlighted the potential issue of weighting of scores (the PGT was developed for a wide range of systems and the questions and scores are not tailored to a particular system or approach). It was highlighted that adjusting scores in accordance with the challenges faced by a particular farm-type or region is likely to lead to different outcomes and could make the assessment process more meaningful and useful for the farmers being assessed. Feedback also highlighted the issue of future development of the farm, an area which was overlooked within the assessment.

There are always areas where improvements can be made, most notably an absence of written plans/records, third-party certification and nutrient planning led to lower scores in some areas (e.g. energy and carbon management, agro-environmental or fertiliser management). Such assessment criteria focus on processes, rather than outcomes (a necessity of the assessment approach) and a more detailed and outcome oriented approach is likely to lead to a more precise evaluation of performance in these and other areas covered by the PGT (Schader et al. 2014).

Conclusion

The SustainFARM project team have developed an existing sustainability assessment framework for application in a range of agroforestry systems in Europe. Results from an initial pilot assessment with the updated tool have revealed that it can provide a useful learning framework; however improvements should be implemented with regard to capturing the future aspirations of the farm-manger and introducing a weighting factor to account for region/system specificity. The results from the assessment itself have also revealed the benefits that diverse agroforestry systems can provide across a range of sustainability criteria. Future research in this area will investigate the potential for adapting the PGT to allow for self-assessments. This will potentially allow for a greater number of assessments and for benchmarking of individual scores and assessment criteria.

Acknowledgements

SustainFARM has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 652615. SustainFARM is a three year project, funded in the UK by Defra, in Denmark by Innovations Fonden (InnoFond), in Italy by Ministry of Education, Universities and Research (MIUR), in Poland by the National Centre for Research and Development (NCBiR) and in Romania by Executive Agency for Higher Education, Research, Development and Innovation Funding as part of the European FACCE SURPLUS ERA-NET co-fund programme formed in collaboration between the European Commission and a partnership of 15 countries in the frame of the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI).

References

Gerrard CL, Smith LG, Pearce B, Padel S, Hitchings R, Measures M, Cooper N (2012) Public Goods and Farming. Farming for Food and Water Security. In: Lichtfouse E (ed) Farming for Food and Water Security. Sustainable Agriculture Reviews, vol 10. Springer Netherlands, pp 1-22.

Marchand F, Debruyne L, Triste L, Gerrard C, Padel S, Lauwers L (2014) Key characteristics for tool choice in indicator-based sustainability assessment at farm level. Ecol Soc 19.

Schader C, Grenz J, Meier MS, Stolze M (2014) Scope and precision of sustainability assessment approaches to food systems. Ecol Soc19.

AGROFORESTRY PRACTICES FOR WATER QUALITY AND QUANTITY BENEFITS

Udawatta RP[1*]

(1) The Center for Agroforestry, School of Natural Resources, University of Missouri, Columbia, MO 65211, USA

*Corresponding author: UdawattaR@missouri.edu

Abstract

Footprints of global agriculture and food will grow over the next few decades. This analysis examined water quality and quantity benefits of agroforestry. Riparian and upland buffers effectively remove sediment and nutrients from agricultural watersheds with efficiencies approaching 100%. Soils of multispecies buffers degrade and store antibiotics and herbicides. Windbreaks established in Canada, USA, and Russia during 1901-2013 have reduced the impacts of droughts and protected soils. Government supported programs helped plant 610 and 217 million trees in Canada and USA and 5.7 million ha of trees in Russia. Plot and small watershed research have shown increased soil water storage in agroforestry areas than conventional farming which supports regional scale observations. The increased soil water was attributed to soil carbon and soil properties. The study indicated that strategically placed agroforestry with proper species selection could further improve water quality and quantity while minimizing the amount of land taken out of production.

Keywords: buffers; nutrients; runoff; sediment; trees; windbreaks

Introduction

Nonpoint source pollution (NPSP) remains a major challenge in protecting and restoring water quality. Globally hypoxia zones have increased by 400% over the last century from less than 10 in 1910 to over 400 by 2010. Despite improvements in soil conservation practices, crop rotation and nutrient management programs, significant concerns still exist regarding soil erosion and nutrient runoff from agriculture (Udawatta et al. 2006, 2017). The U.S. Environmental Protection Agency (2009) noted that agriculture is the leading cause for water pollution which has impacted 44%, 64%, and 30% of evaluated river, lake, and estuary areas, respectively. Values estimated for soil erosion in USA and Europe were about 4-40 times less than the actual losses (Cox 2011).

Establishment of perennial vegetation on agricultural watersheds as upland buffers and streamside riparian buffers improve water quality parameters (Schultz et al. 2009; Udawatta et al. 2011, 2017). Buffers with fast growing trees along water bodies followed by slow growing trees, shrubs, and native grass strips have been effective in removing sediment, nutrients, antibiotics, and herbicides in surface and subsurface water before water enters water bodies (Schultz et al. 2009; Chu et al. 2010). This is because incorporation of permanent vegetation on row crop and pastured watersheds improves soil physical and biological properties compared to row crop management alone (Udawatta et al. 2017). Strategically positioned buffers can enhance environmental benefits by filtering nutrients and reducing sediment losses more effectively. This strategy might include conversion of sensitive areas such as variable source areas or areas with greater runoff potential to perennial vegetation or wetlands.

Agroforestry practices also have been shown to improve soil water holding capacity, soil carbon (C), and crop yields. Windbreaks established in Canada, USA, and Russia to combat drought and soil erosion also helped improve land productivity. These three projects implemented between 1901 and 2013 planted over 800 million trees in Canada and USA. Canadian shelter belt program implementation of water quality protection includes establishing vegetative buffers, protecting streams and stream banks, and managing grazing.

The paper integrated research findings from peer-reviewed manuscripts, reviews, and other published materials to elucidate beneficial effects of agroforestry on water quality and quantity.

Materials and methods

This manuscript used results from existing long-term watershed studies, review papers, and regional projects to describe agroforestry benefits on improvements in water quality and quantity. Two long-term projects with agroforestry and grass buffers on row crop watersheds and grazing watersheds in Missouri were used to explain water quality benefits and reduction of antibiotics in runoff water from these watersheds. Two review papers on water quality were used to elucidate buffer width and water quality benefits. Windbreaks in Canada, USA, and former Soviet Russia were used to explain regional scale soil and water improvements of agroforestry. The relationship between soil carbon and soil properties and water storage and availability were used to describe how agroforestry can be used to improve soil water relationships, soil carbon, and land productivity.

Results and discussion

Two long-term studies in Missouri, one using a paired watershed approach under corn (*Zea mays* L.)-soybean (*Glycine max* (L.) Merr.) rotational management and the second with cattle grazing have shown reductions in runoff, sediment, and nutrients ranging from 45 to 48% with agroforestry and grass buffers as compared to respective control (Table 1). The grazing study was located in deep loess soils and indicated greater filtration efficiencies as compared to the row crop study with clay pan soils. This emphasizes the importance of buffer design factors and selection of site suitable trees for enhanced benefits. In reviewing published data, Liu et al. (2008) and Mayer et al. (2007) showed that 15-m and 110-m wide buffers could remove 90% of the sediment and nitrogen in runoff water, respectively (Figure 1). Although wider buffers have been shown to be more effective, buffers wider than 7 m have often resulted in diminishing filtration of NPSP. Establishment of wider buffers and integration of income generating species could help generation of additional income and to recover the lost income due to wider buffers and loss of productive lands. Shrubs, nut bearing species, ornamental plants, and biomass crops could be integrated within buffers for water quality and other ecosystem benefits.

Table 1: Percent reduction of sediment, total nitrogen, total phosphorus losses on grazing and row crop management practices with agroforestry and grass buffers compared to the respective control treatment (Udawatta et al. 2011).

Parameter	Managements and Treatments			
	Grazing Management		Row crop management	
	Agroforestry	Grass buffer	Agroforestry	Grass buffer
	----------------------------------- % -------------------------------------			
Sediment	48	23	30	28
Total N	75	68	11	13
Total P	70	67	26	22

Agroforestry systems with greater biodiversity promotes greater degradation and stronger binding of contaminants including antibiotics, herbicides, personnel care products and other toxic compounds (Chu et al. 2010; Lin et al. 2011). On grazing watersheds in Missouri, Chu et al (2010) demonstrated stronger sorption capacity of Sulfadimethoxine and Oxytetracycline by soils under agroforestry as compared to soils from crop and grass areas. They have attributed these differences to organic compounds within agroforestry soils. For example, root exudates and root decomposition products including phenolic and carboxyl groups, N-heterocyclic compounds, and lignin decomposition products serve as binding sites (Cheng and Kuzyakov 2005; Chu et al. 2010; Lin et al. 2011). In another study buffers with poplar, eastern gamma grass, and native grasses exhibited stronger degradation potential of parent compounds as compared to the control and individual species (Lin et al. 2011). Some tree root exudates in the rhizosphere promote degradation by soil fauna and bonding of chemical compounds to soil particles (Chu et al. 2010). In another study Chu et al. (2013) noticed that antibiotic transport is governed non-equilibrium processes and AF buffers retained more antibiotics due to enhanced sorption attributed to higher levels of C. Integration of agroforestry can help reduce degradation of water quality by stronger sorption to soils and/or degradation of chemicals.

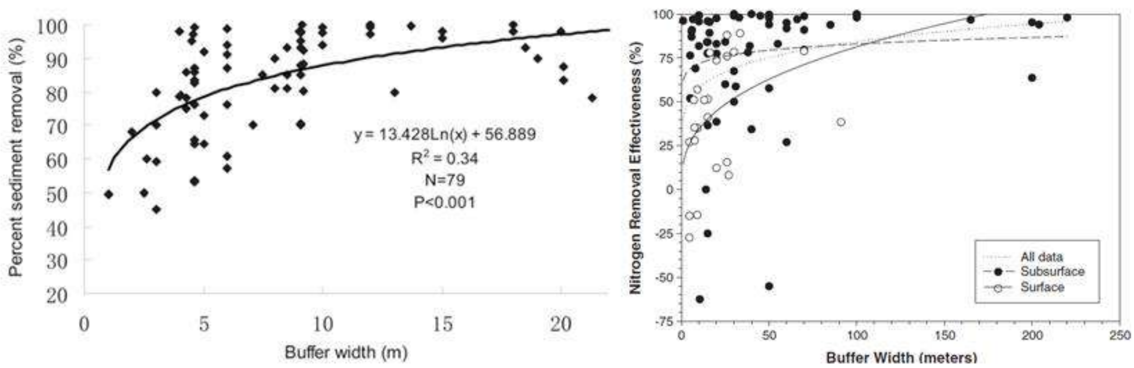


Figure 1: Relationship between buffer width and sediment (Liu et al. 2008) and nitrogen removal (Mayer et al. 205).

Prolong droughts, severe wind erosion, and improper land management which caused economic losses and depression resulted in even death in some areas and these have caused establishment of wind breaks in Canada, USA and Russia (Figure 2). The Prairie Farm Rehabilitation Act (PFRA) funded field shelterbelts program since 1901 with over 610 million trees planted during the last 110 years in Canada. In the US, President Franklin Roosevelt initiated a program in 1934 to stabilize blowing wind. A 100-mile (160-km) wide strip from Texas to North Dakota contained 223 million trees and stretched for 18,599 square miles (48,000 km^2) by 1942. In Russia, Joseph Stalin proposed the “Great Plan for Transformation of Nature” in 1948 due to the 1946 drought, subsequent 1947 famine, estimated 0.5 to 1 million deaths, poor land management, and lower crop yields. The program was based on the findings of Vasily Dokuchaev who has documented damages on steppes for centuries of agriculture and proposed measures for water and soil conservation. Over the last sixty years, the Soviets have planted an exceedingly extensive system of shelter belts throughout much of the steppe region from west bluff of the Volga River from Volgograd in the south to Ulyanovsk in the north and in the Kulunda Steppe in Altay Kray of western Siberia. Shelter belts usually lined both sides of major highways and were often augmented by 15-20 rows of apple trees back from the highway between the shelter belts and the open fields, thus serving both to break the wind and to supply much-needed fruit.

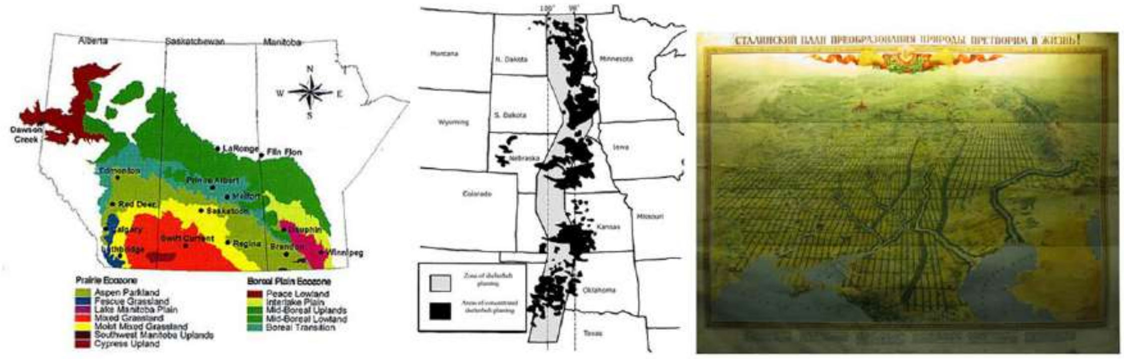


Figure 2: Major shelterbelt areas in Canada (west of Indian Head), USA (Texas to North Dakota) and Russia.

Shelter belt trees increased soil C and thus soil water holding capacity. A white spruce tree, a species planted in Canada shelter belts, contained 287 and 86 kg of above- and below-ground biomass. Assuming 50% C in the biomass, a single white spruce tree would have sequestered 186 kg of C. Hybrid poplar sequesters 367 kg C $tree^{-1}$ in above- and below-ground compared to 110 kg C $tree^{-1}$ in green ash (Koth and Turncock 1999). The Canadian government estimated that all the seedlings distributed by the PFRA program would have sequestered 218 mega tons of C. Increasing soil C increases available water capacity of soils in addition to other ecosystem benefits (Box 1). Available soil water content doubles (from 32 to 65%) for OM increase from 1 to 4%. Plot and watershed research have shown increased AWC in soils under agroforestry in support of the above regional observations. Rehabilitated soils improved soil water storage, soil health, land productivity, and crop yields.

Sand:	AWC=3.8 + 2.2*OM, r^2 0.79
Silt Loam:	AWC=9.2 + 3.7*OM; r^2 0.58
Silty Clay Loam:	AWC=6.3 + 2.8*OM; r^2 0.76

Box 1: Available Water Capacity (AWC) as a function of organic matter (OM) for sand, silt loam, and silty clay loam (Hudson 1994).

Conclusion

In spite of differences in approaches and management systems, results support the hypothesis that integration of agroforestry significantly reduce NPSP losses from grazed and row cropped sites. Furthermore, agroforestry also helped improve available soil water and soil water storage. These improvements can be attributed to changes in soil properties including soil carbon, soil porosity, infiltration, aggregate stability, and other hydraulic parameters. Regional studies have showed that agroforestry windbreaks have helped reduce soil degradation and improved soil properties including soil carbon, soil hydraulic parameters, soil water relationships and land productivity. Water quality and water quantity can be further improved by strategic placement of buffers, selection of site-soil-climate suitable buffer dimensions, improved design factors, and establishment of proper species.

References

Cheng W, Kuzyakov Y (2005) Root effects on soil organic matter decomposition. In Zobel R, Wright S (ed) Roots and soil management: Interactions between roots and the soil. Agron Monogr 48. American Society of Agronomy, Inc, Madison, Wisconsin, USA, pp 119-144.
Chu B, Goyne KW, Anderson SH, Lin CH, Udawatta RP (2010) Veterinary antibiotic sorption to agroforestry buffer, grass buffer, and cropland soils. Agrofor Syst 79: 67-80.
Chu B, Anderson SH, Goyne KW, Lin CH, Lerch RN (2013) Sulfamethazine transport in agroforestry and cropland soils. Vadose Zone J 12: 1-14.

Cox C (2011) Losing Ground. Environmental working group. www.ewg.org/losingground (accessed 11/04/2018).
Hudson DD (1994) Soil organic matter and available water capacity. J Soil Water Conserv 49: 189-194.
Lin C-H, Lerch RN, Goyne KW, and Garrett HE (2011) Reducing herbicides and veterinary antibiotic losses from agroecosystems using vegetative buffers. J Environ Qual 40: 791-799.
Liu X, Zhang X, Zhang M (2008) Major factors influencing the efficacy of vegetated buffers on sediment trapping: a review and analysis. J Environ Qual 37: 1667-1674
Kort J, Turnock R (1999) Carbon Reservoir and Biomass in Canadian Prairie Shelterbelts. Agrofor Syst 44: 175-186.
Mayer PM, Reynolds SK, McCutchen MD, Canfield TJ (2007) Meta-analysis of nitrogen removal in riparian buffers. J Environ Qual 36: 1172-1180.
Schultz RC, Isenhart TM, Colletti JP, Simpkins WW, Udawatta RP, Schultz PL (2009) Riparian and upland buffer practices. In: Garrett HE (ed) North American Agroforestry an Integrated Science and practice. American Society of Agronomy, Inc, Madison, Wisconsin, USA, pp 163-218.
Udawatta RP, Motavalli PP, Garrett HE (2006) Nitrogen losses in runoff from three adjacent agricultural watersheds with claypan soils. Agr Ecosyst Environ 117: 39-48.
Udawatta RP, Garrett HE, Kallenbach RL (2011). Agroforestry buffers for nonpoint source pollution reductions from agricultural watersheds. J Environ Qual 40: 800-806.
Udawatta RP, Gantzer CJ, Jose S (2017) Agroforestry practices and soil ecosystem services. In: Al-Kaisi MM, Lowry B (eds) Soil Health and Intensification of Agroecosystems. London Academic Press, pp. 305-308.
USEPA (U.S. Environmental Protection Agency) (2009) National Water Quality Inventory: Report to Congress, 2004 reporting cycle: findings. https://www.epa.gov/waterdata/2004-national-water-quality-inventory-report-congress (accessed 12/04/2018).

COMBINING OF BIOMASS PRODUCTION FOR ENERGY WITH AGROFORESTRY – EXPERIENCE FROM SHORT ROTATION COPPICE WITH POULTRY BREEDING

Weger J[1*], Vávrová K[1], Bubeník J[1], Lojka B[2], Houška J[3,1], Kotrba R[4]

(1) Dept. of Phyoenergy, Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Publ. Res. Inst., Průhonice, Czech Republic (2) Faculty of Tropical AgriSciences, Department of Crop Sciences and Agroforestry, Czech University of Life Sciences, Prague, Czech Republic (3) Faculty of Agrobiology, Food and Natural Resources, Department Science Sciences and Soil Protection, Czech University of Life Sciences, Prague, Czech Republic (4) Faculty of Tropical AgriSciences, Department of Animal Science and Food Processing, Czech University of Life Sciences, Prague, Czech Republic

*Corresponding author: weger@vukoz.cz

Abstract

The aim of our contribution is to present selected results and conclusions from long term monitoring of selected production and environmental parameters in small agroforestry system which consist of poplar and willow short rotation coppice (SRC) for production of energy biomass combined with poultry breed for self-provision of woodchips and eggs/meat. Mostly positive trends were found of monitored soil parameters in topsoil (5-15 cm) under SRC with poultry after 17 years including stable or increasing levels of C_{ox}, pH, P, K, Ca, Mg despite no fertilization being applied and tree biomass being removed (5 harvests). Additionally, closed canopy of SRC improved welfare of poultry by lowering temporal variations of air temperature and humidity especially in hot days and providing shelter against raptors. Combining poplar/willow SRC for biomass production with poultry breeding can be recommended for its multilateral positive effects on soil, microclimate, welfare and adaptation/mitigation effects.

Keywords: short rotation coppice; grassland; poultry; soil; microclimate; animal welfare

Introduction

Biomass is the most important renewable source of energy in the Czech Republic and whole EU. It covers about 60% of the renewables contribution to total energy consumption similarly as in many Central European Countries. The development of different forms of biomass production is also an important mitigation and adaptation measure in policies of EU countries including energy, environment and agriculture (reduction of GHG, soil erosion control, biodiversity, etc.). Short rotation coppice (SRC) with fast growing trees (poplars and willows) is currently the most widespread and successful “energy crop” in Czechia thanks to good and stable yields, low-input agronomy and good fuel characteristic of their biomass. Currently there are approximately 3,000 ha of these plantations in the Czech Republic (Hudáček 2017). Most of them were established by small landowners for self-provision of firewood and/or woodchips production for local and regional power and heating plants. There are over 650 such growers with plantation sizes ranging typically between 0.5-2 ha, of which many are relatively well suited for agroforestry utilizations (fenced, close to farm). SRC plantations are currently established mostly with poplar clone J-105 (*Populus nigra* × *P. maximowiczii*), but many new species and varieties are tested of poplar, willow, alder, ash or paulownia, which may be used also for non-energy purposes (wood processing, basketing, bee-feeding). Some SRC plantations have been established for their environmental effects such as wind and water erosion control, animal welfare etc (Weger 2008).

Agroforestry has been practiced from the beginning of agriculture in all of Europe; however, currently it is not a common land use system in the Czech Republic and has no recognition in Czech legislation. Traditional agroforestry practically disappeared during the era of collective farming during the 20th century, except for small remnants. Currently, to our knowledge, there are no existing modern agroforestry systems (e.g. alley cropping) for timber production yet, however, potential for producing quality timber (e.g. wild cherry, walnut) and wood biomass exists.

The rapid development of short rotation coppice systems during the last decade demonstrates the growing potential and interest in establishment of these systems in agroforestry schemes. One of the easiest possibilities for farmers is the combination of those plantations with poultry.

The aim of our contribution is to present selected results and conclusions from long term monitoring of selected production and environmental parameters in small agroforestry system which consist of SRC combined with poultry breed both for self-provision of woodchips and eggs/meat.

Materials and methods

The experiment was established on a farm situated in Nová Olešná near Jindřichův Hradec, Southern-Bohemian region. The site is situated 560 meters above sea level, there are mean precipitations of 541 mm and mean temperature is 7.5 °C. The soil type is evaluated as kambizem according to Taxonomic classification of agricultural soils of the Czech Republic (Němeček 2001), Cambisol according to WRB (IUSS Working Group WRB 2015) and Inceptisol according to Soil Taxonomy (USDA-NRCS 2010) with soil pedo-ecological unit numbers 7.29.51. and 7.32.14 (Němec 2001).

The experimental site is divided into three resp. four different plots on a total area of 0.6 ha (Figure 1). The short rotation coppice part consists of the clone test of poplars and willows (0.2 ha), plantations for firewood/woodchips (0.15 ha) and stool bed for cuttings (reproduction material) on 0.1 ha and a garden used for small-scale vegetable production (0.1) including facilities for small scale poultry farming.

Figure 1: Areal picture of the experimental agroforestry system in Nová Olešná (left) and picture of cattle pasture (right) adjacent to SRC visible on left. ALS plots/parts: A) poplar alley and vegetable garden with henhouse, B) poplar/willow experimental SRC clone test (middle and left), C) poplar/willow SRC for energy biomass (right) and D) poplar stool bed; bullets show soil sampling points (SRC1-3, L1-3) of 2017 soil analysis (comparison of SRC and pasture).

Agroforestry systems (AFS) were established gradually since 1999 to 2004 starting with SRC clone test (36 genotypes), SRC plantations for biomass and planting material and ending with introduction of chicken breed to the whole system together with vegetable production garden. Agroforestry systems (all plots) were fenced and they are surrounded from three sides by grasslands (cattle pasture on western-southern side, hay production on eastern side) and by tree vegetation (Ash, Elm and Linden) from the north. Pasture (14 ha) was grazed repeatedly by cattle herd consisting usually between 55-65 cows and calves. Water, hay and additional feeding was provided accordingly on pasture.

Poultry consisted of typically 20-30 hens with one cock and several specimens of ducks, turkeys and geese over the years, depending on the farmer family needs and other factors, e.g. prey by fox and marten. A henhouse with water and feeder is located inside in vegetable garden plot. Poultry has been fed by locally produced cereals and some commercial pellets ad libitum. The AFS and surrounding grasslands has been managed and owned by Mr. Bartoš family (Figure 2).

Figure 2: Poultry in poplar willow clonal SRC test (right: rotten wood removed by chicken).

During the whole experiment we have been monitoring the following production and soil parameters: biomass yield, biometrics, soil changes and nutrients content (pH, Cox) air and soil temperature in the SRC and on grassland.

The goal of soil monitoring in Nová Olešná is to evaluate changes of selected soil characteristics – nutrients (P, K, Mg, Ca – Mehlich III), soil reaction (pH in water) and humus (C_{ox}) in SRC with willow and poplar as part of monitoring of selected experimental SRC plantations on agricultural land. Soil samples have been taken from topsoil (5-15 cm) after each harvest. Three to five soil sub-samples were collected and mixed into one composite sample to represent individual SRC plot or part.

In addition, in 2017 three soil samples were taken from adjacent cattle pasture and SRC using same methodology and analyzing same characteristics as in long term monitoring. Samples in SRC (1-3) represent different managements and tree composition e.g. poplar stool-bed (1-2 year rotation), poplar and willow clonal test (3-year rotation) (see bullets in Figure 1).

Air temperature and humidity at 0.5 m above the ground, soil temperature at 0.25 m below ground and average soil moisture in rooting zone (0.1–0.5 m below ground) have been measured automatically in grassland and SRC.

Results and discussion

Biomass yield of the best 5 clones (out of 36) was 9.04 t DM/ha/year on average from three harvests (9 years) and 17–20 t DM/ha/year in the third harvest. Best clones include natural hybrids of autochthonous willows (*Salix* × *smithiana*, *S.* × *rubens*). In the biomass (SRC) plantation poplar clone J-105 (*Populus nigra* × *P. maximowiczii*) yielded 14.6 t DM/ha/year in the third 3-annual harvest e.g. in 9th year (Weger 2008).

Mostly positive changes were found of monitored soil parameters in topsoil (5-15 cm) under SRC after 17 years. All monitored parameters increased despite the fact that any fertilization was used in 17 years (Figure 3). Similar “improving” trends were found when comparing top soil from SRC with poultry and grassland with cattle in 2017 analysis - except pH which was lower in SRC (Table 1).

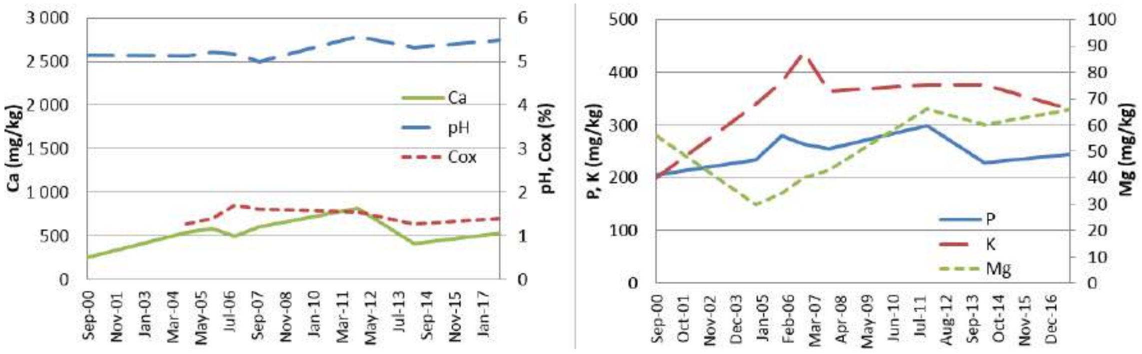


Figure 3: Changes of selected soil parameters in topsoil (5-15 cm) under poplar and willow SRC with poultry breed in Nová Olešná after 17 years (Biomass harvested in 3-year rotations).

Table 1: Results of soil analyses (incl. ANOVA) from topsoil (5-15 cm) in poplar and willow SRC with poultry breed and adjacent grassland (cattle pasture) in 2017 (Weger and Bubeník 2017).

Site - plot	**pH**	**Ca**	**Mg**	**K**	**P**	**C_{ox}**
	H_2O	**(mg/kg)**				**[%]**
Grassland (L1)	5.53	407	49	100	195.9	0.83
Grassland (L2)	5.59	487	50	180	131.4	0.92
Grassland (L3)	5.61	440	53	344	192.8	1.03
SRC 1 (poplar stoolbed)	5.50	533	58	352	227.3	1.31
SRC 2 (willow clone test)	5.49	539	66	315	210.2	1.25
SRC 3 (poplar clone test)	5.47	524	73	323	294.6	1.65
Grassland Ø	**5.58 a**	**445 a**	**51 a**	**208 a**	**174 a**	**0.92 a**
SRC Ø	**5.49 b**	**532 b**	**67 b**	**330 a**	**244 a**	**1.43 b**
p (ANOVA, Tukey-HSD)	0.0246	0.0209	0.029	0.169	0.100	0.025

Regarding climatic efficiency, SRC plantation in Nová Olešná with closed canopy in comparison with grassland have lower the midday air temperatures (by 4-5 ^{o}C on extremely hot days) and also the soil temperature based on previous results (Šír et al. 2009).

SRC with closed canopy provides shelter for poultry against raptors, but still they have been threatened by foxes and martens (Bartoš, pers.comm.). This can be solved by installation of proper fencing or by locking poultry in henhouses before dawn because those small terrestrial predators are mainly nocturnal.

Conclusion

1. Mostly positive trends were found of monitored soil parameters in topsoil (5-15 cm) under poplar and willow SRC with poultry breed in Nová Olešná after 17 years. All parameters have increased despite that any fertilization was used and trees were harvested 5 times.

2. “Better” soil parameters (C_{ox}, Ca, Mg) were found in top soil of SRC with poultry when comparing with grassland (cattle pasture) in 2017.

3. SRC with closed canopy greatly improves welfare of chicken breed by: i) lowering temporal variations of air temperature and humidity especially in hot days, ii) providing shelter against raptors.

4. Widespread use of SRC may be welcomed also for mitigation of climate change thorough carbon sequestration in topsoil by humification of leaves litter and in below ground soil by root biomass.

5. Combining poplar/willow SRC for biomass production with poultry breeding can be recommended for its multilateral positive effects on soil, animal welfare and landscape climatic efficiency.

References

Hudáček J (2017) Growing of SRC on agricultural land. Paper presented at seminar of Poplar commission of Czech Republic; 2017 Oct 4-5; Průhonice, Kunovice, Czech Republic.

IUSS Working Group WRB (2015) World Reference Base for Soil Resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome.

Němec J (2001) Bonitace a oceňování zemědělské půdy. Praha:Výzkumný ústav zemědělské ekonomiky.

Němeček et al (2011) Taxonomický klasifikační systém půd České republiky. ČZU Praha,

USDA-NRCS (2010) Keys to soil taxonomy, 10th ed., USDA-NRCS.

Šír M, Weger J, Vondrka A (2009) Climatic efficiency of stands of fast growing trees in the landscape (In Czech). Acta Pruhoniciana 92: 45–50.

Weger J (2008) Yields of selected willow and poplar clones after 9 years of short rotation coppicing (In Czech). Acta Pruhoniciana 89: 5–10.

Weger J and Bubeník J (2017) Analýza vlivu pěstování rychle rostoucích dřevin (RRD) na zemědělské půdy, zejména v I. a II. třídě ochrany ZPF. Zpráva FÚ MZe no. 667-2017-17253. RILOG, Průhonice; Czech Republic.

Session

Biodiversity and added value

SCA0PEST PESTICIDE-FREE AGROFORESTRY CROPPING SYSTEM: EFFECTS ON WEED COMMUNITIES

François M[1], Seyed Esmail A[2], Garcia E[3], Faucon MP[4], Grandgirard D[4], Simon L[4]*, Salitot G[5]

(1) Université de Loraine Campus Aiguillettes, 54506 Vandœuvre les Nancy, France (2) Université Picardie Jules Verne, 80000 Amiens, France (3) Université Caen Normandie, 14032 Caen, France (4) Institut Polytechnique UniLasalle Beauvais, 60026 Beauvais, France (5) Chambre d'agriculture de l'Oise, 60021 Beauvais, France

*Corresponding author: leo.simon@unilasalle.fr

Abstract

SCA0Pest project tests a pesticides free agroforestry cropping system. The evolution of weed abundance, diversity and the ratios of weed/crops biomass have been assessed over 4 years within the cropping system and show that there are differences according to years, crops and farming practices. Weeds populations are gradually responding to changes in the system and related to management. Landscape seems to have an impact on the weed community structure as presence of grass strips does not.

Keywords: pesticide-free; cropping system; weed management; agroforestry

Introduction

Intensive use of chemistry has simplified the cropping systems and led to the set-up of monoculture and soil tillage reduction (Chikowo et al. 2009; Letourneau et al. 2011). Although pesticides use contributed to end yield losses by stabilizing infestations, it remains responsible for: i) soil *and* water pollution (Pardo et al. 2010) or/and biodiversity loses (Petit et al. 2010; Perronne et al. 2014), ii) appearance of resistance (Valantin-Morison et al. 2008), or again iii) economic issues due to products cost increase. Therefore, alternatives for pest control appear by end 20th century and are multiple: to adapt seedling rate and date, intercropping, mechanical weeding, rotation lengthening and diversification, variety mixtures use (Chikowo et al. 2009; Deytieux et al. 2012; Letourneau et al. 2011).

SCA0PEST project as a PECS (Productive and Efficient Cropping Systems, Grandgirard et al. 2014) tests a pesticides free agroforestry cropping system. The project aims at observing weed communities' evolutions within the cropping system, evaluating effectiveness of the alternative agricultural practices chosen. To this end: i) longitudinal weed density evolution is followed, ii) weed contamination from grass strips is characterized and iii) weed communities (species and traits) is described.

Materials and methods

By September 2013, the SCA0PEST PECS was set up within a 34 ha and 5-years old alley cropping agroforestry matrix (N49°28'21'', E2°03'55''). Each year, 6 over the 8 terms of the crop rotations are present on a 0.5ha acreage plot (P1 to P6) each and are separated by standard trees lines distant of 30m each other (Grandgirard et al. 2014).

Crop rotation includes in order sunflower ("ToLuz"; *Helianthus annuus*) alfalfa association, 2 years alfalfa ("Luz1", "Luz2"; *Medicago sativa*), winter wheat ("blé1"; *Triticum aestivum*), oilseed rape ("Colza"; Brassica napus), spring barley ("OP"; *Hordeum vulgare*), field bean ("FevH"; *Vicia faba*) and winter wheat again ("blé2"). Experimental follow up are organised yearly according to the Res0pest project experimental standards (Cellier et al. 2014). They are dedicated to measurement of crops sanitary status, assessment of the spatiotemporal weeds and pests' pressures, and their consequences on yields and harvest quality (Grandgirard et al. 2014). Each of the 6 plots has 8 measurement stations of $16m^2$ every 20m lengthwise (Figure 1). Distance between grass strips and stations varies from 5 to 14m. Each station includes a 0.36 m^2 quadrat. Weed characterization consist in 4 annual surveys during which i) all different species in the plot are inventoried and weed density is ii) estimated in each 16 m^2 stations (Barralis method) and iii) precisely determined in each $0.36m^2$ quadrat. Last survey includes a biomass sampling. Data analysis was done by using multivariate NMDS and PCA procedures and having recourse to Friedmann and Mann-Whitney post-hoc tests. Statistical analysis was performed using the R 3.3.1 package.

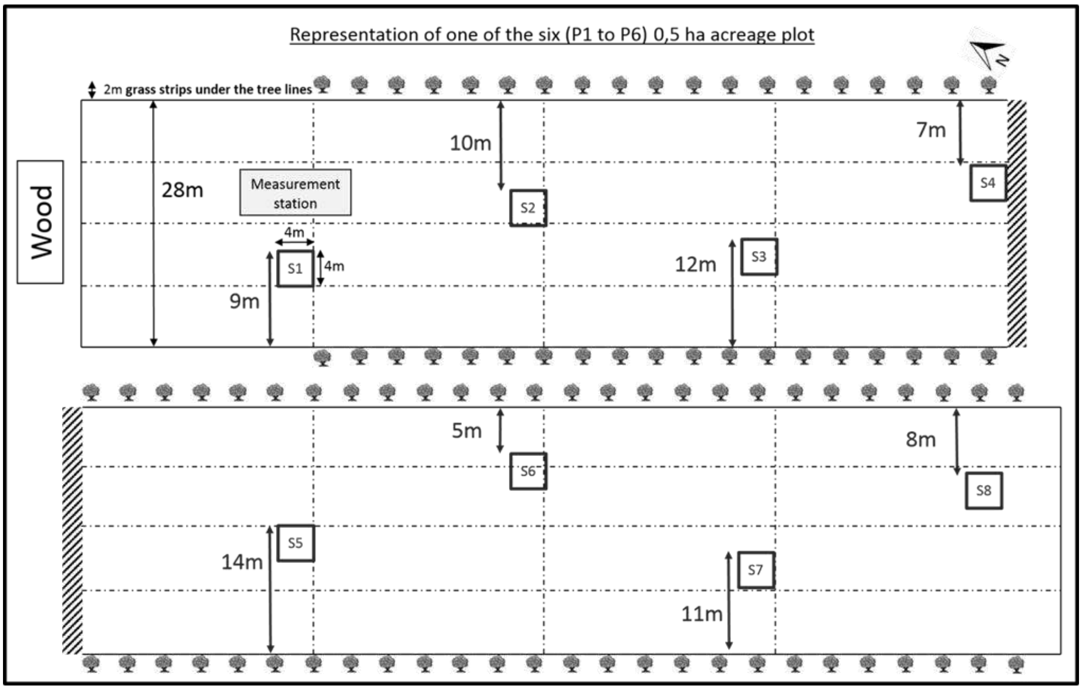


Figure 1: Schematic representation of a plot.

Results

Crops effect on weed density, diversity and dry matter. Friedman test on each plot followed by Mann-Whitney post-hoc paired test were used. Significant crop effect on weed density is observed on several plots. Weed density and dry biomass ratio on P1 plot are significantly higher for Luz1 compared to the years before and after. In the two plots (P1 and P6) where alfalfa cycle was completed (ToLuz – Luz1 – Luz2), weed biomass ratio decreases the second year of alfalfa (Luz2). OP always presents the lowest weed density. Cumulative histogram of weed species by crop (mixing plot and year) shows differences in floristic composition. NMDS (Figure 2) were realised for each year of study (2014 to 2017). Weed species composition differences between plots are stronger last year of study (2017). Weed species composition found in Luz1 and Luz2 seems to differ from other crops.

Effects of cultural interventions. Principal component analysis (PCA) showed links between group of cultural intervention variables and weed density, dry biomass ratio and diversity variables. Correlation and significance tests highlighted negative relations between weed density and the number of hoeing, total annual fertilization, cumulated fertilization, ammo nitrate fertilization; and positive relations with the number of grinding. Weed species richness is positively correlated with weed density but negatively correlated with the number of hoeing, total annual fertilization and cumulated fertilization. Weed dry biomass ratio is positively correlated with weed density and weed species richness.

Grass strips and landscape effects. Cumulative histograms of weed species in stations (S1 to S8) show a visual effect of wood distance (north-south gradient) but no effect of grass strips distance (middle-edges gradient).

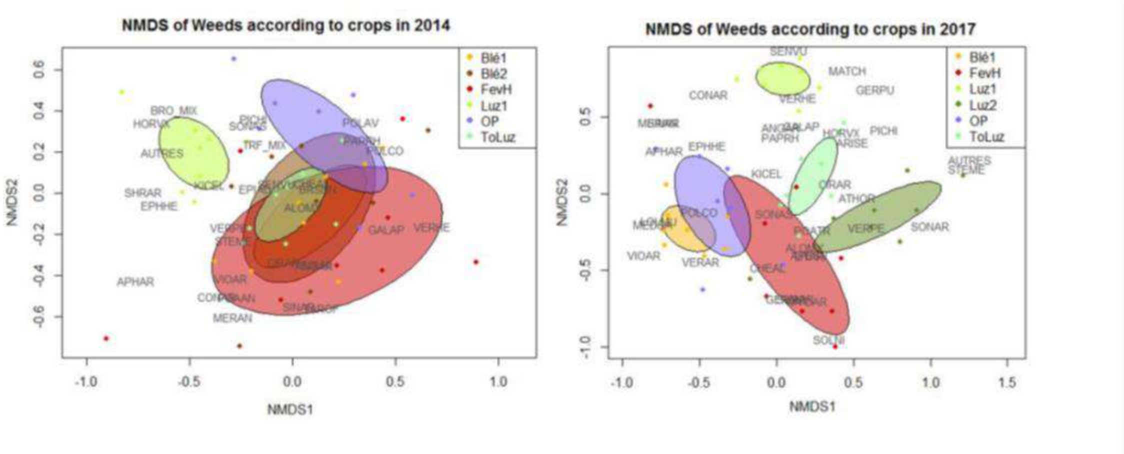


Figure 2: NMDS representations for years 2014 and 2017.

Discussion

Weed density and dry biomass ratio. Crops seem to influence weed density. Analysis did not show any year effect. Weed density differences depend on i) crop competitively potential (Chikowo et al. 2009), ii) specific technical managements (Valantin-Morison et al. 2008). First alfalfa year (Luz1) possesses the greatest weed density as spring barley (OP) possesses the lowest. Spring barley (OP) early sowed in the beginning of spring period often grow and develop before weed species. Sunflower alfalfa association (ToLuz) sowed later during spring period allows more weed species to install, increasing weed density the following year (Luz1). PCA and correlation test showed that certain agricultural practices influence more weed populations than others. Ploughing, hoeing and nitrogen fertilization were correlated with low weed density levels. In four years of study, global weed density did not seem to have negatively evolved. All the agricultural practices and solutions set up to compensate lack of pesticides use seem to maintain control on weed infestation.

Weed species richness. Global cropping system weed diversity remain high (70 different species). First four years of study did not prove weed biodiversity increase. Agroforestry and grass strips constitute habitat for animal and vegetal species (Marshall and Arnold 1995) increasing cropping system biodiversity. This should be considered in species richness calculation. Diversified crop rotation, agroforestry and lack of pesticides use enhance weed species richness compared to more simple cropping systems (Petit et al 2010; Marshall and Arnold 1995). Four years of study do not permit to know how weed communities will evolve on the long term.

Grass strips and landscape effects. Marshall and Arnold (1995) suggest that weed species presence depends on specific habitats within and around the field. Some species found in the grass strips were never found in the cultivated parts. Only few species were regularly found in both field and grass strips. Few species found in the field were never found in grass strips. At plot scale, distance from wood (landscape effect) influence more floristic composition than distance to grass strips.

Conclusion

First results of pesticide free agroforestry Sca0pest cropping system effects on weed communities did not show negative evolution in four years of study. Crop rotation and technical management seem efficient enough to avoid pesticides use. Weed diversity did not show neither positive nor negative evolution. Grass strips floristic diversity (lot of species not found in the fields) has not being precisely characterized but surely contributes to increase global species richness of the cropping system. Moderate grass strips management (one mowing per year) seems to prevent weed species from spreading into the field.

Weed floristic composition changed and adapted in the different plots under cumulated effects of crops, cultural interventions and year.

References

Chikowo R, Faloya V, Petit S, Munier-Jolain NM (2009) Integrated Weed Management systems allow reduced reliance on herbicides and long-term weed control. Agr Ecosyst Environ 5: 237-242.

Deytieux V, Nemecek T, Freiermuth Knuchel R, Gaillard G, Munier-Jolain NM (2012) Is Integrated Weed Management efficient for reducing environmental impacts of cropping systems? A case study based on life cycle assessment. Eur J Agron 36: 55-65.

Grandgirad D, Oheix S, Lançon L., Liagre F., Dupraz C., Mézière D., Poulain J.L., Wartelle R (2014) SCA0PEST, a pesticide-free agroforestry cropping system: its ex-ante performances evaluation. 2nd European Agroforestry Conference, Cottbus, Germany.

Letourneau DK, Armbrecht I, Salguero Rivera B, Montoya Lerma J, Jiménez Carmona E, Constanza Daza M, Escobar S, Galindo V, Gutiérrez C, Duque López S, López Mejía J, Acosta Rangel AM, Herrera Rangel J, Rivera L, Saavedra CA, Torres AM, Reyes Trujillo A (2011) Does plant diversity benefit agroecosystems? A synthetic review. Ecol Appl 21: 9-21.

Marshall EJP, Arnold GM (1995) Factors affecting field weed and field margin flora on a farm in Essex, UK. Landscape and Urban Plan 31: 205-216.

Pardo G, Riravololona M, Munier-Jolain NM (2010) Using a frming system model to evaluate cropping system prototypes: Are labour constraints and economic performances hampering the adoption of Integrated Weed Management? Eur J Agron 33: 24-32.

Perronne R, Gaba S, Cadet E, Le Corre V (2014) The interspecific variation of functional traits in weeds: diversified ecological strategies within arable fields. Acta Botanica Gallica: Botany Letters 161: 243-252.

Petit S, Boursault A, Le Guilloux M, Munier-Jolain N, Reboud X (2010) Weeds in agricultural landscapes. A review. Agron Sustain Dev 31:309-317.

Valantin-Morison M, Guichard L, Jeuffroy MH (2008) Comment maîtriser la flore adventice des grandes cultures à travers les éléments de l'itinéraire technique? Innovations Agronomiques 3: 27-41.

SOWING LEGUME-RICH PASTURES MAKE COMPATIBLE AN INCREASE IN PRODUCTION WITH THE CONSERVATION OF PLANT DIVERSITY OF MEDITERRANEAN DEHESAS

Hernández-Esteban A[1]*, López-Díaz ML[1], Moreno G[1]

(1) INDEHESA (Institute of Dehesa Research), University of Extremadura, 10600 Plasencia, Spain

*Corresponding author: anaherest@unex.es

Abstract

Improvement in forage production and soil quality achieved by sowing legume-rich mixtures in managed grasslands is a reality; however, the compatibility of these kind of pastures with biodiversity conservation it is not so evident. The aim of this study is to evaluate the accuracy of sowing legume-rich pastures in the dehesa from an environmental point of view, by evaluating the changes on the plant community diversity in the medium-long term. Our results show that biodiversity can be sustained while increasing productivity and profitability of the farms through legume-rich pastures, thus they can be considered a suitable option in Iberian dehesas and in all probability, in other Mediterranean silvopastoral systems.

Keywords: legume-rich pastures; pasture biodiversity; species richness; scattered trees; silvopastoral systems.

Introduction

Dehesas, Mediterranean wooded pasturelands, cover around 3.5 million hectares of the south-western Iberian Peninsula, forming one of the largest agroforestry systems in Europe (Den Herder et al. 2017). Dehesas are included in the EU habitat directive as a habitat with community-wide interest (Díaz et al. 2013) and qualified as biodiversity hotspots (Myers et al. 2000; López-López et al. 2011). Due to their shallow depth, and water and nutrients scarcity, fertility is low, thus, native pastures are poor in terms of productivity and quality. Attending to the well-known N limitation in the dehesa, it is essential to find a N self-sufficiency strategy, and sowing legume-rich pastures appear to be part of it. These multi-species pastures show high environmental plasticity. Each species can exploit different ecological niches, increasing the productivity, the production stability and also the pasture lifetime. However, it is still essential to improve our information about the persistence of legumes and the possible influence on biodiversity at pasture level.

Materials and methods

Study area

The study area is characterized by two fundamental features: The Mediterranean character of the climate (dry summers and cold winters) and the low fertility of the soil, particularly P and Ca. The soils are mainly acid varying among Eutric and Distric Cambisols and Luvisols. The *experimental design* was conducted in 2016 and 2017 on seven dehesa farms in Extremadura (West of Spain) where a mixture of forage legume seeds (20 kg seed ha^{-1}) had been sown in different years, following a chronosequence. In each farm, 3-5 different ages (years of sowing) were identified besides a control plot (parcel that has never been sown). The different plot ages were grouped for plotting and some analyses into Control plots, Young plots (0 to 5 years), Mature plots (6 to 10 years) and Old plots (11 to 15 years). In total, 33 plots were monitored, with year of sowing ranging from 2002 to 2015. The plots were representative of the vegetation in the area in terms of botanical composition and phenology.

Regarding sowing, in November, a mixture of legumes was sown. The mixture of *Rhizobium*-inoculated seeds was composed of *Trifolium subterraneum* (61%) (different subspecies as *brachycalycinum* and *yaninnicum*) with other forage legumes: *T. michelianum var balansae* (7%), *T. vesiculosum* (3%), *T. resupinatum* (6%), *T. incarnatum* (8%), *Ornithopus sativus* (12%) and *T. glanduliferum* (3%). Superphosphate was applied as fertilizer in the sown parcels with different frequency among farms. Two microhabitats were clearly defined in each of the 33 plots: beneath oak canopy and outside tree canopy.

Sampling protocol

Botanical composition was determined with the Point Transect method (Southwood and Henderson 2000), noting the species present every 100 cm in eight random 25 m transects. Annual inventory included 264 transects (7 seven farms (*33 plots) · 4 transects ·2 microhabitats*) and a total 6864 individual plants.

Statistical analysis

Statistical analyses were performed with R Software (R Foundation for Statistical Computing, Vienna 2017). Differences in age (quadratic adjustment) and habitat among values of yield, species richness and biodiversity indexes were compared by mixed effects models (LMMs) using the “nlme” package, considering “farm” as random factor and “age” nested in farm. A summary of the statistical considerations and results of the mixed effects models applied is shown in Table 1 and 2. Rarefaction curves were calculated with “vegan” and “iNEXT” packages.

Results

Plant diversity

As said before, plant diversity of dehesas is usually high, and our results in the control unsown plots confirm this statement (*Shannon index value*: 2.744 (beneath) and 2.528 (outside). *Simpson index value*: 0.889 (beneath) and 0.847 (outside)). The mean number of species recorded in each sampling plot was almost 40 species on average (α diversity) and the total number of species recorded per habitat (ϒ diversity) was over 150 species both beneath canopy and out of canopy, with species richness slightly higher in the latter. These differences in richness (Figure 1) are not significant with age; however, depending on the sampling year, habitat becomes significant (Table 1).

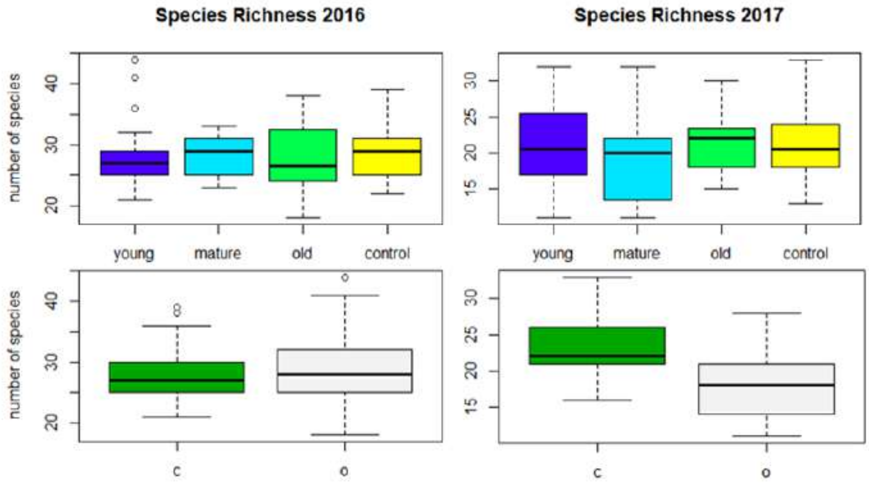


Figure 1: Species Richness in 2016 (left) and 2017 (right) in the studied plots grouped by age, and in the two microhabitats (under canopy (**c**) and out of tree canopy (**o**)).

In the initial years after sowing legume-rich pastures (young pastures in Figure 2), mean species richness per sample decreased slightly both beneath and outside the tree canopy. This loss of α diversity persisted in mature and old plots. However, species richness at higher spatial level (ϒ diversity) did not differ significantly for any of the age groups of the sown pastures with respect to the control unsown plots, indicating that the loss of α diversity in sown pastures is compensated by the high β diversity.

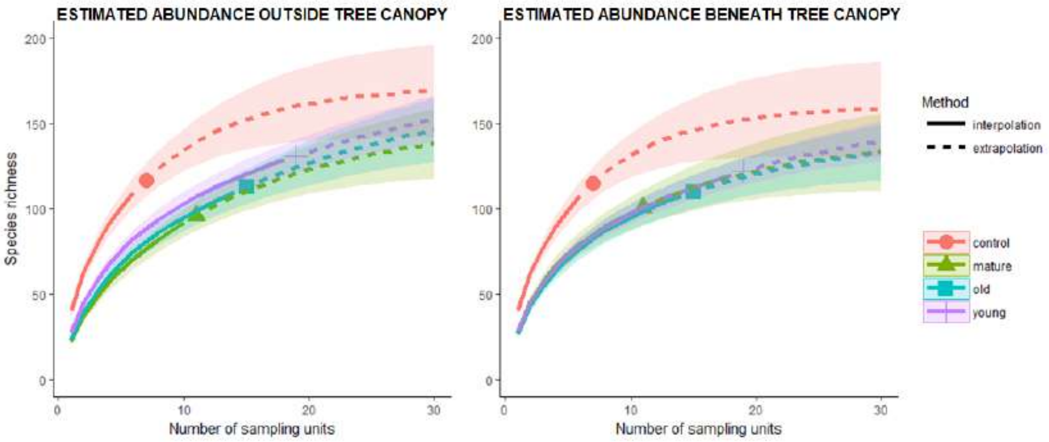


Figure 2: Estimated species richness by accumulation curves (±95 % C.I.) in pastures grouped by age. Solid lines and symbols represent recorded data while dashed lines represent the species richness estimated following the extrapolation (prediction) approaches proposed by Chao (2005) and Colwell et al. (2012) to make comparable values produced with different sampling efforts.

Table 1: Significance (p) effects of LMM to explain variations on α diversity in two consecutive years. Fixed factors were "habitat" (beneath and outside of canopy), "age" of sown legume-rich pastures (year from sowing) and their interaction (age x habitat). Farm was included as a random factor (age is nested in farm). The model included a quadratic term in age.

Year of sampling	Biodiversity measurements	Significance (p) fixed effects			R^2 Model
		age	habitat	age*habitat	
2016	Simpson	0.5472	0.9862	0.3978	0.3154
	Shannon	0.7396	0.9499	0.5226	0.3508
	Species Richness	0.5563	0.0388*	0.6313	0.1540
2017	Simpson	0.7375	0.0013**	0.4213	0.3444
	Shannon	0.7734	4.99e-05 ***	0.2792	0.3881
	Species Richness	0.7838	1.35e-05 ***	0.0564	0.4221

Table 2: Species richness in the considered habitats and groups of age considering the two sampling years of the study (2016 and 2017). It can be observed that Richness is higher beneath the tree canopy when weather is adverse (2017 sampling).

Sampling year	Age of sown pastures	Mean Species Richness by habitat ± s.e	
		Beneath canopy	Outside canopy
2016	control	36.896 ± 6.590	47.054 ± 14.44
	young	36.496 ± 10.432	48.119 ± 18.380
	mature	37.69 3± 7.966	44.357 ± 10.839
	old	37.895 ± 7.857	70.777 ± 43.181
2017	control	34.584 ± 9.293	29.588 ± 13.964
	young	35.581 ± 10.889	20.254 ± 3.288
	mature	38.677 ± 17.579	18.542 ± 5.881
	old	34.045 ± 12.034	24.024 ± 5.879

Pasture production

Yield increased significantly (p=0.018 beneath and p=0.0003 beyond tree canopy) after sowing legume-rich pastures. Mean production for control plots was 1586 kg ha^{-1} ± 132 $CI_{95\%}$ one year after the sowing was almost tripled 4762 kg ha^{-1} ± 389 $CI_{95\%}$. Production decreased gradually in the following years, but maintaining noticeably higher levels than unsown plots.

Discussion

The desirable positive effect in productivity that motivates the sowing of legume-rich pastures was significant and stronger beyond than beneath tree canopies of legume-rich pastures was achieved, with an improvement in yield of more than 200 % over the control levels. This increase in production may be due to the interaction among N_2-fixing and non-fixing-plants (Temperton et al. 2007; Nyfeler et al. 2009) and the mixed-pastures long-lasting character together with the high number of plant species with diverse functions (Fornara and Tilman 2009). The increased yield and legume proportion on the farms (data not shown) appear to justify the sowing of legume-rich pastures. However, the appropriateness of commercial seed mixtures has been seriously questioned by some authors because of their excessive competitiveness or invasive character (Driscoll et al. 2014). In contrast, our biodiversity results indicate unproblematic coexistence of both native and sown legumes, agreeing with Proença et al. (2015). In fact, native *Trifolium* such as *T. striatum, T. stellatum* and *T. glomeratum* were among the most abundant legumes on the study farms.

The response of pasture biodiversity over the years seem to be influenced by the weather, thus, with the habitat. In 2017, pastures experienced unusually high temperatures and scarce rainfall in early spring and species richness was higher beneath the canopy, whereas in 2016, with more favourable climate conditions, species richness was more abundant outside the canopy (See Table 2). We could say that beneath the tree canopy, especially in climatically adverse years, species richness is significantly higher than outside due to the tree “nurse” effect. Taking the increasing recurrence of heat/dry events in the spring/growing season into account, this could be a support to the implementation of sown pastures rich in legumes in silvopastoral systems as dehesa.

References

Chao A (2005) Species richness estimation. In: Balakrishnan N, Read CB, Vidakovic B (eds) Encyclopedia of statistical sciences. Wiley, New York, pp 7909–7916.

Colwell RK, Chao A, Gotelli NJ, Lin S-Y, Mao CX, Chazdon RL, Longino JT (2012) Models and estimators linking individual-based and sample-based rarefaction, extrapola- tion, and comparison of assemblages. J Plant Ecol 5: 3–21.

den Herder M, Moreno G, Mosquera-Losada MR, Palma JHN, Sidiropoulou A, Santiago Freijanes JJ, Crous-Duran J, Paulo J, Tomé M, Pantera A, Papanastasis V, Mantzanas K, Pachana P, Papadopoulos A, Plieninger T, Burgess PJ (2017) Current extent and trends of agroforestry in the EU27. Agriculture Ecosyst Environ 241: 121–132.

Díaz M, Tietje WD, Barrett RH (2013) Mediterranean Oak Woodland Working Landscapes.

Driscoll DA, Catford JA, Barney JN, Huleme PE, Inderjit, Martin TG, Pauchard A, Pysek P, Richardson DM, Riley S, Visser V (2014) New pasture plants intensify invasive species risk. Proc Natl Acad Sci 111:16622–16627.

Fornara DA, Tilman D (2009) Ecological mechanisms associated with the positive diversity-productivity relationship in an N-limited grassland. Ecology 90:408–418.

López-López P, Luigi M, Alessandra F, Emilio B, Luigi B (2011) Hotspots of species richness, threat, and endemism for terrestrial vertebrates in SW Europe. Acta Oecol 37: 399–412

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403: 853–858.

Nyfeler D, Huguenin-Elie O, Suter M, Frossard E, Cannolly J, Lüscher A (2009) Strong mixture effects among four species in fertilized agricultural grassland led to persistent and consistent transgressive overyielding. J Appl Ecol 46: 683–691.

Proença V, Aguiar C, Domingos T (2015) Highly productive sown biodiverse pastures with low invasion risk. Proc Natl Acad Sci U S A 112:E1695-. doi: 10.1073/pnas.1424707112.

Southwood TRE, Henderson PA (2000) Ecological Methods, Third Edition.

Temperton VM, Mwangi PN, Scherer-Lorenzen M, Schmid B, Buchmann N (2007) Positive interactions between nitrogen-fixing legumes and four different neighbouring species in a biodiversity experiment. Oecologia 151: 190–205.

SPECIALTY CROP DEVELOPMENT FOR TEMPERATE AGROFORESTRY SYSTEMS: SUSTAINABLE MANAGEMENT, MARKETING AND PROMOTION FOR THE MIDWEST REGION OF THE USA

Ormsby Mori G[1*], Gold M[1], Jose S[1]

(1) Center for Agroforestry, University of Missouri, Columbia, Missouri, USA

*Corresponding author: ormsbyg@missouri.edu

Abstract

Farmers and rural communities across the American Midwest face numerous sustainability challenges, both economic and environmental. Agroforestry practices present a more sustainable alternative, but key to success is the selection and development of appropriate species to integrate into these systems. The University of Missouri Center for Agroforestry (UMCA), with long-term goals of creating viable on-farm enterprises and promoting the adoption of practices that can contribute to enhanced ecosystem services across the landscape, has focused on the research and development of regionally adapted and promising specialty crops for agroforestry through a comprehensive, multi-foci approach. Key components include breeding and selection of improved cultivars, research and dissemination of production techniques, market research, consumer education and support to growers. This presentation provides an overview of recent advances and remaining challenges of these ongoing efforts.

Keywords: specialty crops; improved cultivars; market development

Introduction

Agriculture is the dominant land use across the American Midwest and the region is home to some of the most agriculturally intensive production in the world. Approximately 66.8 million hectares across the region are under some form of commodity agriculture, just over 50% of the total land surface. U.S. agricultural and rural communities face ongoing challenges including profitability and environmental stresses that threaten the livelihoods and well-being and long-term environmental sustainability of many who work the land and/or live in rural areas. Agroforestry practices present a more sustainable alternative to conventional agricultural practices. An important consideration in the design and promotion of agroforestry systems (AFS) is the selection and development of appropriate species that can be successfully integrated into these systems. For example, comprehensive efforts are underway to develop hybrid hazelnuts as a “third crop” for Midwest agriculture (Molnar et al. 2013). Previous work at the University of Nebraska, beginning in 1999, evaluated the potential of 30 species of fruit and woody floral species in demonstration trials intercropped with corn, soy and wheat. The data from these trials confirmed that a market driven approach to encourage natural resource conservation through agroforestry specialty crops can be a viable approach for the region (Josiah et al. 2004).

The University of Missouri Center for Agroforestry (UMCA), recognizing the importance and potential of specialty crops for design of robust, ecologically sustainable and economically productive agroforestry systems, has placed an emphasis on the research and development of regionally adapted and promising specialty crops. This includes genetic improvement and the release and promotion of cultivars of familiar species like native eastern black walnut – (Juglans nigra) as well as lesser known species such as non-native Chinese chestnut – (Castanea mollissima) for managed production within an agroforestry practice.

This presentation provides an overview of UMCA's comprehensive approach to specialty crop development, with an update on advances and remaining challenges of ongoing efforts with specific candidate species: chestnuts (*Castanea mollissima*), black walnuts (*Juglans nigra*), elderberry (*Sambucus canadensis*), pawpaw (*Asimina triloba*), hybrid pine for pine straw (*P. taeda* x *P. rigida*), shiitake (*Lentinula edodes*). The long-term goals include creating viable on-farm enterprises and promoting the adoption of practices that can contribute to enhanced ecosystem services across the landscape.

UMCA's comprehensive approach to specialty crop development includes multiple foci:

1. Develop, test, and deploy improved cultivars
2. Research, test and disseminate field production and management techniques
3. Conduct market, consumer and value-added research
4. Increase consumer awareness and demand (creating market "pull")
5. Create financial decision support tools
6. Provide grower training and support to promote industry "grower clusters" or coops

Development and testing of improved cultivars

To develop a new chestnut industry in Missouri and surrounding states, it has been important to conduct long-term studies that directly compare *C. mollissima* cultivars at the same location or locations over multiple years to determine their local adaptation and performance (Gold and Hunt 2002). At the University of Missouri Horticulture and Agroforestry Center, New Franklin, Missouri, Center for Agroforestry scientists established a collection of 65 known *Castanea* cultivars from 1996 through 2005 in a germplasm repository for long-term evaluation (Hunt et al. 2004).

A second more limited cultivar trial was established in 1999 in an effort to identify outstanding, locally-adapted cultivars that have traits suitable for commercial chestnut production (e.g., large size nuts and high yields). A replicated cultivar trial, with twelve cultivars and five replications (one tree per replicate) of *C. mollissima* and chestnut species hybrids, was established in 1999. Each fall from 2008 through 2011, plus 2015, nuts were collected, counted, and weighed for each tree and combined to determine yield and average nut weight (Table 1).

Over several decades, UMCA has evaluated dozens of improved cultivars of black walnut. A key target criterion for improvement has been the nut yield ratio. Nutmeat from the nuts of wild trees can average between 7-10% of total weight (nutmeat/shell ratio). Nut yield in cultivars under study at UMCA is averaging around 30% kernel, with some cultivars demonstrating consistent nut yields up to 38% (Coggeshall and Romero-Severson 2013).

Table 1: Average yield per tree (kg and lbs) and per acre (hectare) summed over 4 years, 2008-2011, plus 2015

Cultivar	2008-2011 Average yield / tree kg tree / lbs tree		2015 (Age 16) Average yield / tree kg tree / lbs tree		2008-2011 Average yield / ac. kg hectare/ lbs Acre		2015 Yield kg hectare / lbs acre	
Colossal	42.1	92.6	---	---	5,187	4,631	---	---
Qing	24.0	52.8	42.9	94.4	2,957	2,640	5,285	4,719
Eaton	14.8	18.0	34.6	46.0	1,823	1,628	2,575	2,299
Sleeping Giant	11.3	17.6	29.9	58.7	1,392	1,243	3,289	2,937
Homestead	8.2	14.7	20.9	44.2	1,010	902	2,476	2,211
Mossbarger	8.0	13.6	26.7	70.4	986	880	3,942	3,520
OK-Kwang	6.7	52.8	20.1	76.1	825	737	4,263	3,806
Peach	6.2	32.6	32	65.8	764	682	3,684	3,289

Market research and development

Launching and growing a specialty crop industry is more likely to achieve success when it is "pulled" along by market forces and when development efforts follow a market-oriented strategy. However, for new or emerging niche specialty crops, there is often a lack of detailed market information. Therefore, research into market dynamics and potential has been essential. An important tool guiding much of this research is the Porter Five Forces Model (Porter 1980) (Figure 1).

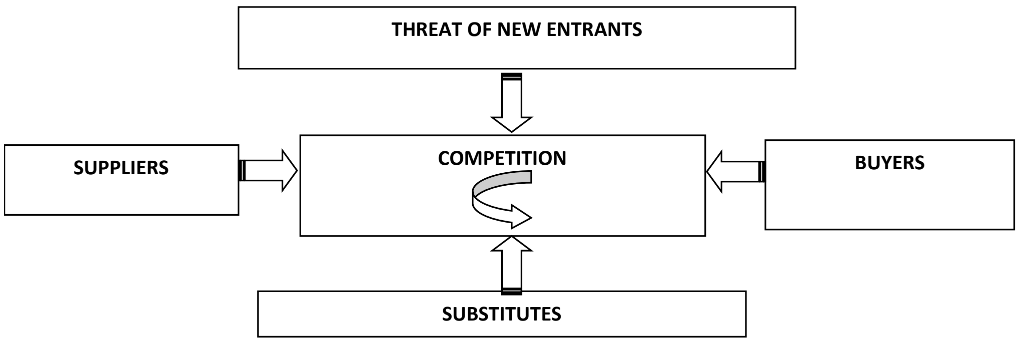


Figure 1: The Porter Five Forces Model (PFFM) (Porter 1980).

This framework is a useful guide for analyzing competition within an industry and considers five areas of competition (competition among producers, bargaining power of suppliers, bargaining power of buyers, potential for substitutes and threat of new entrants) and interaction between these "forces" which defines an industry's structure and nature of the competition (Cernusca et al. 2012). The methodology is particularly useful for farm businesses that are looking to enter new markets, the typical case for agroforestry practices that integrate niche specialty crops.

A nationwide survey of U.S. chestnut (*Castanea spp.)* producers was conducted using a variety of tools (i.e., Strength-Weakness-Opportunity-Threat (SWOT) analysis, the Porter Five Forces Model, Conjoint Analysis choice preference questions) to understand the U.S. chestnut market (Gold et al. 2006). Results indicated that the U.S. chestnut industry is in its infancy. The majority of chestnut producers have been in business less than 10 years and are just beginning to produce commercially. Volume of production is low (less than 1.5 million lb.). U.S. chestnut producers are mainly part-time or hobby farmers with small, manually harvested operations (Gold et al. 2006).

Additional information revealed through the national chestnut market survey (Gold et al. 2006) indicates that demand for quality chestnuts exceeds supply. Demand for fresh chestnuts is expected to continue increasing by 10% - 25% over the next 5 years. Producers who grow chestnuts from cultivars, grow organically, or sell under a brand name achieve the highest prices. Subsequent market surveys have consistently shown that demand exceeds supply.

Conclusion

Expanding access to well researched perennial specialty crops and expanding markets for their products can contribute to more widespread adoption of a range agroforestry practices and ultimately to the long-term economic and environmental sustainability of farming systems throughout the Midwest and beyond. UMCA research and development efforts have followed a strategic approach focusing on several key areas of development and testing of improved cultivars, developing viable markets and promotion and support with producers.

Numerous challenges for the development of emerging specialty crops have been identified and are being addressed. In the early stages, some priming is often required to promote interest, stimulate demand and catalyze the innovation that can fuel the growth of a specialty crop industry. Access to improved cultivars, solid production guidelines, reliable product supply, growing consumer demand, and sound financial decision support tools are supporting the growth of the specialty crop industry and having positive impacts up and down the supply chain. With adequate and reliable supply from growers, processors and entrepreneurs are more likely to invest and expand. In turn, existing growers and potential growers are more likely to expand production if there are active processors and clear consumer demand, a “market-pull” based strategy for increased production, supply and demand. Another important dimension of UMCA efforts includes bioactive phytochemical research to elucidate and test unique compounds found in plants, including the potential to patent and market value-added products for pharmaceutical, cosmetic, and industrial applications. This provides another avenue to create market opportunities and increase the economic attractiveness and adoption of agroforestry.

References

Cernusca MM, Gold MA, Godsey LD (2012) Using the Porter Model to Analyze the U.S. Elderberry Industry. Agrofor Syst 86: 365-377.

Coggeshall MV, Romero-Severson J (2013) Breeding black walnuts in the age of genomic. In: Van Sambeek JW, Jackson Elizabeth A, Coggeshall Mark V, Thomas Andrew L, Michler Charles H (eds) Managing fine hardwoods after a half century of research: Proceedings of the Seventh Walnut Council Research Symposium; 2011 August 1-3; Madison, WI. Gen. Tech. Rep. NRS-P-115. Newtown Square, PA; U.S. Department of Agriculture, Forest Service, Northern Research Station, pp 75-76.

Gold MA, Hunt KL (2002) Growing chestnut in Missouri. Northern Nut Growers Assoc. 93rd Annual Report 93:20-26.

Gold MA, Cernusca MM, Godsey LD (2006) Competitive Market Analysis: Chestnut Producers. HortTechnology 16: 360-369.

Hunt KL, Gold MA, Warmund MR (2004) Chinese chestnut cultivar performance in Missouri. Acta Horticulturae 693: 145-148.

Josiah SJ, Brott H, Brandle JR (2004) Producing woody floral products in an alleycropping system in Nebraska. HortTechnology 14: 203-207.

Molnar TJ, Kahn PC, Ford TM, Funk CJ, Funk CR (2013) Tree crops, a permanent agriculture: Concepts from the past for a sustainable future. Resources 2: 457-488.

Porter ME (1980) Competitive Strategy: Techniques for Analyzing Industries and Competitors. The Free Press, New York.

GRADIENTS IN ABUNDANCE AND DIVERSITY OF GROUND-DWELLING ARTHROPODS IN TEMPERATE SILVOARABLE FIELDS

Pardon P[1,2,3*], Reheul D[2], Mertens J[1,4], Reubens B[3], De Frenne P[1,2], De Smedt P[1], Proesmans W[1], Van Vooren L[1,3], Verheyen K[1]

(1) Department of Environment, Ghent University, 9090 Gontrode, Belgium (2) Department of Plants and Crops, Ghent University, 9000 Ghent, Belgium (3) Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), 9820 Merelbeke, Belgium (4) Department of Applied Biosciences, Ghent University, 9000 Ghent, Belgium

*Corresponding author: paul.pardon@ugent.be

Abstract

Ground-dwelling arthropods play an important role in agricultural systems by providing multiple ecosystem services (ES), such as affecting nutrient and carbon cycling and providing biological pest control. However, potential patterns in presence of these arthropods in temperate agroforestry systems (AFS) have only been investigated to a limited extent. Therefore we have assessed the abundance and diversity of woodlice (Isopoda), millipedes (Diplopoda), rove beetles (Coleoptera: Staphylinidae) and carabids (Coleoptera: Carabidae) in function of distance to the tree row in temperate arable AFS. Abundance and diversity of woodlice and millipedes was significantly increased in the tree rows and in the arable zone near mature trees. These results indicate that the tree component of temperate AFS contributes to the preservation of arthropod biodiversity and the enhancement of associated ES, both in the tree rows and in the arable field zone.

Keywords: woodlice, millipedes, poplar, maize, winter cereals

Introduction

Ground-dwelling arthropods play an important role in agricultural systems by providing multiple ecosystem services (ES). Detritivorous species, for instance, affect nutrient and carbon cycling, and predatory species biological pest control. The presence of semi-natural landscape features, such as the tree component of agroforestry systems (AFS), may contribute to increasing functional agrobiodiversity and optimizing the delivery of abovementioned ES in agricultural landscapes. Alley cropping is a particular type of AFS whereby trees are organized in rows over the field. As a result, it can efficiently be combined with the use of modern farming techniques and machinery for the cultivation of agricultural crops in the intercropping zone between the tree alleys. Hence, this cropping system may be especially suited to increase the presence of semi-natural landscape features while maintaining agricultural production (Quinkenstein et al. 2009; Tsonkova et al. 2012). However, potential patterns in abundance and diversity in temperate alley cropping systems have scarcely been investigated for detritivorous soil-dwelling arthropods and only to a limited extent for predatory arthropods. Therefore we here assess the abundance and diversity of woodlice (Isopoda), millipedes (Diplopoda), rove beetles (Coleoptera: Staphylinidae) and carabids (Coleoptera: Carabidae) as function of distance to the tree row in temperate arable fields.

Materials and methods

Two types of experimental fields were selected to investigate the abundance and diversity of beneficial arthropods on alley cropping fields of varying age (Figure 1). The resulting set comprised six young alley cropping fields. In addition, since older arable alley cropping systems in Flanders are scarce, a set of eight arable fields that are partly bordered by a tree row and partly by a treeless grassy edge (further referred to as "boundary planted fields") was selected as a proxy (Table 1). On the young alley cropping fields, two transects were laid out between and perpendicular to the tree rows. Seven sampling points were fixed on a transect: two were located within the tree alleys ("A"), and the others at distances 1 ("B") and 5 ("C") m away from the field edge near both tree rows and one in the center of the intercropping zone ("D", approximately at 12 m from the field edge) (Figure 1a). Two control points were marked at a distance varying between 18 to 55 m away from the tree rows ("E"). In each boundary planted field, two transects were installed perpendicular to the tree row and to the treeless border (Figure 1b). The treeless parts of these fields hereby act as a reference situation. Four sampling points were marked in each transect, located in the field border ("F") and at distances 1 ("G"), 5 ("H") and 30 ("I") m away from the field edge (Figure 1b). At each sampling point in both systems, a pitfall trap was installed during the last week of May 2015. The traps were in place during four weeks. For each individual trap the total number of woodlice, millipedes, carabid beetles and rove beetles caught was counted. The captured specimens of every taxon, except for rove beetles, were identified to species-level. This procedure was repeated in 2016 on a subset of the fields. Generalized mixed effects models with a Poisson error structure and Linear mixed effects models were used to investigate differences in abundance (expressed as "activity-density"), species richness and Shannon-Wiener diversity.

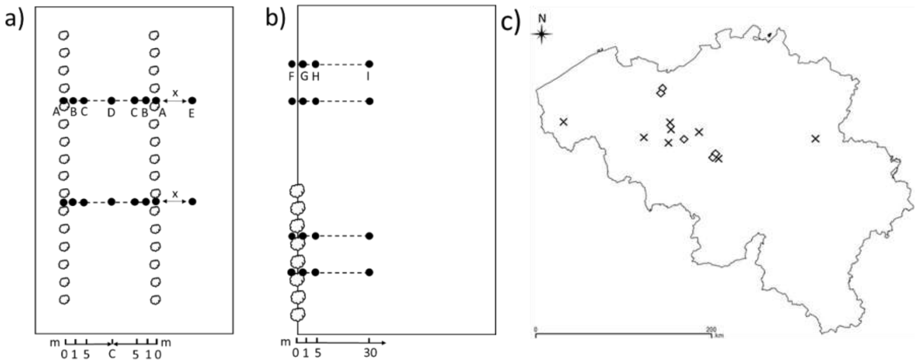


Figure 1: Experimental design. a) alley cropping fields, b) boundary planted fields. Black dots represent measuring positions. c) Location of experimental fields in Belgium (◊ alley cropping, x boundary planting).

Table 1: Characteristics of experimental fields. Year of plantation was estimated based on pers. comm. with farmer and/or tree coring. "Orientation": orientation of tree alleys (EW: East-West, NS: North-South). "Exposition": location of sampling field with regard to tree row. "NA": no samples collected in 2016.

ALLEY CROPPING

Location	Year of plantation	Orientation	Crop 2015	Crop 2016
Lochristi 1	2011	EW	Forage maize	Winter wheat
Lochristi 2	2011	EW	Forage maize	Forage maize
Lochristi 3	2012	EW	Winter wheat	Forage maize
Vollezele	2010	NS	Winter barley	NA
Haut-Ittre 1	2011	NS	Winter wheat	Winter wheat
Haut-Ittre 2	2011	NS	Grain maize	Winter wheat

BOUNDARY PLANTING

Location	Estimated year of plantation	Exposition	Crop 2015	Crop 2016
Sint Pieters Leeuw	2001	West	Grain maize	NA
Haut-Ittre	2000	West	Winter wheat	NA
Maarkedal	1998	East	Grain maize	Grain maize
Tongeren	1998	West	Winter wheat	NA
Ieper	1985	East	Grain maize	Grain maize
Geraardsbergen	1988	West	Winter barley	NA
Herzele	1977	West	Forage maize	NA
Steenhuize	1985	East	Forage maize	NA

Results

Activity-density, species richness and Shannon-Wiener diversity of woodlice and millipedes were significantly affected in both systems by distance to the tree rows/treeless field edges with decreasing values at further distances in the field (Figure 2, Table 2). In addition, for activity-density, species richness and Shannon-Wiener diversity of woodlice and for activity-density of millipedes, a significant effect of tree presence was found on the boundary planted fields with increased values in and nearby the tree rows when compared to the treeless field edges.

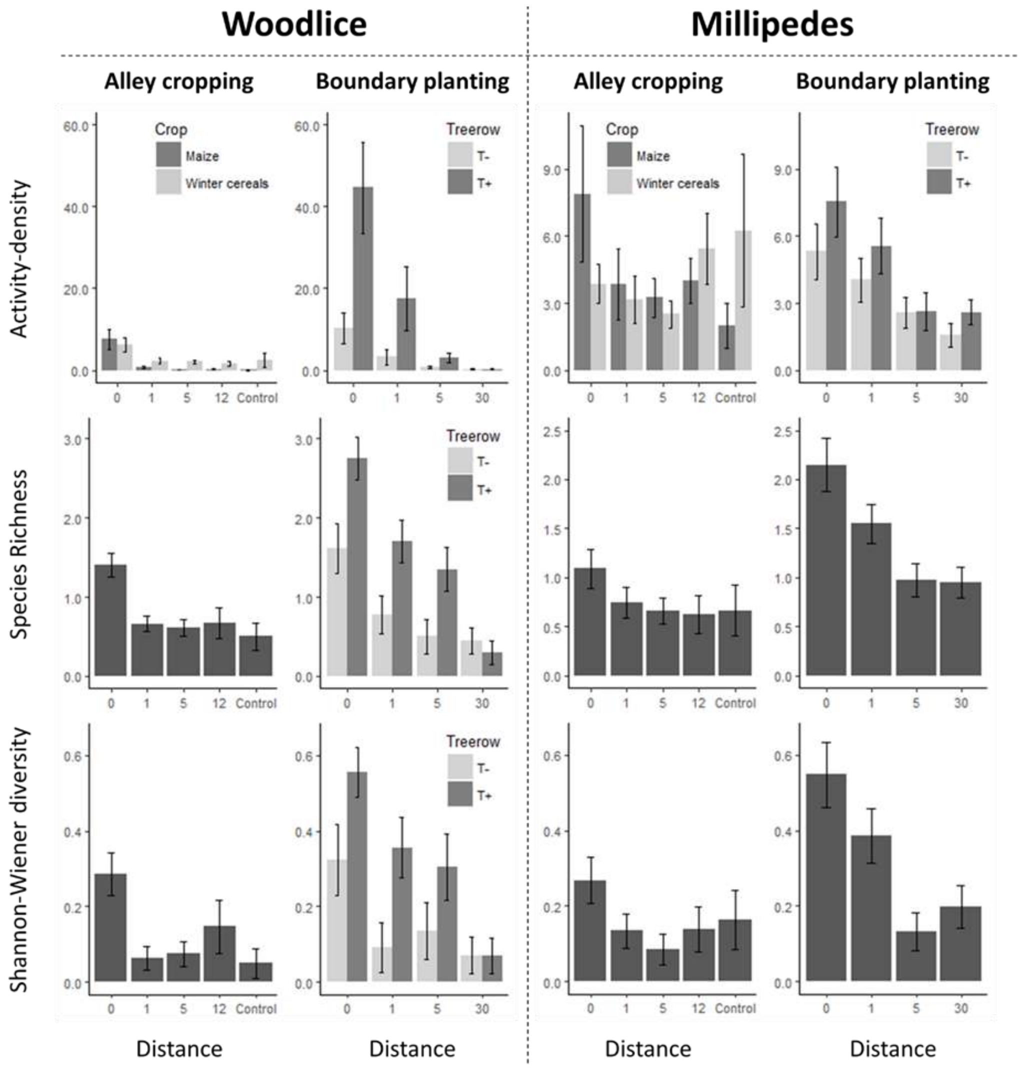


Figure 2: Activity-density, species richness and Shannon-Wiener diversity of woodlice and millipedes in alley cropping and boundary planted fields for each level of significant (interactions between) fixed effects. Barplots and errorbars indicate mean ± S.E.

Table 2: (Generalized) Linear Mixed Modelling results for detritivorous arthropods. Included fixed effects for the alley cropping fields are distance to the field edge ("Distance"), crop type ("Crop") and their two-way interaction. Included fixed effects for the boundary planted field are presence or absence of a tree row ("T+/T-"), distance to the field edge ("Distance"), crop type ("Crop") and their two-way interactions. "*AD*": Activity-density, "*SR*": Species richness, "H" Shannon-Wiener diversity. Bold characters indicate a significant effect (P-value<0.05). (*) indicates 0.05 < P-value < 0.10.

Main effect:		T+T-	Distance	Crop	Distance: T+T-	Distance: Crop	T+T-: Crop
BOUNDARY PLANTED							
Woodlice	AD	**0.0045**	**<0.0001**	0.5349	**<0.0001**	**<0.0001**	0.6556
	SR	**0.0004**	**<0.0001**	0.9077	0.1006	0.1328	0.1209
	H	**0.0017**	**<0.0001**	0.7191	0.1331	0.4350	0.1592
Millipedes	AD	0.0582*	**<0.0001**	0.6359	0.4185	0.3849	0.6254
	SR	0.1168	**<0.0001**	0.2716	0.9177	0.7458	0.7838
	H	0.3660	**<0.0001**	0.1030	0.9782	0.5259	0.6184
ALLEY CROPPING							
Woodlice	AD		**<0.0001**	**<0.0001**		**<0.0001**	
	SR		**0.0001**	0.1860		0.1174	
	H		**<0.0001**	0.7717		0.5887	
Millipedes	AD		**<0.0001**	0.2469		**0.0005**	
	SR		0.0626*	0.9878		0.9108	
	H		**0.0195**	0.2817		0.6620	

Discussion

The increased detritivore abundance and diversity in the tree rows are assumed to result from the favorable habitat and refuge conditions (e.g. increased shade, soil and air humidity, food sources and nesting habitat) created by the relatively diverse and permanent presence of vegetation and litter, the absence of regular (soil) disturbances and the reduced use of crop protection agents. Strongly contrasting conditions occur in the arable field zone where the intensive agricultural management may cause profound adverse effects on the survival and reproduction of soil communities (Paoletti and Hassall 1999; Smith et al. 2008; Souty-Grosset et al. 2005) resulting in the observed decreases in activity-density and diversity.

Based on our results, tree row presence can increase abundance and diversity of detritivores in the arable zone, probably through colonization starting from these semi-natural refuges and through the mitigation of abovementioned adverse field conditions. Farmers may potentially benefit from the enhanced delivery of ES in silvoarable fields (e.g. enhanced decomposition and nutrient cycling), linked to the abovementioned increase in detritivorous arthropod abundance and diversity. However, to optimize this potential for ES delivery, adapted management may be advisable, e.g. by retaining dead plant material in the tree rows (such as pruning material), limiting the use of pesticides and herbicides (both in the tree component and in the arable zone), and striving for a diverse herbaceous composition in the tree rows.

Conclusion

Furthers analysis will focus on predatory arthropods (carabids & rove beetles), whereby a similar approach is used to study gradients in abundance, species richness and Shannon-Wiener diversity.

Acknowledgments

This research is executed within the framework of the project Agroforestry in Flanders, funded by Flanders Innovation & Entrepreneurship (VLAIO).

References

Paoletti MG, Hassall M (1999) Woodlice (Isopoda: Oniscidea): Their potential for assessing sustainability and use as bioindicators. Agric Ecosyst Environ 74: 157–165.
Quinkenstein A, Wöllecke J, Böhm C, Grünewald H, Freese D, Schneider BU, Hüttl RF (2009) Ecological benefits of the alley cropping agroforestry system in sensitive regions of Europe. Environ. Sci Policy 12: 1112–1121.
Smith J, Potts SG, Woodcock BA, Eggleton P (2008) Can arable field margins be managed to enhance their biodiversity, conservation and functional value for soil macrofauna? J Appl Ecol 45: 269–278.
Souty-Grosset C, Badenhausser I, Reynolds JD, Morel A (2005) Investigations on the potential of woodlice as bioindicators of grassland habitat quality. Eur J Soil Biol 41: 109–116.
Tsonkova P, Böhm C, Quinkenstein A, Freese D (2012) Ecological benefits provided by alley cropping systems for production of woody biomass in the temperate region: A review. Agrofor Syst 85: 133–152.

A COST-EFFECTIVENESS ANALYSIS OF TEMPERATE SILVOARABLE SYSTEMS: WHAT CONTRIBUTION DO ECOSYSTEM SERVICES MAKE?

Staton T[1]*, Walters R[2], Smith J[3], Chesshire H[4], Girling R[1]

(1) School of Agriculture, Policy and Development, University of Reading, Reading, UK (2) School of Biological Sciences, University of Reading, Reading, UK (3) Organic Research Centre, Elm Farm, Newbury, UK (4) Woodland Trust, Grantham, UK

*Corresponding author: T.Staton@pgr.reading.ac.uk

Abstract

Silvoarable systems generally support higher biodiversity, but there is limited understanding as to the value of associated ecosystem services such as pest regulation and pollination. This paper reports on preliminary results of a cost effectiveness analysis of apple silvoarable systems, as part of a PhD investigating the influence of silvoarable management on biodiversity-derived ecosystem services. Our results suggest that profitability of an apple alley-cropping system should exceed that of an equivalent arable system six to seven years post-establishment for a typical conventional farm in the UK. This result is strongly influenced by farm productivity and stochastic variability in apple yields, although the latter is partly compensated by price. Biodiversity-derived ecosystem services could improve profitability, for example by reducing inputs and improving yields. However, this analysis is constrained by a scarcity of empirical data. Therefore, we aim to collect data on pest regulation and pollination from a network of silvoarable sites.

Keywords: apple; arable; alley cropping; biodiversity; sensitivity analysis; profitability

Introduction

Silvoarable systems have the potential to be an effective and productive form of sustainable agriculture, in part due to the enhancement of biodiversity and associated ecosystem services. However, currently there is limited understanding of how higher biodiversity in silvoarable systems promotes ecosystem services, such as pest regulation, pollination and nutrient cycling (for example, see Peng et al. 1993; Thevathasan and Gordon 2004; Varah et al. 2013), versus ecosystem disservices, such as encouraging certain pests and weeds (Griffiths et al. 1998; Burgess et al. 2003), and, furthermore, how this cost-benefit ratio might change with how the system is designed, managed and matures over time (but see Burgess et al 2003; Stamps et al. 2009).

This paper reports on preliminary results of a cost effectiveness analysis based on the Farm-SAFE model (Graves et al. 2011; 2016), as part of a PhD investigating how management of silvoarable influences biodiversity-derived ecosystem services, and their economic implications. Our study is focussed on silvoarable systems in the UK that combine top-fruit production with arable alley-cropping, which are emerging as a promising design with limited shade effects (Smith et al. 2016). We compare our findings to a monocropped arable system, with and without purported associated biodiversity benefits (Varah et al. 2013, 2015).

Materials and methods

The profitability and financial resilience of silvoarable systems, and the potential contribution of ecosystem services, will be evaluated by a cost effectiveness analysis conducted on the Farm-SAFE model. First, we are comparing the profitability of a silvoarable versus a monocrop arable system, conducting a sensitivity analysis to establish the robustness of our findings in relation to price fluctuations, yield fluctuations, crop rotations, organic vs. conventional management, system design and other farm-specific factors. Our initial findings presented here are based on a conventional winter wheat / winter wheat / oilseed rape rotation, using 24 m wide crop alleys separated by 3 m wide apple tree rows. These figures will be used as the basis to establish the potential contribution of biodiversity derived ecosystem (dis)services based on forthcoming field surveys and assumptions around improved crop yield/quality and reduced input requirements. This analysis will ultimately serve as the basis for exploring the financial resilience of silvoarable to future economic risk scenarios, such as pesticide resistance, pesticide bans and honey bee declines.

Results and discussion

Silvoarable requires an initial investment in terms of tree establishment costs. Additionally, there is an annual loss of income associated with taking land out of arable production. However, fruit production can deliver higher profits in the long-term. The time taken for establishment costs to be recuperated and for profitability to exceed an equivalent arable system are therefore key factors in encouraging uptake of silvoarable. Based on typical yields and prices for a conventional wheat-based rotation, we predict that silvoarable profitability would exceed an equivalent monocrop arable at six to seven years after establishment. However, this result is sensitive to variation in prices and yields due to site characteristics, weather and stochasticity.

Apple yields fluctuate due to weather conditions and therefore vary to a far greater extent than wheat yields. For example, over the period 1985 to 2016, wheat yield in the UK varied between 6.0 and 9.0 t/ha (+50%) compared to apple yields of 10.9 and 29.1 t/ha (+167%). This could add some element of risk to top-fruit silvoarable systems. Using historic trends to predict upper and lower apple yields based on 95% prediction intervals, the time taken for modelled silvoarable profitability to exceed arable is predicted to range between five and ten years depending on yield (Figure 1a). However, very low yields are historically compensated by higher prices (Figure 2), which could improve the financial resilience of silvoarable to low apple yields. Therefore, we are investigating simulations using random samples from a distribution based on the interaction.

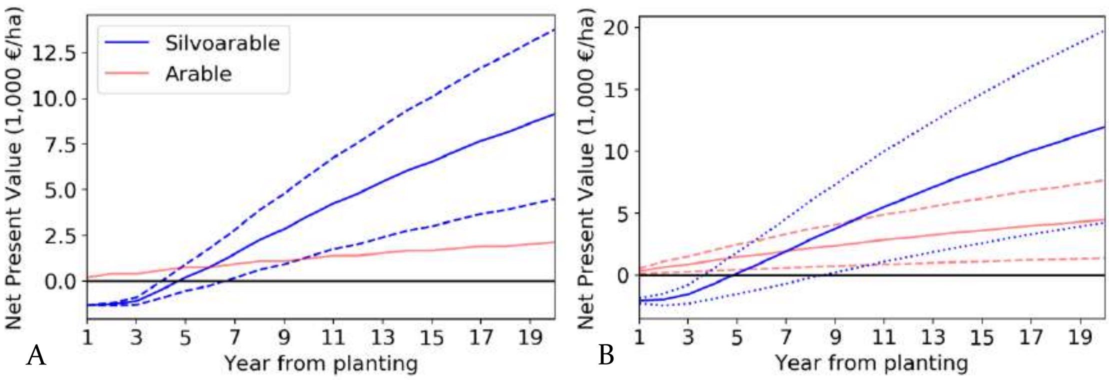


Figure 1: Influence of apple yield variation on silvoarable profitability, based on (a) historic national yield variations, where solid line represents the predicted 2015 yield using a linear model derived from historic yields, and dotted lines represent yields based on the 95% prediction intervals, and (b) high and low productivity farms (dashed lines) versus an ‘average’ level of production (solid lines), using yield values in the John Nix pocketbook (Redman 2017).

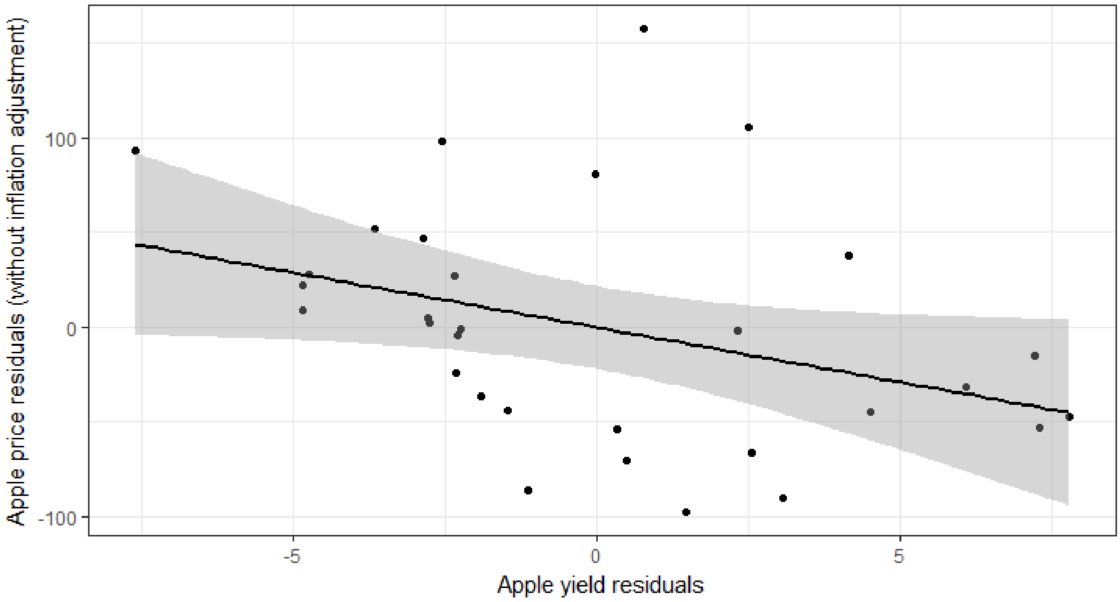


Figure 2: Relationship between apple yield and price residuals (p=0.0524), based on linear models of their respective historic UK trends with time using FAOSTAT data.

Farm characteristics such as soil productivity and location can also strongly influence yields of both the arable and top-fruit components. A simulation using low, average and high yields for both apple and arable components as specified in the John Nix Pocketbook (Redman 2017), which reflect variation in productivity due to farm-specific factors, shows that the profitability of silvoarable relative to an equivalent monocropped arable is strongly influenced by the achievable yield (Figure 1b). For farms with high production levels, silvoarable profitability is predicted to exceed arable at six years, but this increases to 11 years for low productivity situations. Enhanced ecosystem services in silvoarable could help to increase production levels and profitability, for example by reducing pollination deficits.

Ecosystem services derived from biodiversity could also contribute to silvoarable profitability and financial resilience by reducing pesticide input requirements. Although empirical data is lacking as to whether enhanced conservation biological control (CBC) could allow inputs to be reduced in temperate silvoarable systems without incurring a net cost, enhanced CBC arising from hedgerow restoration in California was predicted to reduce insecticide input requirements by 75% (Morandin et al. 2016). If pesticide costs were reduced by 75% in silvoarable, the time taken for profitability to exceed arable is reduced by one year, and net present value at 20 years increases by 22% compared to typical pesticide use (Figure 3). More empirical data is required to inform our understanding as to the contribution of ecosystem services to silvoarable profitability and resilience.

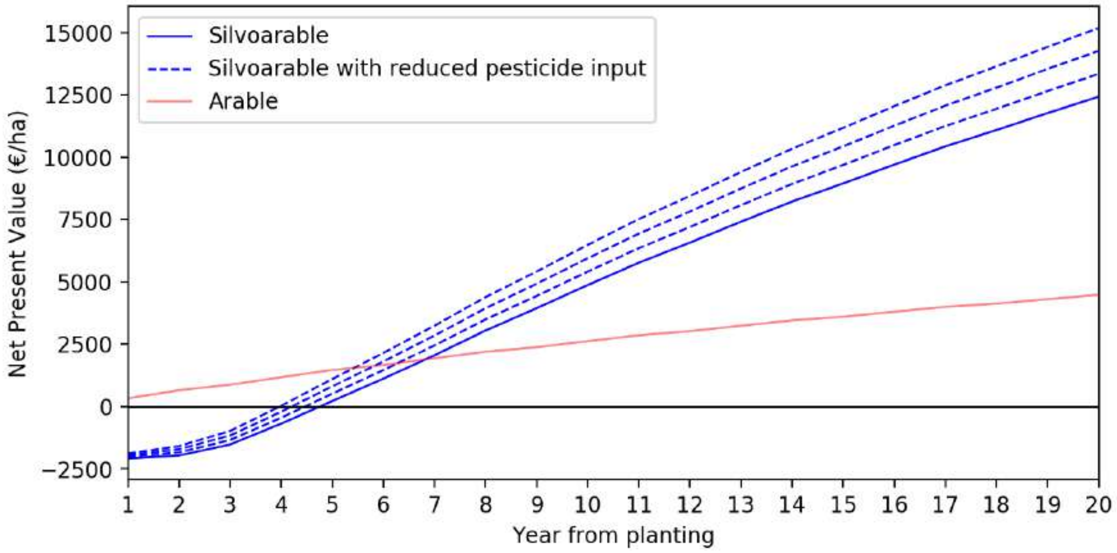


Figure 3: Effect of reducing pesticide costs by 25%, 50% and 75% in silvoarable.

Conclusions and future research

Silvoarable systems based on top-fruit production have potential to provide a relatively rapid return on investment, albeit this is strongly influenced by variables such as apple yield and farm productivity. Ecosystem services derived from biodiversity could improve profitability, for example conservation biological control could reduce input requirements in conventional systems and improve yields in organic systems, whilst pollination services could enhance apple yield and quality. Financial resilience against future risks such as pesticide regulations, resistance and pollinator declines could also be enhanced. However, the quantification of any such benefits is constrained by a paucity of empirical data.

Therefore, the next steps of the project are to carry out biodiversity field surveys at three silvoarable sites in the UK over a three-year period from 2018, to establish the link between biodiversity and ecosystem services and how these are influenced by system design and management. Specifically, we will investigate the associations between natural enemies and pests, and pollinators and pollination, in relation to tree alley width and tree row understorey management, from naturally colonised vegetation to the active maintenance of bare ground, seeding of wildflower mixes and horticultural production.

We plan to incorporate the empirical data collected over the course of the project to inform the financial modelling, with the objective of predicting the value of ecosystem services derived from biodiversity in silvoarable systems, and the influence of management options. This will help to inform policy makers and farmers as to the most effective system designs and the potential financial risks and rewards of silvoarable systems as an alternative to monocropped arable.

References

Burgess PJ, Incoll LD, Hart BJ, Beaton A, Piper RW, Seymour I, Reynolds FH, Wright C, Pilbeam DJ, Graves AR (2003) The impact of silvoarable agroforestry with poplar on farm profitability and biological diversity. Defra Report.

Graves AR, Burgess PJ, Liagre F, Terreaux J-P, Borrel T, Dupraz C, Palma J, Herzog F (2011) Farm-SAFE: the process of developing a plot- and farm-scale model of arable, forestry and silvoarable economics. Agrofor Syst 81: 93-108.

Graves A, Palma J, de Jalon SG, Crous-Duran J, Liagre F, Burgess P (2016) Farm-SAFE: financial and resource-use model for simulating agroforestry in Europe. AGFORWARD. https://www.agforward.eu (accessed 30/04/2018).

Griffiths J, Phillips DS, Compton SG, Wright C, Incoll LD (1998) Responses of slug numbers and slug damage to crops in a silvoarable agroforestry landscape. J Appl Ecol 35: 252-260.

Morandin LA, Long RF, Kremen C (2016) Pest control and pollination cost-benefit analysis of hedgerow restoration in a simplified agricultural landscape. J Econ Entomol 109: 1020-1027.

Peng RK, Incoll LD, Sutton SL, Wright C, Chadwick A (1993) Diversity of airborne arthropods in a silvoarable agroforestry system. J Appl Ecol 30: 551-62.
Redman G (2017) John Nix Pocketbook for Farm Management. 48th edition. Agro Business Consultants Ltd.
Smith J, Wolfe M, Crossland M (2016) Silvoarable agroforestry: an alternative approach to apple production? 12th European International Farming Systems Association Symposium.
Stamps WT, McGraw RL, Godsey L, Woods TL (2009) The ecology and economics of insect pest management in nut tree alley cropping systems in the Midwestern United States. Agr Ecosyst Environ 131: 4-8.
Thevathasan NV, Gordon AM (2004) Ecology of tree intercropping systems in the north temperate region: experiences from Southern Ontario, Canada. Agrofor Syst 61: 257-68.
Varah A, Jones H, Smith J, Potts SG (2013) Enhanced biodiversity and pollination in UK agroforestry systems. J Sci Food Agr 93: 2073-75.
Varah A (2015) Can agroforestry reconcile conflicting demands for productivity, biodiversity conservation and delivery of ecosystem services? PhD thesis, University of Reading, UK.

EXPLORING THE NUTRITIONAL VALUE OF FEEDSTUFFS IN TWO FOOD-FOREST CASE STUDIES IN THE NETHERLANDS

Hanegraaf MC[1*], Van der Horst N[2], Oosterhof G[3]

(1) Animal Husbandry, Van Hall Larenstein (VHL) University of Applied Sciences, Velp, The Netherlands (2) Student Animal Husbandry at VHL, Velp, The Netherlands (3) Delta Area and Resources, VHL, Velp, The Netherlands

[*]Corresponding author: marjoleine.hanegraaf@hvhl.nl

Abstract

Food-forest systems are generally thought to be able to make better use of available nutrients, maintain or even increase soil organic carbon balance while preserving a valuable landscape. In the Netherlands, the contribution of livestock and/or farm animals to such systems is poorly understood. For two food-forest farms with pigs and poultry, respectively, the nutritional value of feedstuff was assessed using the Weende and Kjeldahl-analyses, and the number of bacterial colonies was assessed using agar plates. Comparison was made to grass. N-contents in the feedstuffs of the food-forest systems were low in comparison to intensively managed grassland, which had a N-content of 2.8%, but comparable to that of extensively managed grassland. Total number of colonies did not differ significantly between the plates. It was concluded that the addition of manure may have influenced both the nitrogen content of the aboveground feedstock as well as belowground carbon and nitrogen mineralisation process.

Keywords: food-forest; livestock; poultry; nutritional value; sequestration

Introduction

Food-forest systems are generally thought to be able to make better use of available nutrients, maintain or even increase soil organic carbon balance while preserving a valuable landscape (Shepard 2013). However, not much is known about the perspectives for food-forests with livestock or animals in temperate regions. In the Netherlands, food-forest systems are gaining attention as examples of nature-inclusive agriculture and/or circular economy. At present, a network of pioneering enterprises exist, with mixed farming systems based on woodland, shrubs, and in certain cases also livestock.

Within this network, two farms pioneer with food-forest systems and pigs and poultry, respectively. At the first farm, Tamworth pigs are raised in a woodland with oak trees with grass underneath. This pig species is well-suited for forest grazing and the meat is well known for its superior taste. At times additional feed is given to the pigs, e.g. apple pulp. This farm has recently acquired a plot with nettle - thistle bush, and aims to convert this plot into a grazed food-forest. Major research question at this farm concerns the nutritional values of the vegetation. The second farm includes several small agroforestry plots, e.g. elderberry - grass confinements, with and without the presence of chickens. Both farms are situated on sandy soils in the north and south of the Netherlands respectively. An exploration was made of the nutritional quality of feedstuffs at these food-forest farms. Our main objective was to assess differences between feedstuffs from food-forest systems without and without livestock/animals. Our hypothesis was that, as the presence of pigs and poultry would lead to addition of manure in the food-forest system, the corresponding feedstuff would be of higher nutritional quality. In addition to the main objective, the possible impact of pig and poultry manure on soil bacterial communities was explored.

Materials and methods

Samples were taken in plots of three food-forest systems: oak - grass - pig, elderberry – grass - poultry, and nettle - thistle, in autumn 2017. For each system, samples were taken from vegetation and soil. Mixed samples from vegetation (e.g. leaves, twigs, acorns, and grass). These samples were analysed for nutritional value (Weende analysis) and nitrogen contents (Kjeldahl). For comparison, a grass sample from intensively managed grassland from elsewhere was also included. In each plot, mixed soil samples were taken in two layers (0 - 20 and 20 - 40 cm). For comparison, a soil sample (0 - 20 cm.) was also taken in extensive grassland at the same farm as the elderberry - grass food forest system. In the soil samples, bacterial numbers and diversity were assessed using various dilutions of soil in water, on plates with standard nutrient agar. This part of the analysis was done in duplo.

Results

The crude protein content in the vegetation ranged from 1.71 to 6.71 for the oak – grass - pig and elderberry – grass - poultry systems, respectively (Table 1). Values for the nettles - thistle system and the grass sample (extensively managed) were in between these extremes. The crude fat content of the nettle - thistle system was with only 0.10% about 15 times lower than that in the feedstuffs from the other three systems. However, the nettle - thistle system contained the highest amount of crude fiber (1.63%).

N-contents in the feedstuffs of all four systems were low in comparison to the reference material of the intensively managed grassland, which had a N-content of 2.8% but comparable to that of the extensively managed grassland. Surprisingly, the highest organic matter content in the vegetation was not found in the oak – grass – pig system, but in extensively managed grass (15.1%) (no data available for the elderberry – grass – poultry system). Assuming C% in all plant material is 45%, the C/N-ratio declined following the oak – grass – pig system, extensively managed grass, and nettle - thistle system (18, 11, and 5, respectively).

Table 1: Nutritional value of the feedstuffs in the food forests

Food-Forest System	Crude Protein	Crude Fat	Crude Fiber	Nitrogen	Organic Matter
	%				
Oak - Grass - Pig	1.71	1.45	0.33	0.27	11.1
Elderberry - Grass - Poultry	6.71	1.91	1.56	1.07	n.a.
Nettles - Thistles	3.15	0.10	1.63	0.50	5.3
Grassland (int.)				2.18	
Grassland (ext.)	3.72	1.83	0.95	0.60	15.1

n.a. = not available

Initially, all agar plates were overgrown with bacterial colonies until dilutions of 10^{-4} were used. Total number of colonies did not differ significantly between the plates. Only a few different soil bacterial colonies were found. In the topsoils, soil bacterial diversity was higher for the extensively managed grass and elderberry - no chicken plots then in the other plots (Figure 1). For the subsoil, the nettle - thistle plot showed higher bacterial diversity than the other plots.

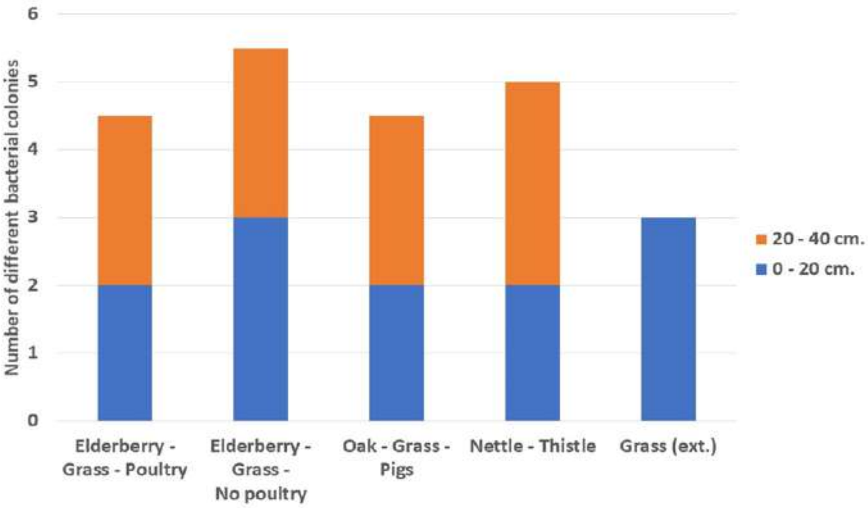


Figure 1: Differences in soil bacterial diversity in the food-forest plots.

Discussion

The oak - grass food forest with pigs provides the pigs with about half the crude protein and one-third crude fibre of what they would get in extensively managed grassland. The difference between the feedstuffs is for crude fat less prominent. The relatively low nutritional value of the oak - grass indicates a need for additional feeding. Dietary fibre is considered important for feed efficiency (Teagasc 2015) for which apple pulp may be a good source. Additional feedstuffs rich in protein may be useful for piglets and/or pregnant sows. In order to assess adequate pig diets, information needs to be collected on the relative proportion of the available sources of organic matter, as well as the daily intake by pigs.

Comparing the food-forest systems oak - grass and elderberry - grass with the extensively managed grassland at the same site, the elderberry - grass system showed the highest protein content. This suggests that the soil in the elderberry - grass system contained more nitrogen than the oak - grass system and the extensively managed grass plot. The presence of poultry manure in the elderberry - grass system could be a possible explanation for this. Considering the feedstuffs of the food-forest systems included, the elderberry - grass feedstuff appears to be of the best quality in terms of crude protein, fat and fibre. However, elderberry contains cyanogenic glycosides in bark, leaves, berries, roots and stems, from which hydrogen cyanide is released. This substance may be toxic to animals or at least affect palatability (Cope, Overview of cyanide poisoning).

The sequestration-mineralisation processes of plant material in soil are in part determined by the difference in C/N-ratio between the plant material and the soil. Materials with higher C/N-ratio than the soil may lead to immobilisation of nitrogen. If we assume a C/N-ratio of 10 in both our soils, decomposition of oak - grass material would require extra nitrogen. Pig manure could be a useful source in this respect, eventually sequestering more carbon in the soil. However, decomposition rates of oak depend on oak species (Jurkšienė et al 2017). Residues from elderberry - grass with its high N-content is expected to release nitrogen in soil. Also in the nettle - thistle bush nitrogen may become available from mineralisation if this bush would be added to the soil. Both nettle and elderberry are known for their high decomposition rate (Atkinson and Atkinson 2002). Conversion of the nettle - thistle bush into a food forest could be accompanied by adding low-N organic material to conserve the nitrogen in the topsoil. In order to assess the carbon sequestration potential of the oak - grass and elderberry - grass food forest, requires modelling of soil organic carbon using detailed information on the quality of the various inputs and their decomposition rates. The ability of an agro-ecological system to provide ecosystem services is regarded as a sign of ecological intensification (Tittonell 2014). However, in the case of carbon sequestration in a food-forest system, this service may be restricted by the natural ecological boundaries prevalent in such soils.

A major ecological feature of soils is the microbial composition, which in forest soils is characterised by a higher fungal / bacteria ratio as compared to agricultural soils (Anderson and Domsch 1975). Knowledge of possible changes in this ratio would help in explaining soil carbon decomposition. The introduction of agricultural activities into pre-existing forest soil may change the ratio in favour of bacteria and possibly increased mineralisation. However, as large numbers of bacterial colonies were found for all soils, no indication for a possible change in bacterial numbers could be established. We did find, however, a lower bacterial diversity in the plots with either pigs or poultry in the food-forest system as compared to plots without animals. This is opposite expectations, as manure application generally increases abundancy (Altieri 1999). Repetition of our research would be needed to ascertain possible changes in bacterial populations in the food-forests concerned.

Conclusion

This research suggests that the nutritional value of the feedstuffs in food-forests may vary considerably and may be smaller as well as greater than that of extensively managed grass, depending on forest species and/or manure added by livestock and/or farm animals. Pigs feeding on a mixture of oak and grass may need additional feedstuff, rich in crude protein and/or crude fibre. Possible toxicity for livestock and/or poultry of forest species such as elderberry may need further attention. The data suggest that the addition of manure may have influenced both the nitrogen content of the aboveground feedstock as well as belowground carbon and nitrogen mineralisation process.

References

Altieri MA (1999) The ecological role of biodiversity in agroecosystems. Agr Ecosyst Environ 74: 19-31.

Anderson JPE, Domsch JH (1975) Measurement of bacterial and fungal contributions to respiration of selected agricultural and forest soils. Can J Microbiol 21: 314-322.

Atkinson MD, Atkinson E (2002) Biological flora of the British isles. Sambucus nigra L. J Eco 90: 895-923.

Cope RB Overview of cyanide poisoning. http://www.msdvetmanual.com/toxicology/cyanide-poisoning/overview-of-cyanide-poisoning (accessed 2/03/2018).

Jurkšienė G, Janušauskaitė D, Armolaitis A & V Baliuckas (2017) Leaf litterfall decomposition of pedunculate (*Quercus robur* L.) and sessile (*Q. petraea* [Matt.] Liebl.) oaks and their hybrids and its impact on soil microbiota. Dendrobiology 78: 51-62.

Shepard M (2013) Restoration agriculture. Real-world permaculture for farmers. Acres, Austin, USA.

Teagasc Pig Development Department (2015) Pig herd performance report. Teagasc, Oak Park, Carlow, Ireland.

Tittonell P (2014) Ecological intensification of agriculture – sustainable by nature. Curr opin Env Sust 8: 53-61.

FAST GROWING TREE SPECIES IN AGROFORESTRY SYSTEMS: SOIL, TREE GROWTH AND UNDERSTORY BIODIVERSITY

Rodríguez-Rigueiro FJ[1], Ferreiro-Domínguez N[1, 2], Rigueiro-Rodríguez A[1], Mosquera-Losada MR[1*]

(1) Department of Crop Production and Engineering Projects, Escuela Politécnica Superior de Lugo, University of Santiago de Compostela, Campus Universitario s/n, 27002 Lugo, Spain (2) Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda s/n, 1349-017 Lisbon, Portugal

*Corresponding author: mrosa.mosquera.losada@usc.es

Abstract

In Galicia (NW Spain) the productivity of the silvopastoral systems can be limited by the high soil acidity, which decreases the availability of nutrients to the pasture and trees. Liming and fertilisation with sewage sludge could improve the soil fertility, favouring the tree growth and the establishment of sowing pasture species in the understory. The aim of this study was to evaluate the effect of liming and fertilisation with three doses of sludge (160, 320 and 480 kg total N ha^{-1}) compared with two control treatments (mineral and no fertilisation) on soil pH (H_2O), tree growth and botanical composition of the understory in a silvopastoral system under *Pinus radiata* D. Don, fifteen years after the establishment of the experiment in Galicia and twelve years after the last organic fertilisation. Results showed that the tree extractions increased soil acidity mainly due to the high tree density. Therefore, tree clearing is advisable in order to allow the light entrance to the soil, which favours soil organic matter mineralization. Understory biodiversity would also benefit from a minor tree density by improving pasture establishment and microorganism activity.

Keywords: silvopastoral system; liming; fertilisation; soil pH; shadow; understory

Introduction

Galicia (NW Spain) has traditionally presented very acid soils due to its high productivity (extraction) and the high rainfall favouring cations leaching. *Pinus radiata* D. Don is widely used as tree species in the establishment of silvopastoral systems in many areas such as Galicia where it was one of the main species used in afforestation and reforestation made during the 1990s and 2000s. Fast-growing conifers cause an acidifying effect of the soil during their development, since the extraction of nutrients made by this species is usually greater than the hardwoods, with the exception of eucalyptus (Fernández-Núñez 2008). Silvopastoral systems production is usually conditioned by low fertility and high soil acidity limiting nutrient availability to the pasture and trees. Thus, it is advisable to conduct soil management activities such as fertilisation and liming in order to increase fertility and enhance soil pH. Sewage sludge (SS) has been lately adopted in many areas as organic fertiliser due to its organic matter and macronutrient content besides the increase in its production related to the compulsory construction of wastewater treatment plants in areas with low population density established in the Council Directive 91/271/EEC (EU 1991). The biodiversity of the understory can be modified by silvicultural practices as herbaceous cover can be created artificially and maintained by periodic clearing and appropriate fertilisation of the soil (Mosquera-Losada et al. 2005). Soil and aboveground carbon sequestration is an important silvopastoral systems benefit, in addition, a larger carbon content is referable to fast-growing conifer forests such as *Pinus radiata* D. Don. The aim of this study was to evaluate the evolution of soil pH, tree growth and botanical composition of the understory trough the studied period in a silvopastoral system established with *Pinus radiata* D. Don in managed (organic fertilisation and liming) soils.

Materials and methods

The study was located in Pol (Lugo, Galicia, NW Spain) at an altitude of 450 m asl in a plantation of *Pinus radiata* D. Don established in 1993 (1667 trees ha^{-1}). Climate study reflected that vegetation development would be limited by cold during the months of December, January and February (T<7.5 ºC) and by a slight period of drought in the months of June, July and August. In autumn 1997, a randomised block designed experiment was carried out managing 27 experimental plots (9 treatments x 3 replicates). Plots were sown with a *Lolium perenne* L., *Dactylis glomerata* L. and *Trifolium repens* L. pasture mixing after ploughing, mirroring the traditional pastures in the region. At first, all plots were fertilised with 120 kg P_2O_5 ha^{-1} and 200 kg K_2O ha^{-1}. The nine treatments were no fertilisation (NF) and three SS doses (160, 320 and 480 kg total N ha^{-1}) with or without liming applied in 1997 before sowing (2.5 t $CaCO_3$ ha^{-1}). A control mineral treatment (MIN) in the unlimed plots was included (500 kg of 8% N – 24% P_2O_5 – 16% K_2O ha^{-1} from 1998 to 2003). SS was applied in 1998, 1999 and 2000. During the period 1998-2012 soil samples were collected each year in each parcel in December at a soil depth of 25 cm. Soil samples were taken from four points chosen at random within each plot, crossing it in zigzag. The soil pH determination was carried out in water with a 1:2.5 ratio between weight of soil and volume of reagent and a reaction time of 10 minutes. At the beginning and end of 1998, 1999 and 2000, the diameter at the base of the nine central trees of each plot was measured, while at the end of the years 2004, 2006, 2007, 2009, 2011 and 2012 it was the normal diameter (1.30 m height). In all the years in which diameter were measured, the total height of the plots central trees was also measured in order to estimate dominant height. The botanic composition of the pasture was estimated by taking four samples of pasture per plot at random (0.3 × 0.3 m^2) during the spring and winter from 1998 to 2012. In the laboratory, pasture samples were separated into the different species by hand. The data were analysed using ANOVA (proc glm procedure) and means separated by using LSD test, if ANOVA was significant (SAS 2001).

Results

Soil pH in H_2O and tree growth

Soil pH in H_2O was significantly reduced from 1998, when SS and lime treatments were applied, to 4.4 in 2012. Tree height grew steadily from 4 to 19 m. It was observed how soil pH decrease meanwhile tree height increased (Figure 1.).

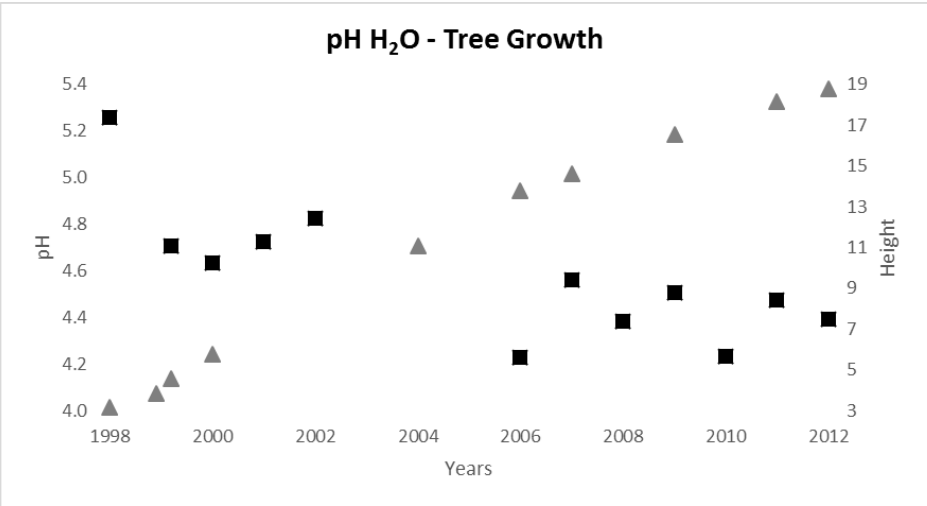


Figure 1: Soil pH in H_2O (■) and tree height growth (▲) evolution during the studied period (1998-2012).

Understory botanical composition

As can be seen in Figure 2, the botanical composition of the understory varied significantly throughout the study period. Needles were the main component of the understory after ten years of the plantation since sown species were disappearing from it. The proportion of needles in the understory was increased as tree height growth raised and replaced year by year *Lolium perenne* L. specially, but also by other herbaceous species and shrubs. *Dactylis glomerata* L. was the better established of the sown species being highly represented in the first half of the study and present in the understory almost until the end of it. A severe reduction in *Dactylis glomerata* L. proportion in the understory was observed from 2003 and again from 2006 matching tree height increase and the consequent needles fall down. *Lolium perenne* L. was well established in the understory during the first couple of years after the sowing but descending in the following years until finally disappearing in 2002. *Trifolium repens* L. was barely established in the first two years and disappeared as early as in 2000.

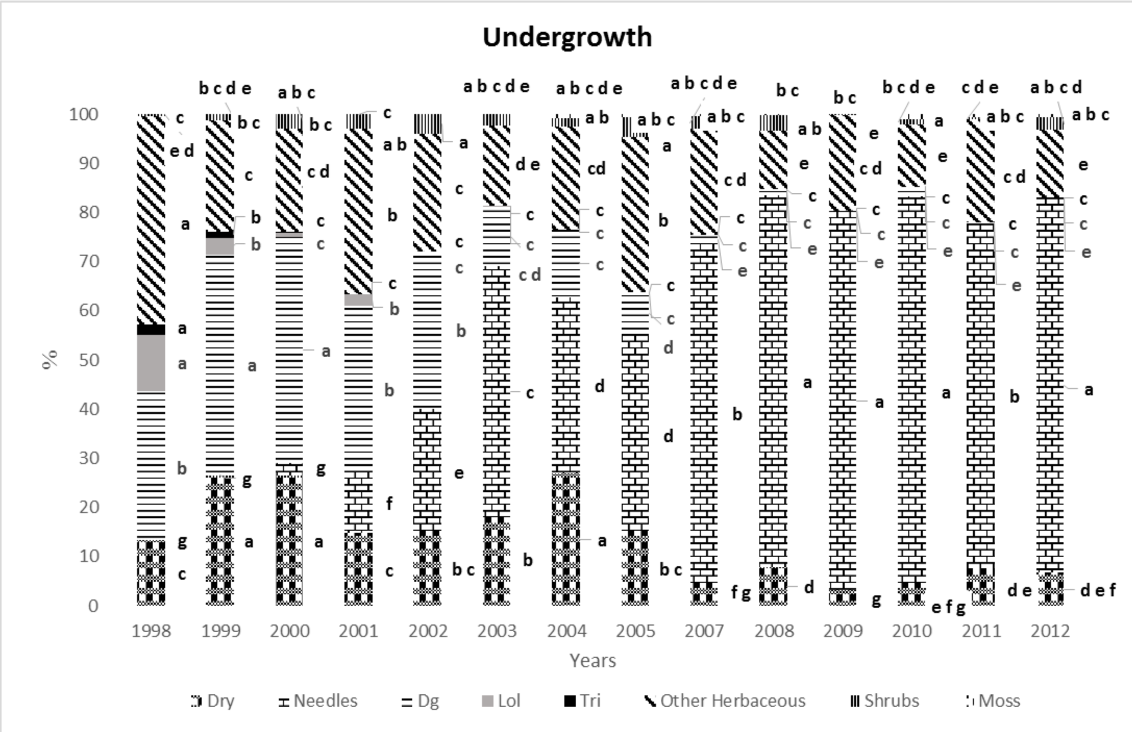


Figure 2: Understory botanical composition throughout the study period (1998-2012), Dg: *Dactylis glomerata* L.; Lol: *Lolium perenne* L.; Tri: *Trifolium repens* L.; Other herbaceous; Shrubs; Dry: senescent material. Different letters indicate significant differences between the years.

Discussion

At the beginning of the experiment the soil pH in H_2O was found on its higher values due to the treatments applied which enhance soil pH and edaphic fertility (Mosquera-Losada et al. 2009a). These results might be explained because of the increase in the mineralisation rate of soil organic matter, the consequent release of nutrients and the ECEC (effective cation exchange capacity) improvement promoted by soil management and treatments applied (Ferreiro-Domínguez et al. 2014). Figure 1 revealed that the pH in H_2O descended through the years meanwhile tree height raised proportionally. It was probably due to the extraction of nutrients and the trees deposition of acidifying material such as needles. On one hand calcium is one of the main components of vegetation that is incorporated in the tree by an intense soil extraction. On the other hand, as seen in Figure 2, the soil deposition of needles became more intense the more the tree grows almost certainly reflecting the limitation of light input to the lower parts of the tree (Mosquera-Losada et al. 2009b; Sibbald et al. 1996). Thus, a reduction in tree density would favour the entrance of light to the understory and consequently an increase in soil temperature promoting the SOM mineralization (Ferreiro-Domínguez 2011) and strengthening an improvement in the understory biodiversity.

Regarding botanical composition of the understory, sown species (especially *Dactylis* glomerata L.) were correctly established the first year of the study. *Lolium perenne* L. almost disappeared four years after being sown while *Trifolium repens* L. just remain as part of the undergrowth a couple years as a consequence of their higher requirements in comparison with *Dactylis glomerata* L. (Grime et al. 2007) concerning soil acidity and shadow conditions caused by the woodland canopy cover besides needles accumulation.

Conclusion

As tree extractions increase soil acidity exacerbated by high tree density and canopy cover that promotes shadow conditions and needles deposition, a reduction trough tree clearing is advisable in order to allow the light entrance to soil, which boost SOM mineralization. Understory biodiversity would also benefit from a minor tree density by improving pasture establishment and microorganism activity.

Acknowledgements

We are grateful to XUNTA DE GALICIA (Consolidation funds and Consellería de Cultura, Educación e Ordenación Universitaria ("Programa de axudas á etapa posdoutoral DOG nº122, 29/06/2016 p.27443, exp: ED481B 2016/0710")).

References

EU (1991) Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A31991L0271 (accessed 13/05/2018).

Fernández-Núñez E (2008) Sistemas silvopastorales establecidos con Pinus radiata D. Don y Betula alba L. en Galicia, productividad, biodiversidad y sumideros de carbono. Servizo de Publicacións e Intercambio Científico. Universidade de Santiago de Compostela, Spain.

Ferreiro-Domínguez N (2011) Efectos sobre la producción y el medio ambiente de la fertilización con lodos de depuradora urbana en sistemas silvopastorales establecidos con Fraxinus excelsior L., Pinus radiata D. Don y Quercus rubra L. Universidade de Santiago de Compostela, Spain.

Ferreiro-Domínguez N, Rigueiro-Rodríguez A, Bianchetto E, Mosquera-Losada MR (2014) Effect of lime and sewage sludge fertilisation on tree and understory interaction in a silvopastoral system. Agric Ecosyst Environ 188: 72–79.

Grime JP, Hodgson JG, Hunt R (2007) Comparative plant ecology : a functional approach to common British species. Castlepoint Press.Dalbeattie, Scotland.

Mosquera-Losada MR, Pinto-Tobalina M, Rigueiro-Rodríguez A (2005) The herbaceous component in temperate silvopastoral systems. CABI, Wallingford, pp. 93–100.

Mosquera-Losada MR, López-Díaz ML, Rigueiro-Rodríguez A (2009a) Zinc and copper availability in herbage and soil of a Pinus radiata silvopastoral system in Northwest Spain after sewage-sludge and lime application. J Plant Nutr Soil Sci 172: 843-850.

Mosquera-Losada MR, Rodríguez-Barreira S, López-Díaz ML, Fernández-Núñez E, Rigueiro-Rodríguez A (2009b) Biodiversity and silvopastoral system use change in very acid soils. Agric Ecosyst Environ 131: 315–324.

SAS (2001) SAS/Stat User's Guide: Statistics. SAS Institute Inc., Cary, NC, USA.

Sibbald A (1996) Silvopastoral systems on temperate sown pastures: a personal perspective. In: Etienne E (ed) Western European Silvopastoral Systems. INRA edictions, pp. 23-36.

Session

Tree fodder: food for thoughts?

NUTRITIONAL POTENTIAL OF FODDER TREES: THE IMPORTANCE OF TREE SPECIES, SOIL TYPE AND SEASONAL VARIATION

Luske B[1*], van Eekeren N[1]

(1) Louis Bolk Institute, Kosterijland 3-5, 3981 AJ Bunnik, the Netherlands

*Corresponding author: b.luske@louisbolk.nl

Abstract

The objective of this study was to assess the effect of soil type and season on the nutritional potential of leaves from Fraxinus excelsior, Alnus glutinosa and Salix viminalis. Leaf samples ands soil samples were collected at 10 sites in the Netherlands on clay and on sandy soils in June, July and September, which were analysed for several nutritional aspects. We found main differences between the studied tree species and sampling period, but no main effect of soil type was found. Significant interactions were found for species x sampling period (digestibility, calcium, sulphur) and species x soil (digestibility, calcium). For the zinc and selenium concentration in tree leaves, a significant species x soil x sampling period interaction was found. We conclude that trees can play a role for supplying protein, and macro and micro elements to livestock, but that it depends on which tree species is used.

Keywords: leaves; digestibility; protein; macro elements; micro elements; mineral cycles

Introduction

Farmers often report that free ranging cows use trees as fodder. Vandermeulen et al. (2016) found that heifers spent a significant time budget browsing on a variety of shrubs and trees. Available literature shows that different tree species are very interesting in terms of nutritional value for ruminants because of high levels of protein and especially macro and micro elements (Rahmann 2004). However, within literature some tree species show remarkable differences in nutritional values (Luske et al. 2017). Therefore the objective of this study was to investigate the effect of soil type (clay and sand) and seasonal variation on the nutritional quality of three common tree species in the Netherlands; ash (*Fraxinus excelsior* L.), common alder (*Alnus glutinosa* L. Gaertn.) and basket willow (*Salix viminalis* L.). We hypothesized that i) there is a significant difference in nutritional value of tree species, ii) the nutritional value of tree leaves decreases as the growing season progresses due to increasing leaf age, and iii) on clay soils the content of macro and micro elements is higher than on sandy soils.

Materials and methods

Ten organic dairy farms located in the province of Noord-Brabant and Utrecht were selected (five on sandy and five on clay soils). On each farm, one site was selected where the tree species, ash (*Fraxinus excelsior),* alder (*Alnus glutinosa*) and basket willow (*Salix viminalis*), were present next to a pasture (not on the pasture) and growing close together (<50m apart). On each site tree leaf samples were taken at three moments in the growing season of 2013, 17 to 25 June, 29 to 30 July and 9 to 10 September. One leaf sample consisted of approximately 500 grams of fresh hand-picked leaves. During the first sampling period, a soil sample (consisting of 40 subsamples) was taken on each site with an augur at a depth of 0-25 cm. Soil samples and oven dried (at 70°C for 24 hours). They were analysed in the laboratory of Eurofins (Wageningen, NL) for a set of soil parameters (pH-KCl, SOM, N-total, clay content, S-total, PAE-P, Mg, Zn, Se, Si, Mo, Fe). The tree leaf samples were analysed in the same lab for a set of crop parameters (DOMD, total-N, Ca, P, S, Zn, Cu, Se).

A split-split plot design (Genstat 13.3) was used to test for differences in nutritional values of the tree leaf samples. The factors taken into account were 'soil type', 'tree species' and 'sampling period' (June, July and September).

Results

A significant (P < 0.05) main effect of tree species on the DOMD, CP, Ca, P, S, Zn and Se concentrations in tree leaves was found. The highest DOMD and Ca concentrations were found for *F. excelsior*, while the highest CP concentration was found for *A. glutinosa*. *S. viminalis* had highest concentrations of P, S, Zn and Se.

Considering the sampling period, a significant (P < 0.01) main effect was found for CP, P and Cu concentrations in tree leaves (Table 1). Highest concentrations of these elements were found in June. No main effect of soil type on the nutritional value of tree leaves was found. Furthermore, significant interactions were found for species x sampling period (DOMD, Ca and S) and species x soil type (DOMD and Ca). For *F. excelsior* the DOMD increased from June to September, while the opposite was true for *A. glutinosa*. No trend was found for *S. viminalis*. The Ca concentration in *F. excelsior* leaves almost doubled from June to September, whereas in *S. viminalis* leaves the Ca concentration tended to increase. In *A. glutinosa* the Ca concentration remained stable. For *S. viminalis* a significant higher DOMD and Ca concentration. was found on clay soils. A significant (P < 0.05) interaction between tree species x soil type x sampling period was found for Zn and Se. For more details we refer to Luske and Van Eekeren (2017).

Table 1: Nutritional values of tree leaves per species and measured at three sampling periods. The average values are displayed ± SEM. Significant effects are indicated by * (P < 0.05) or ** (P < 0.01). Group differences based on the LSD's are indicated with a, b and c's. For correct interpretation of this table, take into account the significant interactions which were found between species, sampling period and/or soil type for DOMD, Ca, S, Zn and Se.

		DOMD	Crude protein	Ca	P	S	Zn	Cu	Se
	Unit	%	g kg DM^{-1}	g kg DM^{-1}	g kg DM^{-1}	g kg DM^{-1}	mg kg DM^{-1}	mg kg DM^{-1}	µg kg DM^{-1}
Tree species	Ash *(F. excelsior)*	71.3 ± 0.89 b	171.5 ± 5.42 a	23.9 ± 1.77 c	2.5 ± 0.14 a	4.0 ± 0.20 b	32.5 ± 2.83 a	9.4 ± 0.65	79.3 ± 8.14 a
	Alder *(A. glutinosa)*	61.5 ± 1.25 a	201.0 ± 4.14 b	12.1 ± 0.59 a	2.0 ± 0.08 a	2.3 ± 0.08 a	74.6 ± 6.80 a	11.2 ± 0.62	43.2 ± 3.93 a
	Willow *(S. viminalis)*	61.5 ± 1.48 a	189.8 ± 6.87 ab	15.7 ± 1.05 b	3.3 ± 0.20 b	5.3 ± 0.21 c	227.4 ± 24.48 b	8.7 ± 0.32	193.1 ± 42.95 b
	P	**	*	**	**	**	**	ns	*
Sampling period	June	66.3 ± 0.93	204.1 ± 6.28 b	12.2 ± 0.92 a	3.0 ± 0.19 b	3.2 ± 0.25	109.1 ± 16.74	10.8 ± 0.57 b	87.7 ± 18.89 a
	July	63.2 ± 1.61	178.7 ± 4.67 a	17.5 ± 1.40 b	2.3 ± 0.14 a	4.0 ± 0.30	104.2 ± 19.09	9.3 ± 0.5 a	93.6 ± 21.51 a
	Sept	64.8 ± 1.77	179.6 ± 5.77 a	20.1 ± 1.93 c	2.6 ± 0.19 a	3.8 ± 0.31	121.2 ± 27.01	9.2 ± 0.63 a	134.2 ± 38.53 b
	P		**	**	**	ns	ns	*	*

Discussion and conclusion

We can conclude that the nutritional value of tree leaves differs between the studied tree species. The higher CP content of *A. glutinosa* could be because of the symbiotic nitrogen fixing ability in association with the Gram-positive species of actinomycete filamentous bacterium Frankia alni (Baker and Mullin 1992). Compared to the literature most of the measured nutritional parameters of tree leaves in our study were within the range mentioned in available recent literature (Côté and Dawson 1999; Trémolières et al. 1999; Kemp et al. 2001; Machatschek 2002; Nijman 2002; Rahmann 2004; McWilliam at al. 2005; Smith et al. 2012; Emile et al. 2016; Emile et al. 2017) and only minor differences were found.

We expected to find downward going trends for the nutritional values of tree leaves, due to leaf ageing. However, this was only true for the CP, P and Cu concentration in tree leaves, which decreased from June to September. The specific tree species react differently to soil type. We found a clear effect of soil type for *S. viminalis*, for which we found a higher DOMD and a higher Ca concentration in tree leaves on clay sites than on sandy sites. For *S. viminalis* in September, we also found higher Se concentrations in tree leaves on clay soils, and on sandy soils higher Zn concentrations (Figure 1). Part of our findings coincide with the finding of Robinson et al. (2005) that micro element accumulation (B, Cd, Mn and Zn) in willow leaves was a function of leaf age.

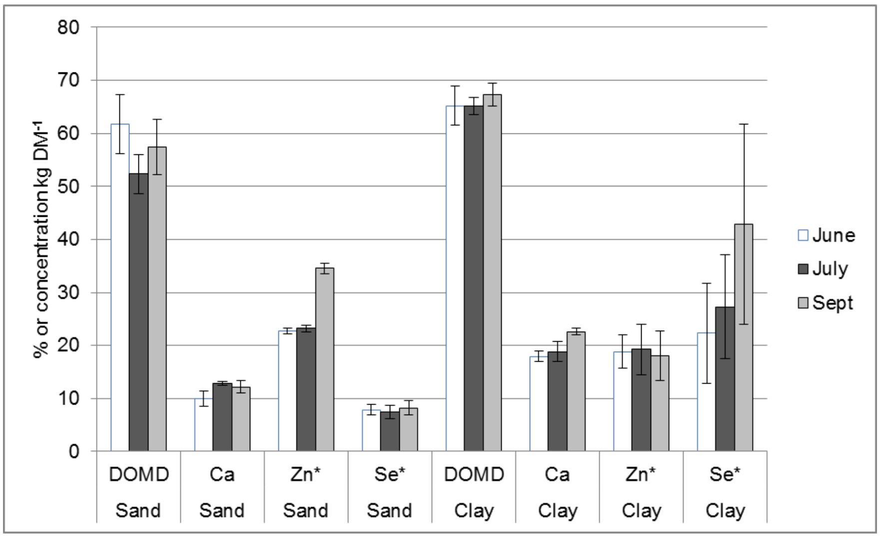


Figure 1. Average digestability (%), calcium (g kg DM^{-1}), zinc (mg kg DM^{-1}) and selenium (µg kg DM^{-1}) concentration in leaves of *S. viminalis* on the sandy and clay sites. Error bars present SEM. *Displayed values are multiplied by 10^{-1} to enable clear presentation of the results.

Our results suggest that the high concentrations of Zn and Se found in tree leaves do not originate from the upper soil, but from deeper soil layers and that trees play a role for supplying micro elements into the agricultural system. Unfortunately, we cannot conclude this directly from our study as we only took samples from the upper soil (<0.25 m deep). For future research it would be interesting to study the correlation between soil components of deeper soil layers (25-200 cm deep), fine root morphology and levels of macro and micro elements in tree leaves. The extreme high concentrations of micro elements that we found in willow leaves on some of our sites might be explained by the fact that willow has a relatively high root length density, root length and fine root biomass (Huber et al. 2012). It is known that plant roots can sense resource availability in the soil and form new roots in places where essential resources are available in high densities (Pregitzer 2008). As Sinclair et al. (1994) stated, tree root characteristics of tree species are increasingly recognized as criteria for the suitability for agroforestry systems. For more detail we refer to Luske and Van Eekeren (2017).

Tree species is the most important factor to take into account when introducing three dimensional grazing with fodder trees or shrubs. *A. glutinosa* is interesting because of high CP and Cu concentrations in the leaves. *F. excelsior* leaves had the highest digestibility and Ca concentration. *S. viminalis* is very interesting for livestock when there is a shortage of micro elements like Zn and Se but less when there is a shortage of Cu. Therefore, before use, we advise to study the nutritional value of specific tree species, for instance by visiting the *Online fodder tree database for Europe* (Luske et al. 2017). Additionally, analyses of locally collected leaf samples can give insight in the local nutritional potential of tree leaves.

References

Baker D, Mullin BC (1992) Actinorhizal Symbioses. In: Gary Stacey, Robert H. Burris, Harold J. Evans (eds) Biological Nitrogen Fixation. Chapman and Hall, New York, NY, pp.259-292.

Côté B, Dawson JO (1991) Autumnal allocation of phosphorus in black alder, eastern Cottonwood, and white basswood. Can J Forest Res 21: 217-221.

Emile JC, Delagarde R, Barre P, Novak S (2016). Nutritive value and degradability of leaves from temperate woody resources for feeding ruminants in summer. 3rd European Agroforestry Conference. Montpellier, France.

Emile JC, Barre P, Delagarde R, Niderkorn V, Novak S (2017) Les arbres, une ressource fourragère au pâturage pour des bovins laitiers? Fourrages 230: 155-160.

Huber J, Häberle K-H, Blaschke H, Schmidt H, Hülsbergen K-J (2012) Fine root morphology of four tree species in two differently managed agroforestry systems. Poster International Society of Root Research, Dundee, Scotland.

Kemp PD, Mackay AD, Matheson LA, Timmins ME (2001) The forage value of poplars and willows. Proceedings of the New Zealand Grassland Association 63: 115–119.

Luske B, Meir I van, Altinalmazis Kondylis A, Roelen S, van Eekeren N (2017). Online fodder tree database for Europe. Louis Bolk Institute and Stichting Duinboeren, the Netherlands. www.voederbomen.nl/nutritionalvalues/ (accessed 9/10/2017).

Luske B, van Eekeren N (2017) Nutritional potential of fodder trees on clay and sandy soils. Agrofor Syst https://doi.org/10.1007/s10457-017-0180-8.

Machatschek M (2002) Laubgeschichten, Gebrauchswissen Schaft einer alten Baumwirtschaft, Speise- und Futterlaubkultur. Böhlau Verlag, Wien.

McWilliam EL, Barry TN, Lopez-Villalobosa, N, Cameron PN, Kemp PD (2005) Effects of willow (Salix) versus poplar (Populus) supplementation on the reproductive performance of ewes grazing low quality drought pasture during mating. Anim Feed Sci Tech 119: 69–86.

Nijman M (2002) Bomen en struiken als Veevoer. Een alternatief voor het voeren van mineralen en sporenelementen aan biologische melkkoeien. Afstudeerscriptie Hogeschool Delft. Louis Bolk Instituut, Driebergen, the Netherlands.

Pregitzer KS (2008) Tree root architecture – form and function. New Phytol 180: 564-568.

Rahmann G (2004) Gehölzfutter – eine neuwe quelle für die öcologische tiernährung. Landbouforschung Völkenrode Sonderheft 272: 29-42.

Robinson B, Mills T, Green S, Chancarel B, Clothier B, Fung L, Hurts S, McIvor I (2005) Trace element accumulation by poplar and willows used for stock fodder. New Zeal J Agr Res 48: 489-497.

Sinclair FL, Verinumbe I, Hall JB (1994). The role of tree domestication in agroforestry. In: Leakey RRB, Newton A (eds) Tropical Trees: Potential for Domestication and the Rebuilding of Forest Resources. HMSO London, pp. 124-136.

Smith J, Leach K, Rinne M, Kuoppala K, Padel S (2012) Integrating willow-based bioenergy and organic dairy production –the role of tree fodder for feed supplementation-. In: Rahmann G and Godinho D (eds): Tackling the future challenges of organic husbandry. Proceedings of the 2nd OAHC, Hamburg/Trenthorst, Germany.

Trémolières M, Schnitzler A, Sanchez- Pérez J-M, Schmitt D (1999) Changes in foliar nutrient content and resorption in Fraxinus excelsior L., Ulmus minor Mill. and Clematis vitalba L. after prevention of floods. Ann For Sci 56: 641-650.

Vandermeulen S, Ramırez-Restrepo CA, Marche C, Decruyenaere V, Beckers Y, Bindelle J (2016). Behaviour and browse species selectivity of heifers grazing in a temperate silvopastoral system. Agrofor Syst DOI 10.1007/s10457-016-0041-x.

MINERAL COMPOSITION OF ASH LEAVES (*FRAXINUS EXCELSIOR* L.) USED AS FODDER FOR THE RUMINANTS IN SUMMER

Mahieu S[1]*, Emile JC[1], Novak S[1]

(1) INRA, UE 1373 FERLUS, les verrines, F-86600 Lusignan, France

*Corresponding author: stephanie.mahieu@inra.fr

Abstract

In this paper, our objective was to study the consistency of the mineral composition of leaves from *Fraxinus excelsior* L. according to their provenance and management, *i.e.* pollarded *vs*. high stem trees. The leaves were collected in August 2016 on 7 sites spread out in 3 regions of France. The concentrations in Ca, Na, Fe, Mn and Cu of ash tree leaves, exhibited a high variability (coefficient of variation, C.V.>30%), while the concentrations in N, K, Mg, P, and Zn varied in a lesser extent (C.V.<30%). Pollarded trees exhibited higher N contents (P<0.001) and lower Ca contents (P<0.05) than high stem trees. There was no significant effect of tree management for the other elements. Our results confirm that ash leaves are rich in Ca, mineral of interest for dairy herd feeding. This tree species is also interesting to provide N, Mg, Fe, Zn and Cu.

Keywords: forage; mineral elements; fodder trees; nutritive value; agroforestry; *Fraxinus excelsior*

Introduction

The use of fodder trees may help to adapt and mitigate effects of livestock production to ongoing climatic change in Europe and increasing demand in animal products. Tree leaves constitute a forage resource which could be used during periods of low grassland production (especially during the summer and autumn) when other feed resources get depleted (Vandermeulen et al. 2018). Previous studies have shown that the leaves of temperate woody species exhibit a great diversity in chemical compositions and they are generally well suited for livestock feeding (Emile et al. 2016; Luske and Van Eekeren 2017). However little is known about the effects of pedoclimatic conditions and tree management.

Ash (*Fraxinus excelsior* L.) is a fodder tree species widespread in all of the Western Europe from the Urals to the south of Scandinavia that was formerly used to complete feeding dietary of ruminants. This specie exhibits a rapid growth and a good aptitude to emit new branches due to its ability to develop a strong root system under weak luminosity conditions (Marty et al. 2012). Analyses of its nutritive value showed that ash presents sufficient *in vitro* digestibility and nitrogen characteristics to be included in the diet of ruminants (Emile et al. 2017). The aim here was to explore minerals content of ash leaves. Many minerals are essentials for ruminants for getting optimum production such as calcium or phosphorus while deficiency or excess may cause poor performances. Ash tree leaves were collected in different regions of France in order to study consistency of macro and trace mineral concentrations in the leaves according to the provenance and the management (pollarded or high stem tree) of ash trees. Results are compared to those of herbaceous forage traditionally used for dairy cows feeding.

Materials and methods

The leaves of 23 ash trees were collected in August 2016 on seven sites located in North, Centre and West of France (see details Table 1). In two locations (Lusignan-Vauchiron and St Gènes Champanelle) samples were collected on high stem and winter pollarded trees. Fresh perennial ryegrass and lucerne were also collected as herbaceous forage controls, harvested above 5 cm from ground level after 6 weeks of regrowth. For these two species, the whole plant (leaves and stems) was considered.

All samples were oven dried at 60°C during 72 h, weighed for dry matter measurement (DM). One subsample was ground to 1 mm, then ground again with a vibro-broyeur from Retsch for measuring total N concentration according to the Dumas method (1831) with a Flash 2000 CHNS/O Analyzers from Thermofisher. Another dry leaves subsamples were ground to pass through a 0.1 mm-grid crude and analysed for minerals P, K, Ca, Mg, Na, Fe, Mn, Zn, and Cu by radial ICP and ash (550°C during 3 h in a muffle furnace).

Table 1: Location and characteristics of the sampling sites in France

Geographic area	Sites	Tree ages	Altitude	Climate	Temperature	Rainfall
North	Brunembert Enquin sur Baillon Zoteux	20-25 y.	46-180 m	Temperate oceanic	Min.:8.4°C Max.:13.4°C	777.9 mm
Center	Saint Gervais Saint genes Champanelle	20-25 y.	390-742 m 660-1252 m	Subcontinental dry	Min.:6.6°C Max.:16.8°C	578.9 mm
West	Lusignan- Les Verrines Lusignan-Vauchiron	3 y. ≈10 y.	99-150 m	Oceanic with relatively dry and hot summer	Min.:6.9°C Max.:16.6°C	685.6 mm

Mineral concentrations were analysed using analysis of variance (ANOVA) using the software program Rstudio Version 1.0.153 – © 2009-2017 RStudio, Inc. Factors studied in this experiment were provenance: site or region and trees management (high stem vs pollarded tree)*provenance. When assumptions of data normality or equality of variances were not met, comparisons of means were carried out using nonparametric Kruskal–Wallis tests with a confidence level of $\alpha=0.05$.

Results and discussion

Histograms presented in figures 1 A and B show that the shapes of distribution of Ca, K, Mg, P, Fe, Zn and Cu concentrations were similar to a normal distribution pattern ($p>0.05$) while those of N, Na and Mn showed concentrated distribution in the lower concentrations ranges (Figure 1).

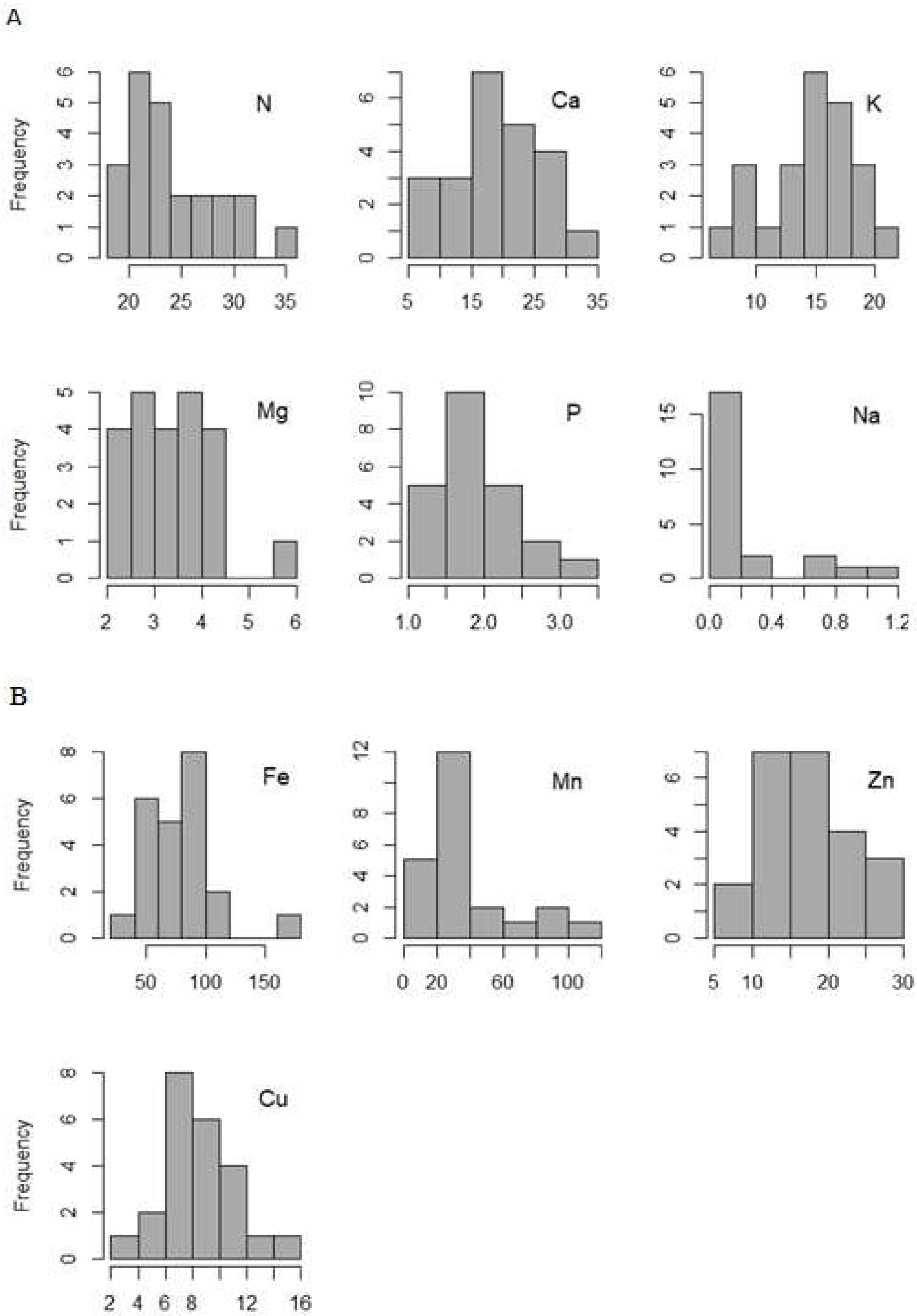


Figure 1: Frequency distribution of the concentrations in major (g kg^{-1}, A) and trace (mg kg^{-1}, B) elements in the leaves of ash trees collected in August 2016.

The distribution of some major and trace elements vary in a wide range indicating that the chemical composition of ash leaves probably depends on multifactorial effects (genetic, climate, growth conditions or soil characteristics). N, K, Mg, P and Zn displayed the lower coefficients of variation ranging from 16.7% to 30% and there was no effect of the provenance (site or geographic area) for those elements (Table 2). The coefficients of variation were slightly higher in Ca (34.6%) and Cu (32.3%), mean concentrations of the two elements were similar between the sites of the same geographic area but were highly different between geographic area North, Centre or West ($p<0.0001$ and $p< 0.01$, respectively). Inversely the concentrations in Fe and Mn were different between sites ($p<0.001$ and $p<0.05$, respectively) but there was no significant difference between geographic area. Na exhibited the highest coefficient of variation (129%) since the concentrations of four samples were below the detection limits while two sites from the

North exhibited concentrations quite higher than in the other sites (p<0.05). These differences could be due to soil mineral composition (not measured).

Pollarded trees exhibited higher N than high stem trees (P<0.001) and a lower Ca (P<0.05), there was no significant effect of tree management for the other elements (Table 2).

Average concentrations in major elements in ash leaves i.e N ≥ Ca > K > Mg > P > Na did not range in the same order than in the grasses lucerne and ryegrass i.e N > K > Ca > P > Mg > Na. Ca and N concentrations in ash leaves were similar with sometimes Ca being higher than N such as in the leaves from ash trees collected in Enquin-sur-Baillons, Lusignan-Les-Verrines and Vauchiron. The order of trace elements was the same in ash leaves and the grasses i.e Fe > Mn > Zn > Cu. Total ashes were slightly lower in ash leaves (8.8%) than in ryegrass (10.2%) or lucerne (9.4%) due to a lower content in K, P, Zn, Fe and Mn. Nevertheless the ash leaves were higher in Ca, Cu and Mg and contain N and Fe concentrations higher than in ryegrass. Especially N content was more than twice higher than in ryegrass.

Table 2: Composition in some major and trace minerals of high stem and pollarded ash tree leaves collected in August 2016 and in the grasses lucerne and ryegrass. Upper case letters (N), (C) and (W) indicate the corresponding geographic area of the sites North, Centre and West of France, respectively.

		major minerals(g kg^{-1})						trace minerals (mg kg^{-1})			
	n	N	Ca	K	Mg	P	Na	Fe	Mn	Zn	Cu
Brunembert (N)	2	21.7	20.1ac[(1)]	16.8	3.4	1.9	0.8a	78.4ab	20.0b	14.2	8.3
Enquin sur B. (N)	2	21.8	24.4ac	13.8	3.5	2.2	0.9a	39.3b	27.5b	15.0	8.3
Zoteux (N)	2	26.2	20.9ac	9.2	2.5	1.7	0.1b	58.9ab	41.5ab	14.4	8.9
St Gervais (C)	2	23.8	13.0cb	12.7	3.5	1.8	0.3b	120.6a	65.9ab	22.8	10.0
St Genes Ch. (C)	3	22.7	12.8c	18.6	3.4	1.6	0.1b	73.8ab	18.0b	16.4	10.5
Lusignan – Vauchiron (W)	3	21.7	24.7ab	12.2	3.5	1.9	0.2b	69.5ab	24.0b	18.0	5.7
Lusignan - Les Verrines (W)	3	21.0	28.8a	16.6	3.8	1.9	0.1b	100.1ab	89.6a	14.3	5.4
P (site effect)	17	ns	<0.01	ns	ns	ns	<0.05	ns	<0.05	ns	ns
P (Geographic origin effect)	23	ns	<0.0001	ns	ns	ns	ns	<0.001	ns	ns	<0.01
High stem	6	22.4	18.8	15.4	3.5	1.8	0.1	71.6	21.0	17.2	8.1
Pollarded	6	29.6**[(2)]	14.3*	15.6	3.5	2.3	0.0	83.1	28.6	22.0	10.1
Ash leaves mean	23	24.4	19.2	14.8	3.4	2.0	0.2	79.3	38.1	17.8	8.5
Min.	23	19.8	9.1	7.2	2.4	1.3	0	38.1	11.4	9.7	3.8
Max.	23	34.1	32.8	21.7	5.6	3.4	1.1	167	103	27.8	15.9
C.V. (%)[(3)]	23	16.7	34.6	25.2	23.7	26.5	129.0	34.6	69.8	30.0	32.3
Lucerne	2	35.7	17.5	20.6	3.1	4.0	0.9	99.0	60.3	23.9	7.8
Rygrass	2	10.1	7.0	28.3	2.0	3.5	0.2	47.0	58.4	11.8	3.6

[(1)]Lower case letters indicate significant difference between sites
[(2)]Level of significance of the comparison between pollarded and high stem ash trees using two way ANOVA sites*tree management. signification code *0.05, **0.001
[(3)] Coefficient of variation

Conclusion

Composition in Ca, Na, Fe, Mn and Cu of ash tree leaves collected in August exhibited large variations probably arising from multifactorial effects (genetic, climate, growth conditions or soil characteristics) while concentrations in N, K, Mg, P, and Zn were relatively constant. Tree management was also shown to have a strong effect on N content and to a lesser extent on Ca content. Overall, our results confirm that ash leaves are rich in Ca, mineral of interest for dairy herd feeding. This species is also interesting to provide N, Mg, Fe, Zn and Cu. Further investigations have to be conducted to compare these results with other tree species, to precise the effects of tree management, to adapt this fodder resource to the dietary of ruminants and to determine the effects of soil composition.

Acknowledgements

We acknowledge the support of ADEME in the frame of the PARASOL project (contract n°1560C0025) and of the EU through the AGFORWARD FP7 research project (contract 613520). Furthermore we are grateful to Philippe Barre, INRA, URP3F for nitrogen analyses.

References

Emile JC, Delagarde R, Barre P, Novak S (2016) Nutritive value and degradability of leaves from temperate woody resources for feeding ruminants in summer. In: Gosmes M. et al. (eds) Celebrating 20 years of innovations in European Agroforestry. The 3rd European Agroforestry Conference, INRA, Montpellier, France, pp 409-412.

Emile JC, Delagarde R, Barre P, Niderkorn V, Novak S (2017) Evaluation of the feeding value of leaves of woody plants for feeding ruminants in summer. Grassland Science in Europe 22: 548-550.

Luske B and Van Eekeren N (2017) Nutritional potential of fodder trees on clay and sandy soils. Agrofor Syst https://doi.org/10.1007/s10457-017-0180-8 (accessed 17/04/2018).

Marty P, Larrieu L, Claessens H, Gonin P, Coello J (2012) Autécologie du Frêne commun (*Fraxinus excelsior* L.) et du Frêne oxyphylle (*Fraxinus angustifolia* Vahl). Forêt-entreprise 204: 9-12.

Vandermeulen S, Ramírez-Restrepo C A, Marche C, Decruyenaere V, Beckers Y, Bindelle J (2016) Behaviour and browse species selectivity of heifers grazing in a temperate silvopastoral system. Agrofor Syst 1-12. https://doi.org/10.1007/s10457-016-0041-x (accessed 17/04/2018).

EXPLORING AN INNOVATIVE APPROACH TO STUDY BROWSING BEHAVIOR OF DAIRY COWS AND THE PERFORMANCE OF SELF-MECATIVE BEHAVIOR IN RELATION BROWSING

Roelen SSM[1*], Luske B[1], Wagenaar JP[1]

(1) Louis Bolk Institute, Kosterijland 3-5, 3981 AJ Bunnik, The Netherlands

*Corresponding author: suzanneroelen@hotmail.com

Abstract

To assess an innovative method, and to get a better understanding of browsing behavior of dairy cows and the performance of self-medicating behavior a 13-day preliminary trial was conducted. On a silvopastoral site of a Dutch organic dairy farm, data were collected with 4 wildlife digital cameras to register browsing behavior combined with cow-specific data including cows' health state and productivity. Dairy cows, in all four lactation stages, and calves made use of willow trees for browsing. Browsing frequency by individual cows however, was low. Browsing behavior could not be related to self-medication nor could potential benefits of fodder trees on animal health be clearly demonstrated. Current method may prove a valuable, accessible and cost-effective approach, and may be used as a stepping stone to future studies. However, we recommend that future studies would include: longer observation period with repeated measurements over time, higher coverage of the browsing area with more cameras, larger sample size and use of diverse groups, and day-to-day collection of a larger variety of physiological and medical data of individual cows.

Keywords: silvopastoral systems, self-medication, feeding behavior, animal health, animal welfare

Introduction

Agroforestry systems are increasingly acknowledged for their environmental, social and economic benefits (Mosquera-Losada et al. 2012). Besides these benefits, livestock may also benefit from the integration of trees (Mosquera-Losada et al. 2012), as silvopastoral systems can contribute to improved animal health and welfare (Eekeren et al. 2014). Moreover, a recent study reported that also for the Dutch farmers these aspects are of importance as animal health and welfare were among the four key drivers that motivated them to implement agroforestry practices (Garcia de Jalón et al. 2017).

Previous studies showed the potential of certain tree species to serve as a supplementary source of macro- and micro elements (like protein, Ca, Zn, Se) for ruminants (Luske and Eekeren 2015). Moreover, certain tree species such as willow (*Salix spp.),* are known to contain active compounds with analgesic, anti-inflammatory, and anti-parasitic properties (Engel 2002). Therefore, there is reason to believe that there are more perspectives to understanding feeding behavior, and that feeding behavior may also be closely linked to health maintenance. Health maintenance can be both preventive and curative and therefore implies that animals are likely to exhibit self-medicating behavior (Engel 2002). However, little is known about the abilities of animals to self-medicate, especially the ability of domesticated animals such as dairy cows.

To further build upon the concept of agroforestry as a multifunctional approach, aspects of animal health and welfare cannot be left out of the equation. Consequently, the overall purpose of this study was to explore the potential benefits of the (re)integration of fodder trees on the health and welfare of dairy cows. A main objective therein was to develop a research methodology that allowed for the identification of self-medicating behavior through browsing which could be applied in practical settings. To test this innovative method, and to get a better understanding of browsing behavior as well as the performance of self-medicating behavior in relation to browsing, we conducted a preliminary case study on an organic dairy farm.

Materials and methods

Study area

Current study took place at organic dairy farm de Kerckhoeve in Helvoirt (51°38'15.65"N; 5°12'27.58"W), with 130 Holstein Friesian cattle. The silvopastoral site comprised an area of 9000 m^2 and included ten tree rows with fodder trees, adjacent to the normal pastures. The silvopastoral site included alternating rows of basket willow (*Salix viminalis* incl. two different cultivars) and common alder (*Alnus glutinosa*). Trees were planted in 2011, and from spring 2015 cows were given access to the site.

On the farm, calves are reared in a suckling system and are allowed to graze with the dairy herd. Furthermore, current farm makes use of an automated milking system which allows for the monitoring of cows on both herd and individual level.

Study design and data collection

To study browsing behavior of dairy cows, four wildlife digital cameras (Dörr Snapshot Mini 5.0 MP, Model -UV555) were installed at the silvopastoral site. Cameras were predominantly placed adjacent to the willow tree rows (3x; 1x alder row). A previous study showed that dairy cows preferred willow over alder trees based on a higher number of browsing marks found on willow trees (Luske et al. 2017). For a period of 13 days, between August 7th-25th 2017, the cameras registered browsing behavior of dairy cows. Wildlife digital cameras took photos based on motion detection (2 shots per motion, 60 sec. interval), and registered date, time and temperature for each photo. Browsing cows were identified by their neck- or ear tags.

To get insight into the cows' health state and level of productivity, data from all individual cows (browsing and non-browsing) were retrieved from the automated milking system and CowVision program in cooperation with the farmer. The CowVision program was used to obtain information on the cow's disease history (like claw and leg injuries), parity (no. of lactations), and stage of lactation (no. of days in lactation), and to collect relevant information from three milk production registration sampling moments (MPR 28-6 / 12-8 / 26-9 '17). MPRs provided information on somatic cell count (SSC), and fat- and protein content in milk (%) for each individual cow. SSC served as an indicator for mastitis; and (deviations in) fat- and protein content (%) served as an indicator for metabolic disorders (like ketosis and milk fever).

Cows were grouped as browsing cows (BC) (i.e. cows identified browsing on camera) or non-browsing cows (NBC). BC and NBC were further divided into subgroups according to their stage of lactation: (1) ≤ 60 days; (2) 61-180 days; (3) 181-304 days; (4) >305 days in lactation respectively.

Data analysis

Data obtained from the camera captures was used to calculate the total number of browsing incidences (per tree row), timing of browsing (morning or afternoon), duration of browsing incidences (min.), and browsing frequency per individual cow.

Data was further analyzed using IMB SPSS Statistics 24. Statistical procedures were performed to compare BC and NBC, subgroups (stage of lactation) of BC and NBC, and to compare subgroups within the group of BC. A parametric Independent T-test was used to test for differences in average no. of lactations, SSC (for all three MPR sampling moments), and fat-and protein contents in milk (%) (for all three MPR sampling moments) between (sub)groups. A non-parametric Kruskal Wallis test and multiple comparisons were performed to test for differences in the distribution of browsing frequency within the different lactation groups of BC. A linear regression was performed to check for possible correlations between parity and average SSC (i.e. ≠SSC for each MPR sampling moment) of BC and NBC respectively.

Results

Describing browsing behavior

At time of observation, 117 cows had access to the silvopastoral site. Cameras revealed browsing behavior of 36 different identifiable animals (incl. 2 calves) (Figure 1) opposed to 81 individual cows that were not registered browsing. Cows and calves browsed from willow trees but not from the alder trees. Fifty-nine browsing incidences were registered over three different willow tree rows. Most browsing incidences (n=29) occurred at one willow tree row which was a wider growing branching out willow cultivar ("Klara" cultivar). In 8 cases, cows seemingly browsed from the trees but could not be confirmed as the identification of these animals was not possible.

Figure 1: Wildlife cameras were used to capture images of browsing cows (and calves). Neck/ear tags enabled the identification of the individual animals within the herd.

Most browsing incidences (48%) took place in the afternoon, between 3:00 and 5:59 pm. About 30% of the total number of browsing incidences took place between noon and 2:59 pm. The remaining 20% of browsing incidences occurred (early) in the morning (between 6:00-11:59 am). Often browsing incidences lasted no longer than one minute (60%), whereas about one-third of the total number of browsing incidences lasted between one and five minutes (n=18). Less than 10% of the browsing incidences lasted longer than five minutes or longer than ten minutes.

Two individual calves were spotted browsing three to four times, respectively. Browsing behavior of calves was always observed in combination with browsing behavior of the mother cow (Figure 1) and/or with peers. Laying behavior often preceded or followed after browsing.

Browsing behavior related to individual cow data

Irrespective of lactation stage, on average 63% of the dairy cows browsed once during the entire observation period, followed by 22% of the cows that browsed twice (Figure 2). Forty percent of the cows that were seen browsing twice were part of the second lactation group (61-180 days), whilst 25% were part of the first lactation group (≤60 days) (Figure 2). On average, less than 10% of cows in lactation group 1 (≤60 days), and group 3 (181-304 days) browsed more than twice, while 40% of cows in group 4 (≥305 days) browsed more than twice. The distribution of browsing frequency did not significantly ($p>0.05$) differ between the different lactation groups of BC.

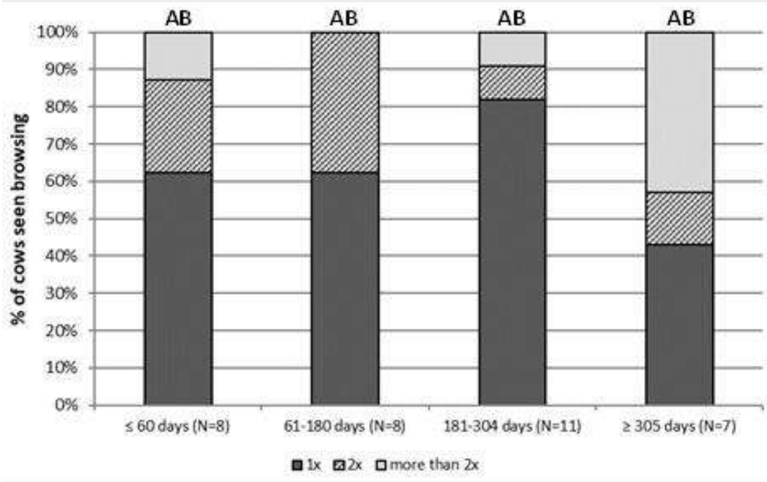


Figure 2: Frequency of dairy cows (N=34) spotted browsing according to their lactation stage. AB indicate that no significant differences in the distribution of browsing frequency between groups were found (p>0.05).

The average no. of lactations (parity) of BC was significantly (p<0.05) lower (2.8±1.3) compared NBC (3.5±1.9).

Across the three MPR sampling moments no significant differences in average SSC between the four different lactation groups of BC and NBC were found. No significant relation was found between parity and average SSC of BC, whilst a significant (p<0.05) though weak (ρ = 0.322) relation was found between parity and average SSC of NBC.

Discussion and conclusions

With this explorative case study we tested an innovative method that included the use of wildlife cameras to register browsing behavior of dairy cows, and subsequent combination of this information with relevant cow specific data regarding health and productivity of individual cows. Although the number of cameras used in this preliminary trial was limited (4), and the observation period was short (13 days) we were able to collect some initial data to study browsing behavior of dairy cows. We found that dairy cows, across all four lactation stages, mostly younger cows, and even calves were captured browsing from willow trees on a frequent basis, but that browsing by individual cows was rather an occasional activity. Such findings suggest that the (in) ability or willingness to browse may be a function of experience, or possibly the lack thereof. Several studies showed that past experiences, social learning processes (like from mother to young), and diversity of environmental circumstances in which animals were reared, play a fundamental role in the development and adoption of dietary habits and foraging skills of domesticated ruminants (Provenza and Balph 1987; Villalba and Provenza 2007; Vandermeulen et al. 2016).

Field pictures were of good quality which enabled the identification of individual animals. We were also able to collect the required information from individual cows which allowed the comparison of browsing and non-browsing cows or other sub groups within the herd. More often dairy farms in the Netherlands are equipped with modern technology, which enables monitoring and registration of animal health parameters on a daily basis. As shown in the current study, the application of modern technology can be considered a valuable tool to study and better understand the complexities of animal behavior, including the act of self-medication. During this experiment however, we had difficulties retrieving daily data from the computer system of the milk robot. In future projects it is therefore advised to consult an expert at an early stage to make sure relevant data is accessible to researchers. These daily measurements will be key to link browsing incidences with relevant physiological data of identified cows.

This study did not provide sufficient evidence to prove the performance of self-medicating behavior among dairy cows. However, it is generally difficult to make a distinction between self-medication and nutrition, whilst both are means to the same end: stay well. Furthermore, according to Engel (2002) it is clear that daily feeding behavior, and therewith choosing the right diet at the right time under the right circumstances, is inextricably linked to health maintenance. From this perspective, and the notion that browsing behavior is a function of social learning processes and experiences, it may be more appropriate to speak of self-regulation or homeostatic behavior (Engel 2002). Furthermore, the possibility to exhibit browsing behavior as well as having dietary choices contribute to an improved animal welfare by allowing the expression of natural behaviors, a better fine-tuning of the cow's individual needs and preferences, and overall reduction of stress (Villalba and Provenza 2007; Manteca et al. 2008).

Altogether, this trial did demonstrate the potential of our method to study self-medication in future research. Additionally, the approach can be used to study other beneficial effects of trees for dairy cows, like the provision of shade in pastures and the physiological effects on cows. Overall, current method may prove a valuable, accessible and cost-effective approach, and may be used as a stepping stone to future studies, provided these would be more properly designed to study self-medicating behavior. We suggest that an improved study design would include a longer observation period with repeated measurements over time, a higher coverage of the browsing area with more cameras, a larger sample size and use of diverse groups (considering both lactating and dry cows; sick and healthy animals; with and without access to medicinal plants) and day-to-day collection of a larger variety of physiological and medical data of individual cows.

References

Eekeren N, Luske B, Vonk M, Anssems E (2014). Voederbomen in de landbouw, meer waarde per hectare door multifunctioneel landgebruik. Brochure Praktijknetwerk Voederbomen en Multifunctioneel Landgebruik, Louis Bolk Instituut.

Engel C (2002) Wild Health, How animal keep themselves well and what we can learn from them. Houghton Mifflin Company, Boston, New York.

García de Jalón S, Burgess, PJ, Graves, A, Moreno G, McAdam J, Pottier E, Novak S, Bondesan V, Mosquera-Losada R, Crous-Durán J, Palma JHN, Paulo JA, Oliveira TS, Cirou E, Hannachi Y, Pantera A, Wartelle R, Kay S, Malignier N, Van Lerberghe P, Tsonkova P, Mirck J, Rois M, Kongsted AG, Thenail C, Luske B, Berg S, Gosme M, Vityi A. (2017) How is agroforestry perceived in Europe? An assessment of positive and negative aspects by stakeholders. Agrofor Syst. https://doi.org/10.1007/s10457-017-0116-3

Luske B, van Eekeren N., Vonk M., Altinalmazis Kondylis A., Roelen S. (2017). Lessons learned- Agroforestry for ruminants in The Netherlands. System report AGFORWARD (613520), Agroforestry for livestock farmers.

Luske B, van Eekeren N (2015) Potential of fodder trees in high-output dairy systems. Grassland Science in Europe 20:250-252.

Manteca X, Villalba JJ, Atwood SB, Dziba L, Provenza FD (2008) Is dietary choice important to animal welfare? J Vet Behav 3: 229-239.

Mosquerada-Losada M.R., Moreno G., Pardini A., McAdam J.H., Papanastasis V., Burgess P.K., Lamersdorf N., Castro M, Liagre F, Riqueiro-Rodriguez A. (2012) Past, Present and Future of Agroforestry Systems in Europe. In: Nair P, Garrity D (eds) Agroforestry - The Future of Global Land Use. Advances in Agroforestry, volume 9, Springer, Dordrecht, pp 285-312.

Provenza FD, Balph DF (1987) Diet learning by domestic ruminants:theory, evidence and practical implications. Appl Anim Behav Sci18: 211-232.

Villalba JJ, Provenza FD (2007) Self-medication and homeostatic behavior in herbivores: learning about the benefits of nature's pharmacy. Animal 1: 1360-1370.

Vandermeulen S., Ramirez-Restrepo C.A., Marche C., Decruyenaere V., Beckers Y., Bindelle J. (2016). Behaviour and browse species selectivity of heifers, grazing in a temperate silvopastoral system. Agrofor Syst DOI:10.1007/s10457-016-0041-x.

TREE FODDER IN UK LIVESTOCK SYSTEMS: OPPORTUNITIES AND BARRIERS

Smith J[1*], Westaway S[1], Whistance L[1]

(1) Organic Research Centre, Newbury, UK

*Corresponding author: jo.s@organicresearchcentre.com

Abstract

In northern European countries, there is little current understanding of the potential of tree fodder. This paper discusses the opportunities and barriers for tree fodder into UK ruminant livestock systems. Key opportunities include improving livestock nutrition and health (particularly as sources of minerals), and as a buffer against climate change impacts or shortages of forage. Key barriers are the mechanisation and management of tree fodder to reduce labour input, and regulatory restrictions that prevent tree and hedge cutting in summer months. Much of the information on tree fodder is anecdotal, and there is a real need for both scientific evidence and practical management advice on differences between tree species and seasonal variations in nutritional value. To take full advantage of this potential, better understanding of the nutritional and health benefits of tree fodder, and more efficient management techniques need to be developed.

Keywords: minerals; tannins; salicylic acid; silvopastoral systems

Introduction

Traditionally, tree fodder has been an important animal feed and remains significant in some farming systems (Eichhorn et al. 2006). However, in northern European countries, while the value of trees for shelter or shade is accepted, there is little current understanding of the potential of tree fodder. Nevertheless, tree fodder offers certain benefits such as buffering against the impact of climate change on forage resources, and meeting specific nutritional or health needs of the animals. The need for better estimates of the nutritional value of browse in relation to management of trees (e.g. impact of harvesting style on the quantity or quality of forage) was identified by European livestock stakeholders as a barrier to greater uptake of agroforestry systems (Hermansen et al. 2015). Can this traditional labour-intensive practice work in modern livestock systems? This paper discusses the potential integration of tree fodder into UK ruminant livestock systems. In addition to a brief overview of available evidence, results from tree fodder analyses carried out as part of the European research project AGFORWARD are presented and discussed.

What are the benefits of, and barriers to, wider use of tree fodder in the UK?

a) Livestock nutrition and health. Fodder from some tree species compare favourably with typical forages such as hay, grass silage and grazed grass (Ministry of Agriculture Fisheries and Food 1990). Of greater value, however, may be their potential as a source of minerals. For example, willow leaves are high in magnesium and zinc (Robinson et al. 2005) and alder is high in copper (Luske and Van Eekeren 2017). Secondary compounds such as condensed tannins can also be of benefit by increasing the flow of rumen-bypass protein and essential amino acids to the small intestine (Rogosic et al. 2006). The potential for self-medication in ruminants is not yet well explained in the scientific literature. Although salicin, in willow, is well known to have anti-inflammatory properties, it has not been widely evaluated in terms of its content within tree fodder or consequent effects on animal health (Boeckler et al. 2011). Comparatively little is known about the potential of temperate browse species, although the evidence base is slowly growing (Emile et al. 2016; Smith et al. 2012) and contributing to an on-line database of nutritional values (Luske et al. 2017).

b) Buffer against climate change impacts or shortages of forage. Trees provide alternative feed resources during periods of low forage availability. In northern temperate systems, this role may increase in importance as the effects of climate change impact on plant growth patterns. There is also potential for preserved tree fodder to fill the ‘hungry gap’ in early spring, before the new season grass is available, (e.g. by drying as ‘tree hay’ (Green 2016), or ensiled (Smith et al. 2014)).

c) Mechanisation and management. The simplest method of managing tree fodder is to allow livestock to have direct access, although this requires careful management that balances keeping tree height accessible to livestock with minimising damage to the tree. Manual cutting and transporting is laborious and time consuming, but there has been recent interest in mechanising the process; Dutch farmers have been investigating ensiling coppiced willow for feeding to dairy goats (see www.voederbomen.nl/oogst for a film of the process).

d) Regulatory restrictions. In England, under Cross Compliance regulations (which farmers must follow if they are claiming rural payments such as for the Basic Payment Scheme or Countryside Stewardship), hedges and trees must not be cut between 1st March and 31st August (although it is possible to coppice trees between 1st March and 30th April) (DEFRA 2017). This conflicts with tree fodder management options which would need to be done during the summer months. Direct browsing would still be possible though.

e) Knowledge gaps. Much of the information on tree fodder is anecdotal, and there is a real need for both scientific evidence and practical management advice on differences between tree species, seasonal variations in nutritional value and appropriate management systems.

Tree fodder analyses

Leaf samples were collected from SRC alder (*Alnus glutinosa*) and basket willow (*Salix viminalis*) in August 2015, and in June 2016 from an ash (*Fraxinus excelsior*), goat willow (*Salix caprea*) and elm (*Ulmus minor*) tree on Elm Farm, Hamstead Marshall, UK (51°23’14.19”N; 1°24’08.34”W). As part of a pilot study on the effect of air-drying tree fodder over winter and testing palatability, branches of the ash, goat willow and elm were bundled, tied and left to dry naturally in a covered barn from June to March (Figure 1a). Leaf samples were then taken before the bundles were fed to housed cattle (Figure 1b and see video at https://vimeo.com/217077820). Leaf samples were oven dried at 40°C until a stable weight was reached, and analysed for neutral detergent fibre (NDF), acid detergent fibre (ADF), lignin and digestible organic matter (DOM) by INRA in France, and for Ca, P, N, Mg, S, K, Fe, Mn, Cu, Zn and B by NRM (www.nrm.uk.com). Results contributed to the Tree Fodder on-line database managed by the Louis Bolk Institute (http://www.voederbomen.nl/nutritionalvalues/).

Figure 1: (a) Harvesting and bundling tree fodder from an ash tree, June 2016 (b) feeding air-dried tree fodder to cattle, March 2017.

Digestible organic matter (DOM) varied between species, with lowest levels recorded for *Salix viminalis* samples collected in August (Table 1). Similarly low levels (42.1%) were recorded in *Salix viminalis* samples from a UK silvoarable SRC system (Smith et al. 2012). However, DOM of the other species was higher (Table 1) and compares favorably with typical livestock forages. Lignin levels were higher in the *Salix viminalis* and *Alnus glutinosa* samples compared to the other three species; this may, however, be due to the samples being taken in August when leaves have matured and become lignified rather than reflecting any species differences.

Table 1: Chemical composition of tree leaves including neutral detergent fibre (NDF), acid detergent fibre (ADF), lignin and digestible organic matter (DOM). DM=dry matter.

Latin name	Date sampled	DM (%)	NDF (%DM)	ADF (%DM)	Lignin (%DM)	DOM (%)
Salix viminalis	Aug-15	33	37.29	22.12	11.33	55.29
Alnus glutinosa	Aug-15	38	37.61	24.76	13.51	76.19
Fraxinus excelsior	Jun-16	39	29.59	14.84	5.02	85.68
Salix caprea	Jun-16	35	32.15	20.57	8.77	73.51
Ulmus minor	Jun-16	37	43.06	12.15	3.31	77.72

The content of selected essential macro- and micro- minerals was tested for the five species of trees. Essential minerals are those which are known to have a metabolic function in animals or plants. All the tested elements increased in the air-dried leaves compared to fresh leaves although where levels were low in the fresh samples, this increase was minimal (Table 2). Levels of phosphorus (an essential element for bones) were highest in the dried goat willow (5.5 g/kg DM) but all trees compare favourably with grass at 2.8-3.5 g/kg DM, silage at 2.0-4.0 g/kg DM and hay at 1.5-3.5 g/kg DM (McDonald et al. 1995).

Table 2: Macro-elements of tree leaves.

Latin name	Date sampled	Ca (g/kg DM)	P (g/kg DM)	N (% w/w)	Mg (g/kg DM)	S (g/kg DM)	K (g/kg DM)
Salix viminalis	Aug-15	18.8	3	2.23	1.8	4.1	10.4
Alnus glutinosa	Aug-15	13.3	2.2	3.16	2.5	1.9	9.1
Fraxinus excelsior	Jun-16	12.8	3.1	1.78	2.2	1.8	14.1
F. excelsior (dried)	Jun-16	16	3.7	2.21	2.7	2.3	20
Salix caprea	Jun-16	10.2	4.2	2.66	1.9	2.1	13.9
S. caprea (dried)	Jun-16	14.5	5.5	2.16	2.7	2.6	19.0
Ulmus minor	Jun-16	11	2.3	2.23	1.9	1.3	14.7
U. minor (dried)	Jun-16	16.8	2.4	2.31	2.8	1.7	20.9

With regards micro-elements, willow was particularly high in zinc, with *Salix caprea* containing 144 mg/kg DM and *Salix viminalis* containing 245 mg/kg DM (Table 3) reflecting previous findings (e.g. Robinson et al. 2005). The level of zinc in willow is substantially higher than those found in grass at 5 mg/kg DM, in silage at 25-30 mg/kg DM and in hay at 17-21 mg/kg DM (McDonald et al. 1995). Zinc is present in all animal tissue, organs and bones, playing an important role in growth, cell repair, hormones, enzyme activation, the immune system, and skin integrity. Levels of iron were notably high in the dried samples and in elm, in particular, at 258 mg/kg DM (Table 3). *Salix viminalis* and *Alnus glutinosa* contained substantially higher levels of manganese than did other tree species (Table 3).

Table 3: Micro-elements of tree leaves.

Latin name	Date sampled	Fe (mg/kg DM)	Mn (mg/kg DM)	Cu (mg/kg DM)	Zn (mg/kg DM)	B (mg/kg DM)
Salix viminalis	Aug-15	73	284	5.5	245	36.7
Alnus glutinosa	Aug-15	92	129	11.2	53	28.9
Fraxinus excelsior	Jun-16	91	25	7.4	18	15.7
F. excelsior (dried)	Jun-16	116	32	9.6	23	17.5
Salix caprea	Jun-16	76	36	7.6	118	12.7
S. caprea (dried)	Jun-16	142	46	10.9	144	18.2
Ulmus minor	Jun-16	138	37	6.5	32	19.3
U. minor (dried)	Jun-16	258	38	9.3	40	26.0

Conclusion

Tree fodder has the potential to play a role in modern livestock systems in the UK; in particular the high levels of minerals in tree fodder suggest that trees can offer an alternative source of supplementation. The higher levels in dried samples, compared to fresh, suggest that there is scope to extend their value beyond the growing season. To take full advantage of this potential, better understanding of the nutritional and health benefits of tree fodder, and more efficient management techniques need to be developed.

Acknowledgements

Thanks to Philippe Barre and the team at INRA for analysing the tree fodder, and to Ted Green and Alun Davies for help with collecting the samples. The AGFORWARD project (Grant Agreement N° 613520; 2014-2017) was co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD, Theme 2 - Biotechnologies, Agriculture & Food.

References

Boeckler GA, Gershenzon J, Unsicker SB (2011) Phenolic glycosides of the Salicaceae and their role as anti-herbivore defenses. Phytochemistry 72: 1497-1509.

DEFRA (2017) The guide to cross compliance in England 2017.

Eichhorn MP, Paris P, Herzog F, Incoll LD, Liagre F, Mantzanas K, Mayus M, Moreno G, Papanastasis VP, Pilbeam DJ, Pisanelli A, Dupraz C (2006) Silvoarable systems in Europe - past, present and future prospects. Agrofor Syst 67: 29-50.

Emile JC, Delagarde R, Barre P, Novak S (2016) Nutritive value and degradability of leaves from temperate woody resources for feeding ruminants in summer. 3rd European Agroforestry Conference, Montpellier, pp 409-412.

Green E (2016) Forgotten food - tree hay. 3rd European Agroforestry Conference, Montpellier.

Hermansen JE, Kongsted AG, Bestman M, Bondesan V, Gonzalez P, Luske B, McAdam J, Mosquera-Losada MR, Novak S, Pottier E, Smith J, van Eekeren N, Vonk M, Burgess PJ (2015) Agroforestry Innovations to be evaluated for Livestock Farmers. Milestone 5.2 (MS 21) for EU FP7 Research Project: AGFORWARD 613520.

Luske B, Meir Iv, Altinalmazis Kondylis A, Roelen S, Van Eekeren N (2017) Online fodder tree database for Europe. Loius Bolk Institute and Stichting Duiboeren, The Netherlands.

Luske B, Van Eekeren N (2017) Nutritional potential of fodder trees on clay and sandy soils. Agroforestry Systems

McDonald P, Edwards RA, Greenhalgh JFD, Morgan CA (1995) Animal Nutrition. Addison Wesley Longman Limited, Harlow, UK.

Ministry of Agriculture Fisheries and Food (1990) UK tables of nutritive value and chemical composition of feedstuffs. Rowett Research Institute, Aberdeen, Scotland.

Robinson BH, Mills TM, Green SR, Chancerel B, Clothier BE, Fung L, Hurst S, McIvor I (2005) Trace element accumulation by poplars and willows used for stock fodder. New Zealand J Agr Res 48: 489-497

Rogosic J, Pfister JA, Provenza FD, Grbesa D (2006) Sheep and goat preference for and nutritional value of Mediterranean maquis shrubs. Small Ruminant Res 64: 169-179.

Smith J, Leach K, Rinne M, Kuoppala K, Padel S (2012) Integrating willow-based bioenergy and organic dairy production - the role of tree fodder for feed supplementation. Tackling the future challenges of organic husbandry Proceedings of the 2nd OAHC, Hamburg, Germany.

Smith J, Kuoppala K, Yañez-Ruiz D, Leach K, Rinne M (2014) Nutritional and fermentation quality of ensiled willow from an integrated feed and bioenergy agroforestry system in UK. Maataloustieteen Päivät 30

EARLY RESULTS OF THE EFFECT OF TWO VARYING CELTIC PIG STOCKING DENSITIES ON IBERO-ATLANTIC OAKWOODS (A CORUÑA, SPAIN)

Silva-Pando FJ[1]*, Alonso Santos M[1], Bustos Vázquez M[1], Ignacio Quinteiro MF[1]

(1) C.I.F. de Lourizán. Xunta de Galicia. Apartado 127. 36080-Pontevedra, España

*Corresponding author: francisco.javier.silva.pando@xunta.es

Abstract

The effect of 2 different pig stocking rates (4 and 8 animals per ha) in a silvopastoral system (SPS) of oak - Celtic pig was evaluated in terms of pig growth and morphometric variables after 7½ months in the forest and the incidence of their manure on the quality of water from fountains and springs. Acorn production was also measured at the trial site as well as at 7 other locations in Galicia. By the end of the fattening period, the pigs had doubled their weight, although the increase was greater in those reared at the high stocking rate (8 pigs/ha). The effect on springs and fountains reflects an increase in physiochemical and microbiological parameters, although low rainfall during the assay year may have altered the results compared to a standard year. Total acorn production varied between 503 and 1,848 kg dry weight (p.s.) per hectare and maximum production rate is found in the second half of September.

Keywords: oakwoods, environment, Celtic pig, carcass, acorns, diffuse contamination

Introduction

Silvopastoral systems (SPS) with Celtic pigs in Galician chestnut groves and oak groves have demonstrated their economic viability and an increasing number of farms have been set up with such a system. Information about this type of system, its effect on the immediate environment, stocking capacity and quality of the carcasses, meat and fat of animals raised on such SPS is scarce. A manual on the Celtic pig [*porco celta*] breed has been published (Lorenzo and Fernández 2013), as has some work on the effects on the environment (Rigueiro et al. 2012).

As a way of understanding the effect of pigs on these systems in Atlantic Galicia more precisely, a trial was set up in order to compare 2 stocking rates. This paper presents the first results about production data and the pigs' morphometric measurements, the effects on spring water and the production of fruit.

Materials and methods

The experimental trial using pigs is located in Rois (C) and is installed in a communal oak forest (*Quercus robur*) with a tree density of 460 per ha, of which 70% are oaks and the rest pines, eucalyptus and other species, with a mean diameter (DAP) of 25 cm and mean height of 16 m. For the breed, we used Celtic pig [*porco celta*] in an extensive farming regime, with stocking densities of 0, 4 and 8 pigs/ha and 3 repetitions. The herds (4 animals per type of treatment plus the repetition), were reared on the farm, fed *ad libitum* with rearing fodder after weaning up to a minimum weight of 60-80 kg (4-6 months of age), at which point they were set loose on the plots in early Spring (April 14, 2017). Females and previously castrated males were randomly distributed on the plots. Fattening in the field was based on wild vegetation and fruits (in the autumn), with 2 kg of feed/head/day until the pigs were removed. The animals were weighed at the outset and at 12 months of age (November 29), after 7½ months roaming free. After that, the animals were slaughtered and their morphometric carcass measurements taken (based on Mayoral 1996, according to Lorenzo and Fernández, 2013). A methodological guide was drawn up for the location of sampling points, sampling and measuring (CIF de Lourizán et al. 2016; Alejano et al. 2011).

There exist several water springs, wells and tanks in the same area downstream from the plots from which samples were collected before and after the pigs' presence. The parameters for analysis were both physiochemical (conductivity, pH, turbidity, ammonium, nitrite, nitrate) and microbiological (total coliforms, *Escherichia coli* and fecal enterococci), determined using official methods.

Acorn production was measured on the experimental plot (Rois, C) and at seven other sites distributed throughout Galicia, NW Spain (Siador, A Lama, Cotobade, Lourizán, PO, A Lastra, Estornin, LU, Xurés, OR). In each locality, 6 x 0.5 m^2 circular collectors (3 static and 3 mobile) were installed (only data from the static units are provided), in a 10 x 10 m square area. Collection took place every fortnight and the acorns were dried in a 60°C oven up to a constant weight.

Results

The pigs went onto the plots with an average weight of 82 kg per head (aged 5-6 months) and at the age of 12 months, they had reached an average weight of 159 kg, thus displaying a growth rate of almost 100% compared to the initial weight. The stocking rate has had a remarkable effect - the initial average weight was 80 and 83 kg (for stocking rates of 4 and 8 pigs/ha respectively) and reached end weights of 140 and 169 kg/pig respectively, which indicates a significant difference between regimes of 29 kg in favor of the higher stocking proportion (Figure 1). Carcass yields grew by over 80%, with a significant difference between the animals in the low stocking rate (84%) and those in the high stocking rate (81%). We did not observe any relationship between carcass weight and fat thickness, although the animals at the high stocking rate had greater fat thickness than those at the low stocking rate. The thickness of dorsal fat or bacon at the 4 measuring points (EDT1, EDT2, EDT3, EDT4) was seen to be high (Table 1), a characteristic feature of the breed. For the high stocking rate group, a strong positive correlation is observed between the end live weight and the perimeter and length of the ankle diameter and compactness index (head-to-tail weight / length ratio, CL). For other parameters, no significant differences were found between stocking rates (Table 1).

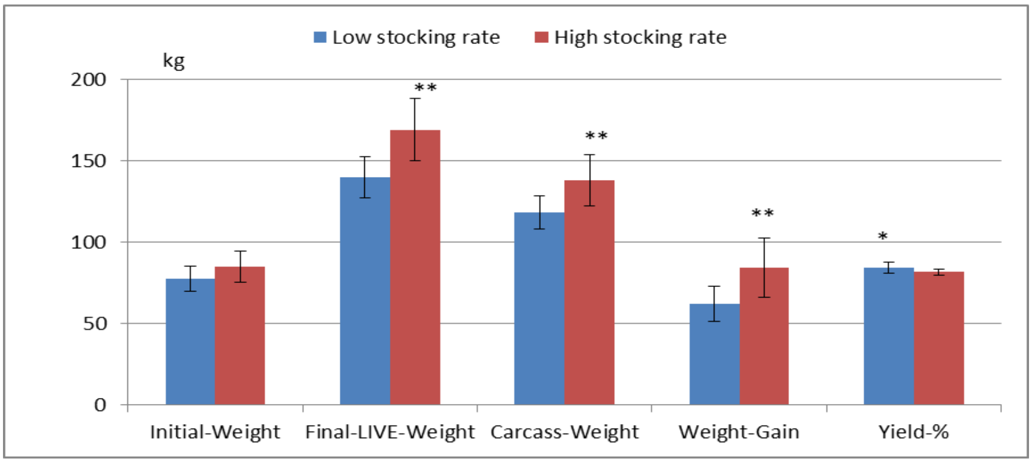


Figure 1: Pig weights (initial, end live, carcass and gain, in kg) and yield (carcass/end live weight ratio in %) on different plots and treatment regimes in Rois. t-test probability, no paired samples (n = 17), two-tailed distribution, two samples assuming unequal variance (** p≤0.05; * p≤0.1).

Table 1: Average morphometric measurements of carcasses. ETD1-EDT4, thickness of back fat or bacon, in mm. LL, leg length; A, ankle diameter; HmL, ham length; PH, perimeter ham; CL, head-to-tail [canal] length; HnL, hand length, all in cm, according to Mayoral (1994) in Lorenzo and Fernández (2013). ([1] semi-extensive system, De la Roza et al. inéd.; [2] extensive system, De la Roza et al. inéd.; [3] Argamentería et al. 2012; [4]Lorenzo and Fernández 2013; *significant difference according to the authors).

	ETD1	ETD2	ETD3	ETD4	LL	A	HmL	PH	CL	HnL
Low stocking Rois	57.2 +12.9	41.7 +9.7	53.9 +11.4	39.0 +10.5	73.2 +1.6	16.4 +0.8	46.1 +1.2	73.3 +4.2	91.8 +2.4	48.0 +5.3
High stocking Rois	64.5 +13.0	44.8 +4.5	55.3 +3.9	43.4 +5.0	73.9 +2.5	16.6 +1.8	46.3 +1.9	72.6 +4.3	93.0 +3.7	43.9 +4.1
Gochu Astur-Celta[1]		18.1*		19.9*	69.6	23.6*	43.3	66.7	93.5	41.1
Gochu Astur-Celta[2]		35.4*		40.9*	70.2	25.3*	46.6	77.6	95.7	42.0
Gochu Astur-Celta[3]		41.1 +1.2		53.5 +1.3	68.9 +6.8	22.5 +2.9	43.7 +4.4	83.7 +8.83	97.1 +8.5	39.7 +4.24
Celtic pig[4]	56.0	40.3	46.7	40.5	72.0		44.9	76.1	91.6	41.1

The soils at the experimental site have developed on granite rock and produced clearly sandy textures (>80% of total sand). To analyze water affectation due to pig manure, it should be taken into account that 2017 was one of the driest years on record (R = +1,000 mm), when the average in the area stands at around 1,700 mm. Towards the end of the fattening period, an increase in some physiochemical parameters can be observed, such as turbidity and conductivity, possibly related to low rainfall. With regard to microbiological parameters, an increase in total coliforms is observed at several of the sampling points -including those at Sources 1a, 1b and 1c, which are not influenced by the test plots- (Figure 2), while a significant increase is observed for *Escherichia coli* and intestinal enterococci at the Source3 sampling point, which is located very close to the edge of one of the plots and thus seems to indicate a certain degree of affectation. The increase in fecal parameters is significant, especially at the Source3 sampling point, because although total coliforms may have increased as a result of concentration due to low rainfall, that does not explain such a remarkable increase in fecal parameters, which were absent before the pigs' arrival, measured in both June 2016 and March 2017. The sustained increase over time in the number of total coliform colonies forming units at distribution Source2 may be related to the decrease in rainfall in 2017.

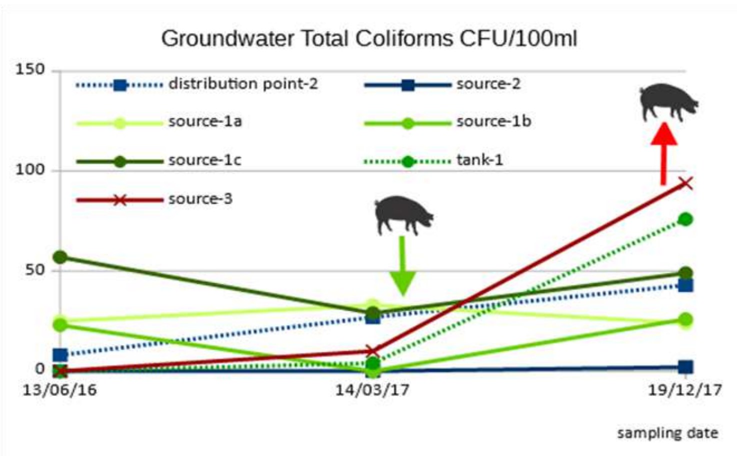


Figure 2: Evolution of total coliforms in springs, tanks and reservoirs, prior to and during the pig fattening period. The green arrow denotes the pigs' arrival on the plots and the red arrow their departure.

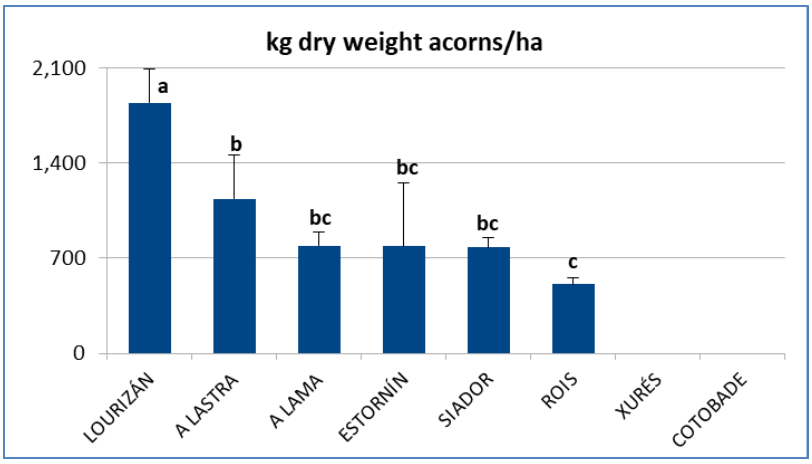


Figure 3: Aggregate dry weight kg/ha during the 2017 campaign at the 8 trial locations. The error bars represent the standard deviation for the mean of the 3 static baskets. Different letters indicate significant differences between localities for p <0.05. Locality factor (F = 9.80, Prob> F 0.0006).

In 2016, the production of acorns was null in the 8 sampling plots, while in 2017 all the locations bore acorns except in 2 (Cotobade, Xurés). The production, with significant differences between localities, varies between 507 in Rois (C) and 1,848 kg p.s./ha in Lourizán (PO), both localities correspond to those of lower height, while in A Lastra, 850 m high, the production was 1,130 kg p.s./ha (Figure 3), but no relationship was observed with height. In general, the highest production of acorns is recorded in the second half of September, although the broadest period of fruition occurs in the plots of height, Estornín and A Lastra (Figure 4). In Siador, the largest acorns were collected, both in length and width, as well as the higher relationship between the them (ratio = 1.7).

Discussion

The data obtained corresponds to a single fattening cycle. The animals at the high stocking rate (8) grew more than the ones at the low stocking rate (4) and lumbar bacon thickness was slightly lower in the latter. Carcass yield was higher at the low stocking rate, compared to those in the high stocking rate group or in other native Iberian and European breeds (De la Roza et al. 2012; Lorenzo and Fernández 2013). Fat thickness in the Rois pigs is clearly greater than for Goucho Astur-Celtic pigs in an extensive regime but similar to that found in semi-extensive farming regimes (Table 1, De la Roza et al. 2017; Argamentería et al. 2012). The results in terms of weights may seem contradictory and may be influenced by the size of the subplots (the plots with the high stocking rate measure 0.5 ha versus the 1 ha of the low stocking rate group) and by the distances the pigs travel within them, so we intend to follow up this matter using GPS this year. The next fattening cycles will confirm these trends.

The impact on waters has probably been affected by the irregular rainfall, so although there is an increase in several parameters at the end of the pigs' fattening period, which is apparently logical, we cannot determine what influence on that the scant rainfall, responsible for the low flow levels in water springs and sources, has played.

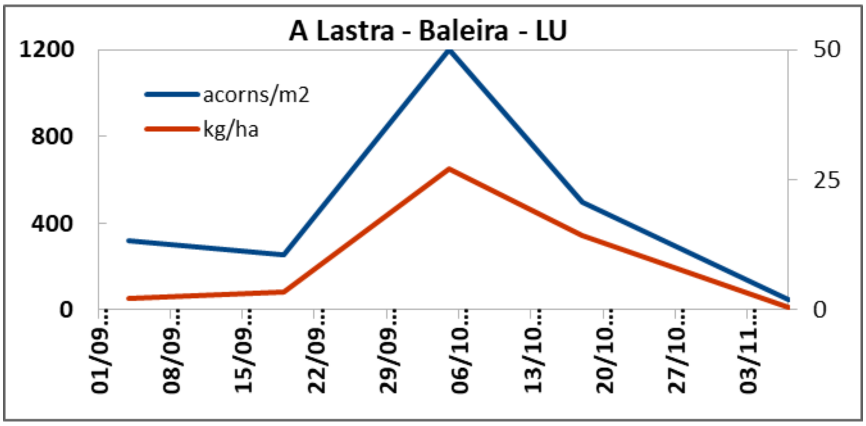


Figure 4: Acorn falling evolution over time in A Lastra (O Cadavo, Lugo) expressed as number of acorns per m2 (blue-right) and d.w. per ha in kg (red-left) in the static collectors. The X axis represents the sampling dates (2017).

Acorn production corresponds to the significant year-on-year variation in oak (*Quercus* spp.) fruit bearing (Johnson et al. 2009), since they bore no fruit in 2016 but they did in 2017) (Figure 3). The values obtained are in general notably higher than in France (Caignard et al. 2017) or in oak or cork oak (*Quercus ilex, Q. suber*) stands in southern Spain, although oak acorns are wider and shorter than those of Ilex or cork oak (Alejano et al. 2011). A comparison of Galician and Polish acorns reveals that the Spanish acorn is bigger and thinner but somewhat shorter (weigth: 3.80 d.w. g; width: 1.54 cm; length: 2.32 cm;) than those described by Luczaj et al. (2014) (weigth: 3.15 d.w. g; width: 1.48 cm; length: 2.71 cm) for Poland, in both cases with a large variability.

Acknowledgements

To María José Rozados (data processing and graphic production), Aurea Pazos and Kike Diz for their field and laboratory work; to CMVMC of Cubela, Cuntimonde and Rois for the transfer of the land and their collaboration with animal management and surveillance. This project RTA2014-00051-C04-01 has been funded by the INIA and the Spanish Ministry of Economics and Competition and co-funded with FEDER funds.

References

Alejano R, Domingo Santos JM, Fernéndez M (2011) Manual para la gestión sostenible de las dehesas andaluzas. Foro para la conseravción y la defensa de la dehesa El Encinal y Universidad de Hueelva. Huelva, Spain.

Argamentería A, Roza-Delgado B, de la Cueto-Ardavín MA, Hidalgo CO, Tamargo C, Rodríguez Pérez A, Fernández García A, Merino MJ, Menéndez Fernández J (2012) Manual del Gochu Asturcelta. Ed. SERIDA. Villaviciosa, Asturias, Spain.

Caignard T, Kremer A, Firmat C, Nicolas M, Samuel Venner S, Delzon S (2017) Increasing spring temperatures favor oak seed production in temperate areas. Natura Com/Scientific Reports 7: 8555.

CIF de Lourizán, USC, SERIDA, NEIKER (2016) RTA2014-00051-C04. Informe sobre metodología de recogida de muestras. Documento interno. Pontevedra, Spain.

De la Roza B, Ciordia M, Feito Díaz I, Modroño Lozano S, Piñeiro Sierra I, Argamentería Gutiérrez A (2017) Calidad diferenciada de la carne de Gochu Asturcelta en régimen extensivo. Información Agraria 19: 23-28.

Johnson PS, Shifley SR, Rogers R (2009) The ecology and Silviculture of Oaks. 2nd ed. CAB International, Wallingford.

Lorenzo JM, Fernández M (coords.) (2013) Manual del Cerdo Celta. Centro Tecnológico de la Carne-ASOPORCEL. Ourense, Spain.

Luczaj L, Adamcsk A, Duda M (2014) Tannin content in acorns (Quercus spp.) from Poland. Dendrobiology 72: 103-111.

Rigueiro A., López-López C., Santiago-Freijanes J.J., Ferreiro Domínguez N, Mosquera-Losada MR (2012) Efecto del pastoreo con cerdo celta sobre el componente edáfico y la producción de pasto en un bosque de Quercus robur L. Cuadernos de la Sociedad Española de Ciencias Forestales 33: 65-70.

FEEDING VALUE OF DIFFERENT PLANT FUNCTIONAL TYPES OF OAK MEDITERRANEAN ECOSYSTEMS

Castro M[1*], Fernández-Núñez E[2]

(1) Mountain Research Centre (CIMO), Polytechnic Institut of Bragança, Campus de Santa Apolónia, 5300- 253. Bragança, Portugal (2) Escuela Politécnica Superior. Campus Terra. Universidad de Santiago de Compostela, 27002 - Lugo, Spain

*Corresponding author: marina.castro@ipb.pt

Abstract

The aim of the study was to assess the seasonal variation of Crude protein (CP) and In vitro organic matter digestibility (IVOMD) of key plant functional types (PFT's) present in oak Mediterranean ecosystems of the North of Portugal. The PFT's were legume, spiny and aromatic for shrubs and sclerophyllous, deciduous and coniferous for trees. PFT's varied in crude protein (CP: 4.16- 15.87% DM) and in digestibility (IVOMD: 34.48-63.36%, $p<0.001$). Legume showed the highest CP and the IVOMD, coniferous showed the lowest CP content and aromatic showed the lowest value of IVOMD. In terms of the capacity of these PFT's to suppress the protein needs of livestock animals considering goats of 45 Kg body weight in dry periods (summer and autumn), the coniferous group alone can't cover the needs for maintenance. In the case of late pregnancy, only legume and deciduous and spiny can cover it.

Keywords: goats; late pregnancy; maintenance North of Portugal; protein needs

Introduction

Different reasons motivate the growing interest for trees and shrubs as fodder for ruminants in the Mediterranean region. They are useful sources of cheap feed for ruminant animals, especially during dry or cool seasons when conventional forages are scarce and of low quality (Olafadehan and Okunade 2018). Further, livestock farmers experience increased food insecurity because of climate change and tree fodders and shrubs resilience to variability in weather patterns (Dawson et al. 2014). However, amongst ligneous species there is a great variability on their feeding value, since the proportion between contents (protein, sugars, starch) and cell walls (cellulose, hemicellulose, lignin), the production of secondary metabolites (phenols, tannins) and other defence mechanisms (thorns) against herbivory depends on the ecological strategy of the plant which influences their chemical composition. For instance, the leaf nitrogen and lignin contents were related with the leaves longevity (Grime et al. 1996). The aim of the study was to assess the seasonal variation of Crude protein (CP) and In vitro organic matter digestibility (IVOMD) of key plant functional types (PFTs) present in oak Mediterranean ecosystems of the North of Portugal. The functional groups were legume, spiny and aromatic for shrubs and sclerophyllous, deciduous and coniferous for trees.

Materials and methods

The study was carried out in Trás-os-Montes, Northeast of Portugal. The species studied were *Quercus pyrenaica* Willd., *Quercus faginea* Lam., as deciduous trees, *Quercus suber* L., *Quercus ilex* L. as sclerophyllous trees and *Juniperus oxycedrus* L. as coniferous trees; *Cytisus scoparius* L., *Cytisus striatus* (Hill) Rothm. and *Cytisus multiflorus* (L'Hér.) Sweet, as legume shrubs, *Genista falcata* Brot., as spiny shrubs, *Lavandula stoechas* L. and *Cistus ladanifer* L. as aromatic shrubs. Samples of the different species were taken along the seasons, In the spring, in April, July in the summer, November in autumn and February in winter. Three samples from each species per location and season were collected, from five randomly selected plants. Samples were air-dried to constant weight in a fan-assisted oven at 60°C for 48h and they were ground in a mill through a 1-mm sieve. Crude protein contents (CP) were evaluated and recorded following the methods of AOAC (1997). In vitro organic matter digestibility (IVOMD) was evaluated using the two-stage technique (Tilley and Terry 1963, modified by Marten and Barnes 1980). CP and IVOMD were analysed by ANOVA (Proc GLM procedure, for the factors “PFTs” and “sampling date”) using the SAS (2001) software. Turkey’s test was used for subsequent pairwise comparisons ($p \leq 0.05$; $\alpha = 0.05$).

Results

PFTs varied widely in crude protein (CP: 4.16- 15.87% DM) and in digestibility (IVOMD: 34.48 - 63.36%, $p<0.001$) (Figure 1). Legume showed the highest CP and the IVOMD, coniferous showed the lowest CP content and aromatic showed the lowest value of IVOMD. CP and IVOMD parameters were significantly influenced by mature stage of plants ($p<0.001$), being the highest values found in spring. The conifers leave this pattern, showing the highest value of IVOMD in autumn (55.05% DM).

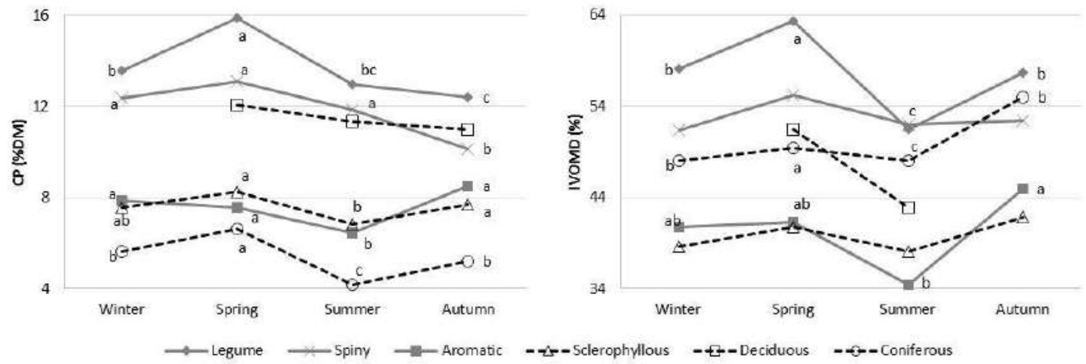


Figure 1: Crude protein content (CP) and In vitro organic matter digestibility (IVOMD) in different functional groups of trees (deciduous, sclerophyllous and coniferous) and shrubs (legume, spiny, and aromatic). Different letters indicate significant differences between seasons in the same functional group.

Discussion

PFTs place a species in a group, the members of which have similar functional attributes (Solbrig 1993). In our study, we considered the N leaves (CP) and the proportion between contents and cell walls (IVOMD). Concerning CP, 4 groups were found, being the legume the one which showed the highest value of CP and the coniferous the one which presented the lowest. One of the other groups is composed by deciduous and spiny, and the other one is composed by sclerophyllous and aromatic. Regarding IVOMD, 4 groups were also found, but different from the first: legume, followed by coniferous and spiny, deciduous, and finally sclerophyllous and aromatic. Feeding value of PFTs showed a great variation between them and along the year. Legume and deciduous and spiny seem a good fodder resource set particularly in periods of food shortage, while the sclerophyllous and aromatic is a poor group in quality of fodder. Also, unfortunately, it is in the summer (dry season), when pastures are very scarce, that their values are at their lowest.

In terms of the capacity of these PFTs to suppress the protein needs of livestock animals considering for instance goats of 45 Kg body weight (7.2% and 11% of DM Intake, NRC 2007), in dry periods (summer and autumn), the coniferous group alone can't cover the needs for maintenance. In the case of late pregnancy, only legume and deciduous and spiny can cover it.

References

AOAC (1997) Official Methods of analysis. 17th ed. Association of Official Analytical Chemists, Washington DC, USA.

Dawson IK, Carsan S, Franzel S, Kindt R, van Breugel P, Graudal L, Lillesø J-PB, Orwa C, Jamnadass R (2014) Agroforestry, livestock, fodder production and climate change adaptation and mitigation in East Africa: issues and options. ICRAF Working Paper No. 178, World Agroforestry Centre, Nairobi.

Grime JP, Hodgson JG, Hunt R, Thompson K, Hendry GAF, Campbell BD, Jalili A, Hillier SH, Díaz S, Burke MJW (1996) Functional types: Testing the concept in Northern England. In: Smith TM, Shugart H, Woodward, FI (eds) Plant functional types. Cambridge University Press, Cambridge, pp 123-131.

Marten GC, Barnes RF (1980) Prediction of energy digestibility of forages with in vitro rumen fermentation and fungal enzyme systems. In: Pigden WC, Balch CC, Grahmam M (eds) Standartization of analytical methodology of feeds. IDRC, Ottawa, pp 61-71.

NRC (National Research Council) (2007) Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids. The National Academies Press, Washington, DC.

Olafadehan OA, Okunade SA (2018) Fodder value of three browse forage species for growing goats. Journal of the Saudi Society of Agricultural Sciences 17: 43-50.

SAS (2001) User's guide, Statistics. SAS Institute Inc. Cary, NC, USA.

Solbrig OT (1993) Plant traits and adaptative strategies: their role in ecosystem function. In: Schulze ED, Mooney HA (eds) Biodiversity and Ecosystem Function. Ecological Studies, 99. Springer, Berlin, pp 97-116.

Tilley JM,Terry RA (1963) A two stage technique for the in vitro digestion of forage crops. J Brit Grassland Soc 18: 104-111.

Session

Innovations in agroforestry

CREATING AGROFORESTRY INNOVATION AND BEST PRACTICE LEAFLETS

Burgess P[1*], Moreno G[2], Pantera A[3], Kanzler M[4], Hermansen J[5], Van Lerberghe P[6], Balaguer F[7], Girardin N[8], Rosati A[9], Graves A[1], Watté J[10], Mosquera-Losada R[11], Waldie K[12], Pagella T[13], Liagre F[8]

(1) Cranfield University, Cranfield, Bedfordshire, MK43 0AL, UK (2) Universidad de Extremadura, Plasencia, Spain (3) Technological Education Institute (TEI) Stereas Elladas, 36100 Karpenissi, Greece (4) Brandenburg University of Technology Cottbus-Senftenberg, Germany (5) Department of Agroecology, Aarhus University, Denmark (6) Institut pour le Développement Forestier, 75116 Paris, France (7) Association Française d'AgroForesterie, 32 000 Auch, France (8) AGROOF, 30 140 Anduze, France (9) Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria (CREA), 00198 Rome, Italy (10) Wervel vzw, 1050 Elsene Belgium; (11) University of Santiago de Compostela, 27002 Lugo, Spain (12) Organic Research Centre, Berkshire, UK (13) World Agroforestry Centre, Nairobi, Kenya

*Corresponding author: P.Burgess@cranfield.ac.uk

Abstract

A key output of the EU FP7 project AGFORWARD was a series of 46 agroforestry innovation and 10 agroforestry best practice leaflets for European farmers and other stakeholders. This paper describes the process of over 80 people working together to create the leaflets and the overall result.

Keywords: promotion; innovation; dissemination; communication; internet

Introduction

As indicated in the abstract, a major output of the EU FP7 project AGFORWARD was a series of 46 agroforestry innovation and 10 agroforestry best practice leaflets. This paper briefly describes the process of creating the innovation leaflets, the best practice leaflets, and an accompanying folder, together with the initial dissemination of the leaflets in hard copy and on the internet.

Creation of the innovation leaflets

The original format of the innovation leaflets was discussed at the Third General Assembly meeting of the AGFORWARD project in Montpellier in 26-27 May 2016. One of the original proposals was a series of case study stories, but eventually the consensus of the participants was that a two-sided leaflet format was the most useful way of describing the wide range of agroforestry innovations tested across 40 stakeholder groups. After the meeting, it was decided to pilot the format using the results from the Italian asparagus and olive system, but it proved difficult to make progress using only electronic communication. The need to use professional design software and the high memory requirements of the high resolution images meant that logistically all of the design work needed to be undertaken at the AGROOF offices in Anduze, France. Eventually in March 2017, the first leaflet was produced through an intensive iterative "try-it and see" process when Cranfield staff visited the AGROOF offices.

Each subsequent leaflet followed the same format of the pilot leaflet. The top of the front page included a number for reference, the title "Agroforestry Innovation", the AGFORWARD logo, a large landscape format photo, the main and secondary titles, and the www.agforward.eu web-address. The remainder of front page was then split into a left-hand column occupying a third of the page and a right-hand column comprising two-thirds. The title of least one column (on 38 of the 46 leaflets) was phrased in the form of a question and there was always at least one additional colourful image. The second side of the leaflet also followed a third and two-thirds of a page column split. The left hand column included a section entitled "Advantages", an image, and the author contact details. The second column provided detailed information about the innovation and always concluded with sources of further information. Eventually by November 2017, 46 agroforestry innovation leaflets were produced describing 15 innovations related to agroforestry of high nature and cultural value, 11 related to agroforestry with high value tree systems, 12 related to agroforestry for arable farmers, and 8 related to agroforestry for livestock farmers (Table 1). The leaflets encompassed 13 countries including Spain (12 leaflets), the UK (7), France (6), Italy and Greece (4), two leaflets each from Germany, Hungary, the Netherlands, Portugal, and Romania, and a single leaflet each from Denmark, Sweden, and Switzerland.

Each of the leaflets was reviewed by at least two participants on the AGFORWARD project for the technical content, and two participants in terms of the English and layout. The initial draft text was created in Microsoft Word, but the final formatting was undertaken by AGROOF using Adobe InDesign. Many of the images used in the design were of high resolution and the process of creating the leaflets necessitated the purchase of additional storage on DropBox file hosting service. The final leaflets were produced in a pdf format with margins suitable for commercial printing, and also as pdfs without margins which could be printed directly from the web. Each of the innovation leaflets is available from the following webpage: http://www.agforward.eu/index.php/en/Innovation-leaflets.html

Table 1: The innovation leaflets co-authored by 83 people covered 46 topics and 13 countries http://www.agforward.eu/index.php/en/Innovation-leaflets.html

Category	No	Title	Country
Agroforestry of high nature and cultural Value (Moreno et al. 2018)	01	Establishing pastures rich in legumes	Spain
	02	Triticale in Iberian dehesas	Spain
	03	Fast rotational intensive grazing	Spain
	04	Tree regeneration in grazed wood pastures	Spain
	05	Managing shrub encroachment in cork oak montado	Portugal
	06	Modelling livestock carrying capacity in montados	Portugal
	07	Rediscovering valonia oak acorns	Greece
	08	Shade tolerant legumes	Italy
	09	Multi-functional hedgerows in the bocage systems of France	France
	10	Invisible fencing in wood pastures	UK
	11	Trees and the restoration of waterways in the Spreewald floodplain	Germany
	12	Restoration of abandoned wood pasture	Hungary
	13	Protecting large old trees in wood-pastures	Romania
	14	Grazing and biodiversity in Transylvanian wood-pastures	Romania
	15	Enhancing reindeer husbandry in boreal Sweden	Sweden
Agroforestry for high value tree Systems (Pantera et al. 2018)	16	Grazing sheep under walnut trees	Spain
	17	Protecting trees in chestnut stands grazed with Celtic pigs	Spain
	18	New approaches to producing selected varieties of chestnut	Spain
	19	Wild asparagus in olive orchards	Italy
	20	Olive trees intercropped with chickpeas	Greece
	21	Olive trees intercropped with cereals and legumes	Greece
	22	Orange trees intercropped with legumes	Greece
	23	Apple orchards grazed in France	France
	24	Economic benefits of grazed apple orchards in England	UK
	25	Key challenges of orchard grazing	UK
	26	Farming with pollards	France
Agroforestry for arable Farmers (Kanzler et al. 2018)	27	Cropping cereals among timber trees	Spain
	28	Productivity and quality of maize under cherry trees	Spain
	29	Intercropping medicinal plants under cherry timber trees	Spain
	30	Organic crops in olive orchards	France
	31	Understorey management in alley cropping systems in France	France
	32	Hybrid poplar and oak along drainage ditches	Italy
	33	Walnut and cherry trees with cereals in Greece	Greece
	34	Agroforestry and decentralised food and energy production	UK
	35	Trees and crops: making the most of the space	UK
	36	Yield and climate change adaptation using alley cropping	Germany
	37	Agroforestry with standard fruit trees in Switzerland	CH
Agroforestry for livestock farmers (Hermansen et al. 2018)	38	Weed suppression in alley cropping in Hungary	Hungary
	39	Commercial apple orchards in poultry free-range areas	NL
	40	Silvopoultry: establishing a sward under the trees	UK
	41	Lactating sows integrated with energy crops	Denmark
	42	Pigs and poplars	Italy
	43	Mulberry (*Morus* spp.) for livestock feeding	Spain
	44	Fodder trees for micronutrient supply in grass-based dairy systems	NL
	45	Fodder trees on dairy farms	France
	46	Combining organic livestock and bioenergy production	UK

CH = Switzerland; NL = the Netherlands; UK = United Kingdom

Creation of the best practice leaflets

Unlike the agroforestry innovation leaflets, the ten best practice leaflets were authored by a single person: Philippe Van Lerberghe of the Institut pour le Développement Forestier in France. In this case, some of the leaflets extended to four rather than two sides. The leaflets are primarily focused on the process of creating an alley cropping system starting with the key objectives, the choice of tree species and planting material, the selection of tree density and planting distances, tree protection, land preparation, mulching, and lastly tree pruning (Table 2). The format of the front page was similar to the innovation leaflets but used an orange, rather than a blue, banner. The last page again provided contact details and a list of references for further information. There was also a similar process for reviewing the best practice leaflets for their technical content and to minimise English and presentation errors.

Table 2: The agroforestry best practice leaflets comprised 10 titles (Liagre et al. 2018) http://www.agforward.eu/index.php/en/best-practices-leaflets.html

Number	Title
01	Alley cropping systems: key objectives
02	Analysing the site and choosing tree species
03	Choosing quality-planting material
04	Planning an agroforestry project
05	Protecting trees against wildlife damage: assessing the options
06	Preparing the land
07	Planting the trees
08	Fitting tree protection to prevent deer damage
09	Mulching for healthy tree seedling
10	Shaping the trees

Creation of the folder, launch and next steps

In addition to the innovation and best practice leaflets, staff at AGROOF also led on the design of a folder to hold the leaflets (Figure 1). A number of designs were reviewed with the final design including four images on the front page to encompass the wide range of agroforestry systems covered. The inside of the folder comprised two flaps. The left-hand flap provided a description of the AGFORWARD project and outlined the nature of the leaflets. The right-hand flap included a montage of nine agroforestry images which could then be opened to reveal the leaflets. Behind the leaflets was a map showing the location of the 46 innovations and the right-hand panel provided the titles listed in Table 1 and a reference for the folder (Balaguer et al. 2017).

a) b)

Figure 1: The 46 innovation leaflets and 10 agroforestry best practice leaflets were included in a folder (Balaguer et al. 2017). The images show the a) front and b) back page of the folder.

The back page of the folder answered the question “What is agroforestry?”, a range of web-links, and the logos of 28 participants in the project. Over 800 hardcopy packs of the leaflets and the folders were assembled at the Wervel offices in Brussels in November 2017 which required substantial manpower! The completed leaflets and folder were launched at the European Parliament on 29 November 2017. The leaflets are now being translated into a range of languages to maximise their impact and the plan is that copies of the folder will be available at the 2018 European Agroforestry Conference.

Acknowledgements

We are thankful to the 83 authors of the innovation leaflets. We acknowledge support of the European Commission through the AGFORWARD FP7 research project (contract 613520). The views and opinions expressed in this report are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

References

Balaguer F, Waldie K, Van Lerberghe P, Liagre F, Girardin N, Pagella T, Burgess PJ (Eds) (2017) Folder for AGFORWARD Agroforestry Innovation and Best practice Leaflets. 8 November 2017. AGFORWARD project. www.agforward.eu (accessed 17/04/2018).

Hermansen JE, Bestman M, Westaway S, Kongsted AG, Bondesan V, Mosquera-Losada MR, Luske B, Novak S, Smith J (2017) Guidelines for improved agroforestry systems for livestock production. Deliverable 5.15 (5.3) for EU FP7 Research Project: AGFORWARD 613520. (15 January 2018), 23 pp. http://www.agforward.eu/index.php/en/guidelines-for-improved-agroforestry-systems-for-livestock-production.html (accessed 17/04/2018).

Kanzler M, Tsonkova P, Arenas G, Dalla Valle C, Desclaux D, Ferreiro-Domínguez N, Guérin O, Herzog F, Jäger M, Kiss-Szigeti N, Mantzanas K, Marosvölgyi B, Mézière D, Mirck J, Moreno G, Mosquera-Losada MR, Panozzo A, Paris P, Rigueiro-Rodríguez A, Romero-Franco R, Schettrer P, Smith J, Vityi A, Wartelle R, Westaway S, Wolfe M, Burgess, PJ (2018) Agroforestry for arable farmers: guidelines. Deliverable 4.12 (4.3) for EU FP7 Research Project: AGFORWARD 613520. (17 January 2018), 33 pp. http://www.agforward.eu/index.php/en/agroforestry-for-arable-farmers-guidelines.html (accessed 17/04/2018).

Liagre F, Van Leberghe P, Balaguer F, Waldie K, Girardin N, Pagella T, Moreno G, Pantera A, Kanzler M, Hermansen J, Burgess PJ (2018) Deliverable 9.30 (9.6) Agroforestry folder for farmers and advisors. AGFORWARD project. 26 January 2018, 45 pp. http://www.agforward.eu/index.php/en/best-practices-leaflets.html (accessed 17/04/2018).

Moreno G, Amaral Paulo J, Aviron S, Berg S, Burgess PJ, Cáceres Y, Catalán M, Chinery F, Crous-Duran J, Eriksson E, Faias S, Firmino P, Franca A, Giannitsopoulos M, Guéhenneuc T, Hartel T, Hernández-Esteban A, Lind T, Menguy C, Mirck J, Oliveira TS, Palma JHN, Palomo G, Papadopoulos A, Pérez-Casenave C, Pershagen E, Poblaciones MJ, Pulido F, Re GA, Sanna F, Rodrígo S, Santamaría O, Thenail C, Tsonkova P, Valinger E, Varga A, Viaud V (2018) Agroforestry of high nature and cultural value: Guidelines for farmers. Deliverable 2.6 for the EU FP7 Research Project: AGFORWARD 613520. (7 January 2018), 37 pp. http://www.agforward.eu/index.php/en/agroforestry-of-high-nature-and-cultural-value-guidelines-for-farmers.html (accessed 17/04/2018).

Pantera A, Burgess PJ, Mosquera-Losada MR, Rosati A, Moreno G, McAdam J, Mantzanas K, Corroyer N, Van Lerberghe P, Ferreiro-Domínguez N, López ML, Santiago Freijanes JJ, Rigueiro-Rodriguez A, Fernández-Lorenzo JL, González-Hernández P, Fraga-Gontán P, Martínez-Cabaleiro M, Chinery F, Eriksson G, Pershagen E, Perez-Casenave C, Giannitsopoulos M, Colin J, Balaguer F (2018) Agroforestry for High Value Tree Systems: guidelines for farmers. Deliverable 3.9 (3.3) for EU FP7 Research Project: AGFORWARD 613520. (17 January 2018), 30 pp. http://www.agforward.eu/index.php/en/agroforestry-for-high-value-tree-systems-guidelines-for-farmers.html (accessed 17/04/2018).

Agroforestry innovation leaflets QR code

Agroforestry best practice leaflets QR code

LESSONS LEARNT FROM THE INTERCROPPING AND GRAZING OF HIGH VALUE TREE SYSTEMS ACROSS EUROPE

Pantera A[1*], Mosquera-Losada MR[2], Burgess P[3], Graves A[3], Ferreiro-Domínguez N[2], Corroyer N[4], McAdam J[5], Rosati A[6], López-Díaz ML[7], Mantzanas K[8], Moreno G[7], Papadopoulos A[1], Papanastasis VP[8], Van Lerberghe[9], Giannitsopoulos M[3]

(1) TEI Stereas Elladas, Karpenissi, Greece (2) University of Santiago de Compostela, Department of Crop Production, University Campus, 27002-Lugo, Spain (3) Cranfield University, Cranfield, Bedfordshire, MK43 0AL, UK (4) Chambre d'agriculture de Normandie, Chemin de la Bretèque, CS 30059, 76232 Bois Guillaume Cedex, France (5) Agri Food and Biosciences Institute, Newforge Lane, Belfast BT9 5PX, UK (6) Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, centro di ricerca Olivicoltura Frutticoltura Agrumicoltura (CRA – OFA), via Nursina 2, 06049 Spoleto (PG), Italy (7), Forest Research Group (INDEHESA), University of Extremadura. Plasencia 10600, Spain (8) Aristotle University of Thessaloniki, Department of Forestry & Natural Environment, Thessaloniki, Greece (9) Institut pour le De´veloppement Forestier, Auzeville-Tolosane, France

*Corresponding author: pantera@teiste.gr

Abstract

Intercropping or grazing of orchards or groves of fruit trees (e.g. olive, carob, pine-nut, walnut, almond, chestnut, apple, pear), or plantations of trees grown for high value timber (e.g. walnut and wild cherry) can be characterized as a "high-value tree agroforestry systems". The systems can be combined with agricultural crops such as chickpeas and barley or grass grazed by sheep. The introduction of sheep to apple orchards can minimise the need for mowing and at the same time provide animal feed for sheep production enterprises. Pollarding is still a living practice in France where it is linked to the management of a traditional hedgerow network known as "bocage". In Spain, hardwood species are commonly grown using rotations of up to 50-60 years, and establishing a legume based mixed pasture understorey and introducing sheep can increase the financial and environmental benefits from such plantations. Chestnut agroforestry is a traditional land use system in Spain after fruit drop. Chickpeas can be a successfully intercropped below orange or olive trees. In addition to chickpeas, olive trees can be intercropped by species such as asparagus and flowers.

Keywords: apple; orange; olive; chestnuts; walnuts

Introduction

Agroforestry is "the deliberate integration of woody vegetation (trees and/or shrubs) as an upper storey on land with pasture (consumed by animals) or an agricultural crop as the lower storey. The woody species can be evenly or unevenly distributed or occur on the plot border. The woody species can deliver forestry or agricultural products or other ecosystem services (i.e. provisioning, regulating or cultural)" (Mosquera-Losada et al. 2016). Agroforestry is a traditional land use system that can help address many current environmental problems. In many agroforestry projects, the focus is on integrating trees within arable or livestock systems. There are also reviews of maintenance and improvement of established wood pasture and hedgerow systems of known cultural and biodiversity significance (Moreno et al. 2017). However an alternative approach is to integrate understorey crops or grazing within existing high value tree systems such fruit orchards, olive groves, or high value timber plantations (Rosati et al. 2012; López-Díaz et al. 2013, 2014). Examples of fruit trees include olive, carob, pine-nut, walnut, almond, chestnut, apple and pear. Trees grown for high value timber in Europe include walnut and wild cherry. Olive trees are one of the most important species in the Mediterranean regions (Camarsa et al. 2016) and apple trees are common in Atlantic and Continental regions (Robertson et al. 2012; Lebon 2016). This article provides an overview of the results from the experiments or field trials that were conducted by ten stakeholder groups with high value tree systems, within the AGFORWARD research project.

Materials and methods

Ten stakeholder groups focused on the intercropping or grazing of high value trees covered apple trees (Burgess 2014; Corroyer 2014; McAdam 2014), olive trees (Pantera 2014a, 2014b; Rosati 2014), and orange trees (Pantera 2014c), chestnut (Mosquera-Losada et al. 2014) and walnut trees (Moreno 2014) (Table 1). The stakeholder groups included farmers, breeders, foresters, landowners, and representatives of regional and national associations, agricultural suppliers, extension services, NGOs, policy makers, and scientists. These stakeholder groups cover the North and South Mediterranean, and the North, Central, and Southern Atlantic agroclimatic zones. In the case of olives (Greece and Italy) and apples (UK and France), the same tree species were studied in different areas with opportunities to compare and exchange ideas, information and knowledge between countries. Even though an initial stakeholders' group was created for walnut in Greece and chestnut trees in Switzerland, these did not continue for local logistical reasons. During 2014, each group identified some potential innovations to be tested and during the next three years detailed experimental and/or economic measurements were taken at each site. Farmers could freely suggest potential innovations and research team members contributed only to facilitating the discussion and on the feasibility of the suggested actions. Depending on the site, some innovations were tested experimentally with replicates or by on-farm demonstrations. Additionally, research team members were responsible for gathering data from each site which included site and system characteristic as well as past and present economic information of the system.

Table 1: Components of selected High Value tree agroforestry systems

System	Tree component	Crop/understorey component	Animal component
Grazed orchards in England, UK	Apple (*Malus domestica* L.)	Perennial ryegrass (*Lolium perenne* L.)	Sheep: Shropshire breed
Grazed orchards in Northern Ireland, UK	Apple cider variety: Coet-de-linge, and dessert variety: Jonagold	Perennial ryegrass	Sheep: mixed breeds including Texel, Belclare, LLeyn and Highlander
Grazed orchards in France	Apple	Perennial ryegrass	Sheep: Shropshire breed
Intercropping of olive groves, Molos, Greece	Olive (*Olea europea*)	Cereals, maize, grape vines, vegetables, grass, and chickpea (*Cicer arietinum*)	Sheep
Intercropping of olive groves, Kassandreia, Greece	Olive (*Olea europea* L.), Pear (*Pyrus* sp.), Pines (*Pinus halepensis* Mill.)	Wheat and barley	No animals
Intercropping in olive orchards, Italy	Olive	Asparagus (*Asparagus acutifolius* L.) and bulbs (*Narcissus* and *Tulipa* species	No animals
Intercropping of orange groves, Greece	Orange (*Citrus sinensis* L.)	Vegetables (here chickpea (*Cicer arietinum* L.)	No animals
Grazing walnut timber plantations in Spain	Hybrid walnut (*Juglans major* x *regia*) Mj209xRa	Grass species	Sheep: Merina breed
Chestnut agroforestry in Galicia, Spain	Chestnut (*Castanea sativa* L.)	*Ulex* sp., *Pteridium* sp. *Rubus* sp., and mushrooms	Pigs: Celtic breed

Results and discussion

The main results are described in terms of two main types of intervention: i) intercropping, and ii) grazing.

Timber from species such as walnut, wild cherry and chestnut and fruit from olive and orange trees can produce high revenues, but some production systems involve substantial energy, water, and agrochemical inputs. The experimental work demonstrated that there are benefits from planting a nitrogen-fixing intercrop, such as chickpeas or alfalfa, rather than investing substantial energy in regular cultivation between the trees. For example, sowing rich-legume pasture in the alleys could roughly double the stocking rate without compromise the tree growth. As an overall conclusion, managing of Mediterranean hybrid walnuts and wild cherry timber plantation under silvopastoral schemes seem a feasible way to reduce the high economical maintenance costs of these plantations and the ecological risks, without compromising their productivity. Similar promising results on the positive effect of the legumes to the walnut overstory were reported by Homar et al. (2014).

As mentioned above, grazing may be beneficial from an environmental and an economic perspective. This is also evidenced from a “chestnut grazed by pig” system in Galicia, Spain. With proper management this system is productive and has many environmental and economic profits, preserving biodiversity, increasing nutrient cycling and enhancing farmer’s income. In specific, adequate stocking rates and space-distribution of the pigs are important to limit any damage to the trees.

Olive is one of the most popular and characteristic trees in the Mediterranean. Based on the results from the three stakeholders groups in Greece and Italy, intercropping can be a successful choice to enhance the farmer’s income while producing multiple products and reducing the need for chemical fertilizers. The choice of the intercrop species is an important parameter in the management scheme of such a system. For example, chickpeas successfully complement olive cultivation, as, besides being a leguminous species that enhances soil nitrogen level, it is also a low water demanding species. Similar results were obtained from a trial in the island of Crete, Greece, where orange trees were intercropped with a leguminous crop. As Greece produces over 0.8 million tonnes of oranges annually (1.1% of total global production), this combination can be a profitable choice for the farmer and the environment. Actually, intercropping with a leguminous species not only enhances soil nitrogen levels, but also increases income to the farmer by the extra product (e.g. chickpeas). There is a plethora of species for intercropping olive groves. For example, in Italy, olives were successfully intercropped with wild asparagus plants and flowers such as narcissus and tulips.

The focus with the apple systems in France and the UK was on the grazing of orchards using sheep. The experiments comparing orchards where the understorey was either grazed or mown demonstrated that orchard grazing can be profitable and productive but it is not suitable for all orchards. Grazing was most successful where the lower branches of the apple trees have already been pruned to a height of at least 1.2 m (to minimise yield loss from the browsing sheep). In these systems tree height is of great importance and should represent an important parameter in the management of such system. Grazing is also likely to be more successful where the apple trees receive a minimal spray programme e.g. grazing is easier in an organic than an intensively-sprayed system. The other two important issues are selection of an appropriate “lowland” sheep breed and regular monitoring of the sheep, the surface height and quality of pasture, and the status of the trees.

Of the numerous traditional agroforestry systems in Europe, “bocage” is one of the popular in South-West France. It represents an excellent example of the wisdom acquired through time where farmers gained as many products as possible by this system such as wood (mostly fire-wood) from the branches of the pollarded trees and dairy products from the livestock grazed.

Conclusion

The intercropping of high value tree systems can help to reduce cultivation costs, while the use of understorey nitrogen-fixing crops can reduce fertiliser needs for the tree crop and maintain or increase tree yields. However it is noted that additional phosphorus may be required in some soil types. The grazing of high-stem orchards and timber plantations, typically with sheep, can reduce mowing costs and provide an additional source of revenue.

Acknowledgment

We are thankful for the responses from a range of stakeholders who spared their time in meetings during 2014. The AGFORWARD project (Grant Agreement N° 613520) was co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD, Theme 2 - Biotechnologies, Agriculture & Food. This research has been co-funded by the Hellenic Ministry of Education, Research and Religion, General Secretariat for Research and Technology.

References

Burgess PJ (2014) Initial stakeholder meeting report: grazed orchards in the UK. http://www.agforward.eu/index.php/en/Grazed_Orchards.html (accessed 23/04/2018).

Camarsa G, Gardner S, Jones W, Eldridge J, Hudson T, Thorpe E, O'Hara E (2016) LIFE among the olives: Good practice in improving environmental performance in the olive oil sector. LIFE report available on line: http://ec.europa.eu/environment/life/publications/lifepublications/lifefocus/documents/oliveoil.pdf (accesed 23/04/2018).

Corroyer N (2014) Initial stakeholder meeting report: grazed orchards in France. http://www.agforward.eu/index.php/en/grazed-orchards-in-france.html (accessed 23/04/2018).

Homar-Sánchez C, Urbán-Martínez I, Rigueiro-Rodríguez A, Mosquera-Losada MR (2014) *Juglans* growth under ploughing and *Vicia villosa* sowing understory management. 2nd European Agroforestry Conference, Cottbus, Germany.

Lebon G. SVPC (2016) Observatoire économique cidricole: couts de production 11 P. Chambre d'agriculture de Normandie, 6 rue des Roquemonts – 14000 Caen France.

López-Díaz ML, Rolo V, Moreno G (2013) Manejo silvopastoral para la producción de madera de calidad: bases funcionales, productividad y servicios ambientales. 6º Congreso Forestal Español. Monte: Servicios y desarrollo rural. Vitoria-Gasteiz, Spain.

López-Díaz ML, Moreno G, Bertomeu M (2014) Pasture management under hardwood plantation: legume implantations vs. mineral fertilization. 2nd European Agroforestry Conference, Cottbus, Germany.

McAdam J (2014) Initial stakeholder meeting report: grazed orchards in Northern Ireland, UK. http://www.agforward.eu/index.php/en/grazed-orchards-in-northern-ireland-uk.html (accessed 23/04/2018).

Moreno G (2014) Initial stakeholder meeting report: grazing and intercropping of plantation trees in Spain. http://www.agforward.eu/index.php/en/grazing-and-intercropping-of-plantation-trees-in-spain.html (accessed 23/04/2018).

Moreno G, Aviron S, Berg S, Crous-Duran J, Franca A, García de Jalón S, Hartel T, Mirck J, Pantera A, Palma JHN, Paulo JA, Re GA, Sanna F, Thenail C, Varga A, Viaud V, Burgess PJ (2017) Agroforestry systems of high nature and cultural value in Europe: provision of commercial goods and other ecosystem services. Agroforestry Systems (2017). https://doi.org/10.1007/s10457-017-0126-1 (accessed 23/04/2018).

Mosquera Losada MR, Ferreiro-Domínguez N, Fernández Lorenzo JL, González-Hernández P, Rigueiro Rodríguez A (2014) Initial stakeholder meeting report: chestnut agroforestry in Galicia, Spain. file:///C:/Users/Nuria/Downloads/WP3_ES_chestnut%20(3).pdf (accessed 23/04/2018).

Mosquera-Losada MR, Santiago-Freijanes JJ, Rois M, Moreno G, Pisanelli A, Lamersdorf N, den Herder M, Burgess PJ, Fernandez-Lorenzo JL, Gonzalez-Hernandez P, Rigueiro-Rodriguez A (2016) CAP and agroforestry practices in Europe. 3rd European Agroforestry Conference, Montpellier, France.

Pantera A (2014a) Initial stakeholder meeting report: intercropping of olive groves in Greece (Kassandreia). http://www.agforward.eu/index.php/en/intercropping-of-olive-groves-in-greece.html (accessed 23/04/2018).

Pantera A (2014b) Initial stakeholder meeting report: intercropping of olive groves in Greece (Molos). http://www.agforward.eu/index.php/en/intercropping-of-olive-groves-in-greece.html (accessed 23/04/2018).

Pantera A (2014c) Initial stakeholder meeting report: intercropping of orange groves in Greece http://www.agforward.eu/index.php/en/intercropping-of-orange-groves-in-greece.html (accessed 23/04/2018).

Robertson H, Marshall D, Slingsby E, Newman G (2012) Economic, biodiversity, resource protection and social values of orchards: a study of six orchards by the Herefordshire Orchards Community Evaluation Project. Natural England Commissioned Reports, Number 090 (accessed 23/04/2018).

Rosati A, Castellini C, Dal Bosco A, Mugnai C, Paoletti A, Caporali S (2012). Olive agroforestry: an inverse approach to agroforestry. 1st European Agroforestry Conference, Brusseles, Belgium.

Rosati A (2014). Initial stakeholder meeting report intercropping and grazing of olive orchards in Italy http://www.agforward.eu/index.php/en/intercropping-and-grazing-of-olive-orchards-in-italy.html (accessed 23/04/2018).

SIDATIM: ASSESSING THE POTENTIAL OF NEW BIOMASS CROPS AND VALUABLE TIMBER TREES IN AGROFORESTRY SYSTEMS

Paris P[4*], Augusti A[4], Burgess P[5], Bury M[6], Chiocchini F[4], Cumplido-Marin L[5], Facciotto G[3], Chiarabaglio PM[3], Graves A[5], Lauteri M[4], Leonardi L[4], Martens R[2], Morhart C[1], Rossi AE[3], Tarchi M[7], Nahm M[1]

(1) Albert-Ludwigs-University, Freiburg, Germany (2) 3N Centre of Experts-Lower Saxony Network for Renewable Resources, Werlte, Germany (3) Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA) - Research Centre for Forestry and Wood Casale M, Italy (4) CNR-Institute of Agro-environmental and Forest Biology, Porano, Italy (5) Cranfield University, Cranfield, UK (6) West Pomeranian University of Technology, Szczecin, Poland (7) W2 Agency, Osimo, Italy

*Corresponding author: piero.paris@ibaf.cnr.it

Abstract

The SidaTim project is investigating new pathways for biomass production for a circular bio-based economy. Part of the project activities are focused on two new bioenergy crops, *Sida hermaphrodita* and *Siphium perfoliatum*, both perennial herbaceous crops, not native to Europe. Sida can produce both biomass for biogas, when freshly harvested with leaves, and “woody” biomass during the dormant season with a moisture content lower than 30%. Silphium can be used as an alternative biogas feedstock to maize, with a water use efficiency higher than the latter in dry seasons. A network of experimental plots was established in 2016 and 2017 in Poland, Germany, the UK, and Italy, comparing Sida and Silphium to maize and *Salicaceae* short rotation coppice. Preliminary results from experimental plots are presented here, along with ecophysiology measurements and biodiversity test. Research activity is being continued concerning the two novel crops on yield, ecology, biodiversity impacts, and their economic integration into agroforestry systems.

Keywords: combustion biomass; biodiversity; biogas; drought adaptation; *Sida hermaphrodita*; *Silphium perfoliatum*

Introduction

Current production methods of producing wood from forests and of crops from agriculture are unlikely to meet the multiple demands put on biomass for food, feed, bioenergy, timber, fibres, and bioplastics within a future circular bio-economy (Morhart et al. 2014). For example, the principal feedstock for much biogas production in Europe is maize (*Zea mays*), which can cover more than 50% of agricultural land in some regions, leading to ecological degradation. Fast growing tree plantations are often not financially attractive to farmers because of their low profitability and lack of flexibility in response to market variation. Hence, new land use approaches are needed to enhance the production of wood and food, as well of biomass for the energy sector. Agroforestry systems, combining trees and crops, can potentially address these issues, with more efficient use of environmental resources and management inputs, whilst providing ecosystem services. New multipurpose biomass crops, which can be easily adapted to standard farm management and market variation, are also required in a future circular bio-economy. The FACCE SURPLUS sponsored project SidaTim (www.sidatim.eu/en) aims to strengthen the circular bio-economy by researching and promoting new land use concepts that comprise innovative multipurpose plant species and novel agricultural management approaches. SidaTim consists of two research pillars (RP). RP1 is assessing the performance of *Sida hermaphrodita* (Sida), a promising multipurpose plant that has received little attention until recently. Potential uses of Sida include: energy provision through both direct combustion of the stem biomass (up to 15 Mg dry matter (dm) ha^{-1} $year^{-1}$ with a moisture rate at harvest <30%) and biogas production from the stems and leaves (up to 25 Mg dm ha^{-1} per year with two harvests; Jablonowski et al. 2017); pollinator food, and use as a material for fibre products, and particle and insulation boards (Nahm and Morhart 2018). Along with Sida, *Silphium perfoliatum* (Silphium) is also being investigated as a promising feedstock for biogas production (Bauböck et al. 2014). It is a perennial plant native to temperate Northern America. Silphium is particularly suitable as an energy crop owing to its low maintenance requirements (lasting up to 15 years without replanting) and high biomass and thus, biogas yields. Additionally, Silphium is an important source of food for pollinating insects (Gansberger et al. 2015).

RP2 is advancing knowledge about the production of valuable timber on agricultural land, particularly along field boundaries. The final objective of the project is to merge the two RPs by assessing and modelling the economic and ecological potential of growing Sida in combination with valuable timber trees. The present contribution focuses on RP1. It presents the preliminary findings obtained by the project so far on: i) Sida and Silphium growth in a network of experimental plots in Europe; ii) eco-physiological characteristics of Sida, and; iii) the ecological values of Sida and Silphium, using a Biological Soil Quality Index.

Experimental plots

Five experimental plots were established by the project in: Poland (53.20°N; 14.58°E), Germany (52.85°N; 7.67°E), the UK (52.07°N; -0.63°E), northern (45.13°N; 8.51°E) and central Italy (41.95°N; 14,78°E). Climate conditions range from sea-continental-warm humid in Poland, to temperate oceanic in Germany and the UK, and to humid-subtropical in Italy. Plots were established in both 2016 and 2017 due to procurement challenges. Experimental designs consist of randomized blocks, for comparing two Sida provenances (Sida 1 and 2, grown from parent stocks in northern and southern Germany, respectively) and one Silphium provenance with two planting methods (sowing and seedling transplanting) and two harvesting methods (for biogas and biomass production). Sida and Silphium seedlings were planted at 44,000 plants ha^{-1}. In some experimental areas the novel crops were compared to reference crops such as maize and short rotation willow coppice (SRC).

In Lipnik, Poland, the average annual temperature was 8.5°C, with an annual precipitation of 555 mm, which peaks in summer. The soil texture was sandy (72% sand) with an acid pH. Two experimental fields were established in 2016. The reference crop is Salix SRC with 44,000 plants ha^{-1}.

In the UK, an experimental area was established in the early part of 2017 near Silsoe, Bedfordshire. The soil was ploughed and harrowed in March 2017, and fenced during May 2017. Silphium and Sida were then planted during June-July 2017 .The Silphium plants, both those planted as seedlings and those sown directly from seed, grew well forming rosettes, and finished 2017 having reached growth stage 3, according to the general BBCH-scale (Jablonowski et al. 2017).

In Germany, at the experimental area of Werlte, the average temperature is 9°C, with the annual precipitation of 768 mm with a summer peak. Soil texture is sandy (76% sand) and acidic (pH = 5.6). The experimental field for the project SidaTim was established in 2016. In this site the reference crop is Silphium planted in 2010 (the oldest Silphium test field in Germany with an annual average yield of 13.1 dm ha^{-1}).

In northern Italy, in the experimental field of Casale the average annual temperature was 12.5°C, with an annual precipitation of 784 mm and a dry period in July. The soil texture was sandy loam with a pH of 7.8-8.0. Experimental plots were established in spring to summer 2016. The reference bioenergy crop was poplar SRC (10,000 cuttings ha^{-1}), with two different harvesting cycles (one and two year). During the growth phase of 2016, Sida1 and 2 were harvested once for biogas and biomass.

In central Italy, in the experimental area of Montenero the average temperature was 17.5°C, with an annual precipitation of 364 mm and a dry period from May to September (monthly reference evapotranspiration varies between 110-150 mm and precipitation is about 23 mm per month). Soil texture was clayey (44% clay) with an alkaline pH. Experimental plots were established during spring and summer in 2017. A sowing treatment was not used for Sida and Silphium, as during preliminary testing, its inefficacy for the local site and seasonal conditions had become evident. The reference bioenergy crop was silage maize, sown at a density of 84,000 seeds ha^{-1}.

Preliminary results of experimental plots

In Poland, during the growth phase in 2016-17, Sida and Silphium were harvested once: for biogas, the average yield was 3.1 Mg dm ha^{-1}, with the highest yield being for Sida1 of 4.5 Mg dm ha^{-1} without any marked difference between seed or seedling planting methods. In 2017, two harvests for biogas were taken in June and October. Sida1 produced 14.4 Mg dm ha^{-1}, and Silphium produced 25.6 Mg dm ha^{-1}.

In the UK, the Sida plants that had been established using seedlings grew well, and reached growth stages 3-7. However, the sown Sida plants generally failed to grow, possibly as sowing had been later than is ideal. Those that did grow reached only growth stage 1. In November 2017 a white fungal infection, probably *Sclerotinia sclerotiorum* was noticed on those Sida plants that had been established as seedlings. Yield results have been recorded and the results are currently being analyzed.

In Germany, marked differences were found between the two planting methods (5.7 vs 13.7 Mg dm ha^{-1} for seed and seedling, respectively), with an annual yield for the first growing season reaching a maximum yield of 16 Mg dm ha^{-1} for Sida2.

In northern Italy, for biomass (January 2017), the average annual yield was 1.9 Mg dm ha^{-1}, with a marked difference in yields between the seed and seedling planting methods (0.54 and 3.20 Mg dm ha^{-1} $year^{-1}$, respectively). In 2017, two biogas harvests were taken in July and October. When planted as seedlings, Sida1 produced 11.2 Mg dm ha^{-1}, and Silphium 14.4 Mg dm ha^{-1}. The yield difference between seedling and seed treatments was very large particularly for Sida. Poplar yield, in a two year cycle, was estimated to be 33.4 Mg dm ha^{-1} after the first two growing seasons, and for a one year cycle it was estimated to be 5.7 Mg dm ha^{-1} in the second year. For Sida and Silphium harvested for biomass production, the yield was 7.1 and 10.3 Mg dm ha^{-1} $year^{-1}$ in October 2017.

For the experimental plots in central Italy, so far, data for biogas production are available, with Sida1 being harvested in late August 2017 after 90 days of cultivation, producing 4.6 Mg dm ha^{-1}, while the maize yield was 18.4 Mg dm ha^{-1}. Drip irrigation was used for both crops, with 225 and 340 mm being applied to Sida1 and maize respectively. A first estimation of the irrigation use efficiency is 23 and 54 kg dm $(ha\ mm)^{-1}$ for Sida1 and maize respectively. Further collection of data and data analysis are in progress.

Ecophysiological performance of Sida

A greenhouse experiment was set up during the summer 2016 at CNR-IBAF in Porano, Italy, to characterise the ecophysiological performance of Sida under drought stress.

Sida seedlings were transplanted in 25 l pots on the 16th of June, adopting two planting densities, 1 or 2 seedlings per pot, in order to evaluate the effects of plant competition. After one month, water stress was applied by an 80% reduction of irrigation. Photosynthesis and predawn leaf water potential (Ψ_{PD}) were measured after one week from drought imposition. After two weeks from drought imposition, the total above ground biomass was collected to measure plant productivity and carbon (C) and nitrogen (N) contents and isotope compositions.

Control plants showed a mean assimilation rate (*A*) of about 15 µmol CO_2 m^{-2} s^{-1}. On average, water stress decreased *A* by about 18% compared to control, despite a decrease in stomatal conductance (g_s) of about 72% and a decrease of around 54% in Ψ_{PD}. These figures were similar for both plant densities, indicating a similar increment of intrinsic water-use efficiency. When considering single plant biomass, control plant yields were about 60.0 g for the low density treatment vs 37.8 g for the high density treatment. When considering control plant biomass on a pot basis, the high density treatment showed a value as high as 75.7 g. Drought stress caused a decrease in dry matter production of 38 and 53% for low and high density treatments, respectively. Nevertheless, in the drought treatment, the amount of biomass produced on a pot basis was about 36 g, irrespective of the plant density.

The C and N contents in Sida leaves did not show any remarkable variation, irrespective of plant density and watering treatment. On the contrary, carbon isotope composition measured on leaf material showed enriched values in drought conditions compared to control ones. As expected, this result is associated to lower *A* rates, owing to the negative effect of water shortage on g_s. Our results indicate that drought effectively decreases Sida productivity. However, increasing plant density did not cause further biomass decrease under drought. Finally, it is noteworthy that, in control conditions, increasing plant density is associated with a higher productivity.

Biodiversity

The Biological Soil Quality Index (BSQ) is based on the evaluation of the community of soil arthropods in the first 10 cm of the soil: these invertebrates are particularly sensitive to soil quality and therefore to human activities (Andrews et al. 2002). In the experimental field in Casale, during the second year, three soil samples about 1 kg were collected for Sida1 and 2, Silphium, poplar and, as a reference, in an agricultural crop (maize) and in a natural forest near to the experimental field. The soil samples of the four sampling sessions were subjected to dynamic extraction of arthropods. In order to calculate BSQ, the eco-morphological indices were assigned to each arthropod extracted. The results obtained show that Sida, Silphium and poplar have a very similar BSQ, while that of maize is slightly lower, and that of natural forest has the highest value. The results of the fourth sampling session indicate that maize has the lowest value (55) whereas Silphium, Sida and poplar are a little higher (respectively 69, 80 and 91). All the data obtained in the cultivated land were much lower compared to natural forest where the index reached a value of 173.

Preliminary conclusions

Given the necessity to replace fossil fuels with renewable energy sources, it seems likely that the interest in Sida and Silphium will increase further, as they combine high biomass productivity with ecologically valuable effects when grown in appropriate climate conditions. It will be interesting to evaluate the biomass productivity of these plants in the coming years, as it is known that both Sida and Silphium productivity increases considerably after the first years of growth (Gansberger et al. 2015; Nahm and Morhart 2018).

At present, however, different important research gaps need to be addressed in addition to collecting further data on yield productivity, thermophysical properties, and the management cost of the examined plant species. For example, Sida and Silphium are neophytes in Europe, and it is of crucial importance to assess their competitive and invasive potentials, as well as their susceptibility to *Sclerotinia sclerotiorum.*

Acknowledgements

SidaTim Project has received funding from the European Union‘s Horizon 2020, grant agreement No 652615 (FACCE-JPI). Funding is provide to each partner by national agencies (see https://www.sidatim.eu/en/)

References

Andrews SS, Karlen DL, Mitchell JP (2002) A comparison of soil quality indexing methods for vegetable production systems in Northern California. Agric Ecosyst Environ 90: 25-45.

Bauböck R, Karpenstein-Machan M and Kappas M (2014) Computing the biomass potentials for maize and two alternative energy crops, triticale and cup plant, with the crop model BioSTAR in the region of Hannover (Germany). Environ Sci Europe 26: 19-31.

Gansberger M, Montgomery LFR, Liebhard P (2015). Botanical characteristics, crop management and potential of *Silphium perfoliatum* L. as a renewable resource for biogas production: A review. Ind Crop Prod 63: 362–372.

Jablonowski ND, Kollmann T, Nabel M, Damm T, Klose H, Muller M, Blasing M, Seebold S, Krafft S, Kuperjans I, Dahmen M, Schurr U (2017) Valorization of Sida (*Sida hermaphrodita*) biomass for multiple energy purposes. GCB Bioenergy 9: 202-214.

Morhart CD, Douglas GC, Dupraz C, Graves AR, Nahm M, Paris P, Sater UH, Sheppard J, Spiecker H (2014) Alley coppice—a new system with ancient roots. Ann For Sci 71: 527-542.

Nahm M, Morhart C (2018) Virginia mallow (*Sida hermaphrodita* (L.) Rusby) as perennial multipurpose crop: Biomass yields, energetic valorization, utilization potentials, and management perspectives. GCB Bioenergy, doi: 10.1111/gcbb.12501.

USING BIOCHAR FROM SEWAGE SLUDGE AND OTHER FEEDSTOCKS IN EUROPEAN AGROFORESTRY: OPPORTUNITIES AND CHALLENGES

Nair VD[1*], Freitas AM[1], Mosquera-Losada MR[2], Ferreiro-Domínguez N[2, 3], Nair PKR[4]

(1) Soil and Water Sciences Department, University of Florida, Gainesville, Florida, USA (2) Department of Crop Production and Engineering Projects, High Polytechnic School, University of Santiago de Compostela, 27002, Lugo, Spain (3) Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda s/n, 1349-017 Lisbon, Portugal (4) School of Forest Resources and Conservation, University of Florida, Gainesville, Florida, USA

*Corresponding author: vdn@ufl.edu

Abstract

Forty to fifty percent of the nutrient-rich sewage sludge (SS) from wastewater treatment plants is used as a soil amendment in Europe and the USA. When applied in excess of crop requirements, this sludge can cause environmental problems due to loss of nutrients to adjacent water bodies. Conversion of SS to biochar likely leads to more stable form of nutrients, decreasing their loss through runoff or leaching, while converting carbon to a more stable phase. A biochar developed from SS and plant residues such as pruned materials from agroforestry systems would result in an interesting soil amendment with properties less detrimental to the environment. Compared with SS biochar, such tailored biochars could be lower in nutrient content and at the same time remove bulky "waste products" from agroforestry systems that would normally have to be moved off-site.

Keywords: anaerobic digestion; animal-based feedstocks; extractable phosphorus; nutrients; plant-based feedstocks

Introduction

Agroforestry systems on arable lands could have the woody components distributed in even or uneven configurations. In Europe, the common practices involve woody components as boundary plantings (along field boundaries) and as hedgerows around field plots. Substantial amounts of woody materials and other biomass products are obtained when these woody components are pruned periodically, which is an essential aspect of their management. These woody materials can be used to produce bioenergy or composted and used as a soil amendment or as a nutrient source. Because of their low nutrient contents and wide carbon: nitrogen (C:N) ratios, however, they by themselves have only limited value as nutrient sources. Combining these materials with other farm residues such as nutrient-rich sewage sludge (SS) – also known as biosolids – and the development of a biochar from it for field application could be one such promising opportunity. This paper examines the scope and potential of this seemingly win-win situation in European agroforestry within the bioeconomy framework.

Sewage sludge from wastewater treatment plants often ends in landfills all over the world. European regulations promote its use as compost, manure, or after anaerobic digestion; but still quite a major proportion goes to landfills. This poses a problem since natural decomposition of the sludge would result in the generation of gases, primarily methane, a greenhouse gas. Moreover, the landfills are getting filled at a rapid rate and creating social problems as most people do not like to have landfills in their vicinity. Further, nutrients such as phosphorus and nitrogen from SS could move out from the landfill and cause eutrophication of nearby water bodies. The high nutrient content of the SS makes it a very valuable fertilizer, but its repeated application could likely result in soil phosphorus (P) saturation and eventual loss of nutrients from the soil (Mosquera-Losada et al. 2010a; 2010b; Ferreiro-Domínguez et al. 2016).

Converting the SS into biochar may lead to more firm retention and less release of nutrients, while converting carbon to a more stable phase. A white paper by the International Biochar Initiative states: “Pyrolysis and gasification—a continuum of thermochemical conversion processes—have been shown to minimize harmful air emissions, while producing energy and biochar, a carbon-rich solid material with beneficial soil health properties.” The paper also pointed out that over 7 million dry tons of stabilized SS was produced per year in the US, of which 49% was used for agricultural land application (IBI 2013).

Sewage sludge application in Europe

The production of SS in Europe has increased in the last century due to the implementation of Directive 91/271/CEE (EU 1991), which makes it mandatory to treat wastewaters in all cities with more than 2000 inhabitants. Over 10 million tons of SS are produced every year in Europe with a projected production of 13 million tons in 2020 (EU 2008). In 2010, about 42% of Europe’s municipal SS was treated and used on farmlands, 27% incinerated, 14% sent to landfills and about 17% disposed off in other ways (EUROSTAT 2018).

Biochar from sewage sludge and other feedstocks

Comparative data on nutrient contents of SS produced by anaerobic processes and their corresponding biochars in Spain and from a US facility (Table 1) can be used to evaluate the potential for using the material as a nutrient source in agricultural and agroforestry systems. All biosolids were converted to biochar using the same process at the University of Florida for the Spain and US samples to minimize differences arising from analyses in different laboratories. We also determined nutrients in biochar prepared from other animal- and plant-based feedstocks (Table 1) including commercial biochar products using the same procedure.

Table 1: Properties of sewage sludge (SS) and their corresponding biochars from i) Spain and USA and ii) non-sewage sludge feedstocks including commercially available products

Material	**Total P**	**TKN**	**M3-P**	**M3-K**
	mg kg^{-1}			
Anaerobic SS (Spain)	19 500	32 960	2 010	910
Anaerobic SS – Biochar (Spain)	21 100	16 400	1 920	720
Anaerobic-composted SS (Spain)	22 600	21 700	2 460	3 080
Anaerobic-composted SS – Biochar (Spain)	39 400	13 900	2 130	2 880
Anaerobic-pelletized SS (Spain)	21 300	32 200	1 560	810
Anaerobic-pelletized SS – Biochar (Spain)	41 300	18 100	2 440	840
Anaerobic SS (USA)	32 500	54 200	10 960	2 220
Anaerobic SS – Biochar (USA)	67 300	50 700	7 060	500
Non-SS feedstocks				
Poultry litter biochar	32 460	34 900	22 370	64 900
Hardwood biochar	870	10	90	4 340
Maple biochar	730	3 050	100	4 140
Pine biochar	410	0	70	450
Commercial products				
Earth Activated biochar (USA)†	12 080	7 230	2 730	3 340
EarthSpring biochar (USA)†	1 560	7 470	300	4 290
BCX biochar (India)‡	710	1 940	60	960

TKN = Total kjeldahl nitrogen; M3-P = Mehlich 3-P; M3-K = Mehlich 3-K

† EarthSpring (50% mixture of hardwood biochar and organic compost) and Earth Activated biochar (obtained from the supplier): http://earthspringbiochar.com/

‡ BCX biochar (from wood chips with microorganisms added; Chatterjee N, personal communication)

A general trend of increases in total P concentrations when SS is converted to biochar is evident from Table 1, but not for extractable P (Mehlich 3-P). Total P and extractable P content of the SS vary substantially depending on the source of material. Many of the differences in releasable P upon conversion to biochar could be related to the biochar source, the biochar-conversion process and the form in which P is held in the biochar. This suggests that the mineral composition of the final product is likely dependent on the origin and process of the SS production. Total nitrogen (TKN) is generally lower in biochar compared to the corresponding SS. Biochar production facilities range from large- to mid-scale in the US and Europe, while small- and micro- scale kilns are used by smallholder farmers to convert agricultural residues to biochar, particularly in Africa and Asia. It is important to follow standardized procedures for conversion of biochar from SS and other feedstocks to ensure a final product of similar quality—a major challenge, irrespective of whether it is produced in local facilities or large commercial biochar plants.

Dari et al. (2016), using an x-ray diffraction procedure identified whitlockite, a sparingly soluble Ca (or Ca-Mg) P form in poultry litter biochar that could behave as a slow release P fertilizer. Similar associations were not found in the biochars from SS in this study. Additional biochar samples from different processes need to be evaluated to determine process-specific benefits of biochar production from SS.

Heavy metal concentrations do not differ much in these samples upon conversion of SS to biochar; mean values obtained in this study were: Cd = 0 mg kg^{-1}; Zn = 240 mg kg^{-1} for the Spain samples and 60 mg kg^{-1} for the USA sample; Pb <18 mg kg^{-1} and Cu < 60 mg kg^{-1} for all samples.

Use of biochar from mixed feedstocks vs. sewage sludge

The differences in biochar properties between animal- and plant-based sources suggest that SS biochar could be combined with biochar from locally available woody materials to create a mix for land application. These tailored biochars could reduce excess nutrients in the SS biochar and at the same time remove “waste products” from agroforestry systems that would normally have to be moved off-site or disposed of otherwise. Commercially available biochar, such as those analyzed in this study, often use combinations of such materials. Addition of biochar while composting is another potential applicability in agroforestry systems.

Other benefits and challenges

Conversion of feedstock to biochar brings about a substantial reduction in the volume of the materials (up to 90% http://earthsystems.com.au/wp-content/uploads/2014/09/Conversion-of-Waste-Wood-to-Biochar.pdf). This makes storage and transportation of biochar easier and cheaper, compared to the raw materials. Nair et al. (2017) have discussed several other desirable properties of biochar in the context of land-application, including increases in nutrient retention, soil carbon sequestration, water-holding capacity and soil microbial activity, and decrease of soil bulk density. Further, conversion of agricultural wastes to biochar could reduce greenhouse gas emission from feedstocks during natural decomposition or burning of the waste material.

Several other issues are important in the context of practical applications of biochar. The price of biochar products varies from country to country: US$ 0.09 kg^{-1} in the Philippines and US$ 8.85 in the US in 2003. Although a viable alternative to chemical fertilizers, the behavior of biochar prepared from varying feedstocks including SS is unpredictable and depends on the soil type where the material is applied (Dari et al. 2016). For example, the rate and frequency of biochar application cannot be the same for a sandy soil where P is readily lost from a soil vs. a high P retentive soil. Adequate information is not available on the impact of adding biochar from varying feedstocks in different agro-ecological settings such as the humid tropics, arid, and semi-arid regions. In brief, it is a challenge to find the ideal rate of application of biochar derived from SS or mixed feedstocks for specific conditions and objectives in agroforestry and other land-use systems. Nevertheless, on-site conversion of locally available waste materials to biochar could be a win-win situation in terms of combined benefits of waste disposal, increased farm outputs, and environmental advantages.

References

Dari B, Nair VD, Harris WG, Nair PKR, Sollenberger L, Mylavarapu R (2016) Relative influence of soil- vs. biochar properties on soil phosphorus retention. Geoderma 280: 82–87.

EU (European Union) (1991) Council Directive of 21 May 1991concerning urban waste water treatment. http://eurlex.europa.eu/legalcontent/EN/TXT/?uri=celex%3A31991L0271 (accessed 25/01/2018).

EU (European Union) (2008) Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0098 (accessed 25/01/2018).

EUROSTAT (Statistical Office of the European Union) (2018) Sewage Sludge and Disposal. http://ec.europa.eu/eurostat/web/products-datasets/product?code=env_ww_spd (accessed 07/02/2018).

Ferreiro-Domínguez N, Nair VD, Freese D (2016) Phosphorus dynamics in poplar silvopastoral systems fertilised with sewage sludge. Agr Ecosyst Environ 22: 87–98.

IBI White Paper: Pyrolysis and gasification of biosolids to produce biochar. 2013. http://www.biochar-international.org/sites/default/files/IBI_white_paper_biosolids_biochar_final.pdf (accessed 25/01/2018).

Mosquera-Losada MR, Ferreiro-Domínguez N, Rigueiro-Rodríguez A (2010 a) Fertilization in pastoral and Pinus radiata D. Don silvopastoral systems developed in forest and agronomic soils of Northwest Spain. Agr Ecosyst Environ 139: 618–628

Mosquera-Losada MR, Muñoz-Ferreiro N, Rigueiro-Rodríguez A (2010 b) Agronomic characterization of different types of sewage sludge: policy implications. Waste Manage 30: 492–503.

Nair VD, Nair PKR, Dari B, Andressa, AM, Chatterjee, N, Pinheiro, FM. (2017) Biochar in the Agroecosystem–Climate-Change–Sustainability Nexus (2017) Front Plant Sci 8. 2051 doi: 10.3389/fpls.2017.02051

AFINET: AGROFORESTRY INNOVATION THEMATIC NETWORK

Villada A[1, 2], Verdonckt P[3], Ferreiro-Domínguez N[1, 4], Rodríguez-Rigueiro FJ[2], Arias-Martínez D[2], Rois-Díaz M[1, 5], den Herder M[5], Paris P[6], Pisanelli A[7], Reubens B[8], Nelissen V[8], Paulo JA[4], Palma JHN[4], Vityi A[9], Szigeti N[9], Borek R[10], Galczynska M[10], Balaguer F[11], Smith J[12], Westaway S[12], Rigueiro-Rodríguez A[1], Mosquera-Losada MR[1]

(1) Department of Crop Production and Engineering Projects, Escuela Politécnica Superior de Lugo, University of Santiago de Compostela; Campus Universitario s/n, 27002 Lugo, Spain (2) European Agroforestry Federation, France (3) INAGRO, Belgium (4) Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda s/n, 1349-017 Lisbon, Portugal (5) European Forest Institute, Yliopistokatu 6, 80100 Joensuu, Finland (6) CNR-Institute of Agro-environmental and Forest Biology, Porano, Italy (7) Istituto di Biologia Agro-Ambientale e Forestale, Consiglio Nazionale delle Ricerche, Porano (TR), Italy (8) Flanders Research Institute for Agriculture, Fisheries and Food, Merelbeke, Belgium (9) University of Sopron Co-operational Research Centre Non-profit Ltd, Hungary (10) Department of Bioeconomy and Systems Analysis, Institute of Soil Science and Plant Cultivation - State Research Institute, Puławy, Poland (11) French Agroforestry Association (AFAF), France (12) Organic Research Centre, Newbury, UK

*Corresponding author: mrosa.mosquera.losada@usc.es

Abstract

AFINET is one of the seventeen thematic networks that the European Union has financed under the H2020 framework and it is supervised by the EIP-Agri in order to foster innovation in Europe. The main topic of AFINET is agroforestry a practice of deliberately integrating woody vegetation with crops and/or animal systems and the promotion of this practice to foster climate changes. AFINET follows a multi-actor approach linked to the nine Regional Innovations Networks created to identify main challenges and develop main innovations about agroforestry. Main challenges were related to technical, economic, communication and policy issues.

Keywords: knowledge transfer; multi-actor approach; silvoarable; silvopastoral

Introduction

Agroforestry (AF) is the practice of deliberately integrating woody vegetation with crop and/or animal systems to benefit from the resulting ecological and economic interactions. It is a highly knowledge intensive practice and system that requires intensive knowledge transfer to encourage agroforestry implementation by farmers. Therefore, the existing gap between research and innovation is even higher in agroforestry compared with other land use systems. To fill the gap, the European Commission launched a series of activities implemented by the European Innovation Partnership in Agriculture (EIP-AGRI) including the Horizon 2020 EU projects called Thematic Networks. AFINET (Agroforestry Innovation Networks) is a thematic network for agroforestry innovation at EU level in order to take up research results into agricultural practice, improving knowledge exchange between scientists and practitioners on agroforestry activities, with a special focus on silvoarable and silvopastoral systems design, management, and production and profitability. AFINET started in 2017 and has a consortium of 12 partners from more than nine countries and proposes an innovative methodology based on: (i) the creation of an EU reservoir of scientific and practical knowledge of agroforestry with end-user friendly access (the “Knowledge Cloud”) and (ii) the creation of a European Interregional network (composed of “Regional Agroforestry Innovation Networks” - RAINs) considering a multi-actor approach (including farmers, policy makers, advisory services, extension services, etc.), and articulated through the figure of the “Innovation Broker” (Figure 1). These RAIN groups will be interconnected in nine strategic regions of Europe from Spain, UK, Belgium, Portugal, Italy, Hungary, Poland, France and Finland, representing different climatic, geographical, social, and cultural conditions at the European level and will meet every six months during the three years of the project. This paper aims to describe the results at the

European level of the first RAIN meetings mainly related with the identification of the knowledge gaps to implement agroforestry.

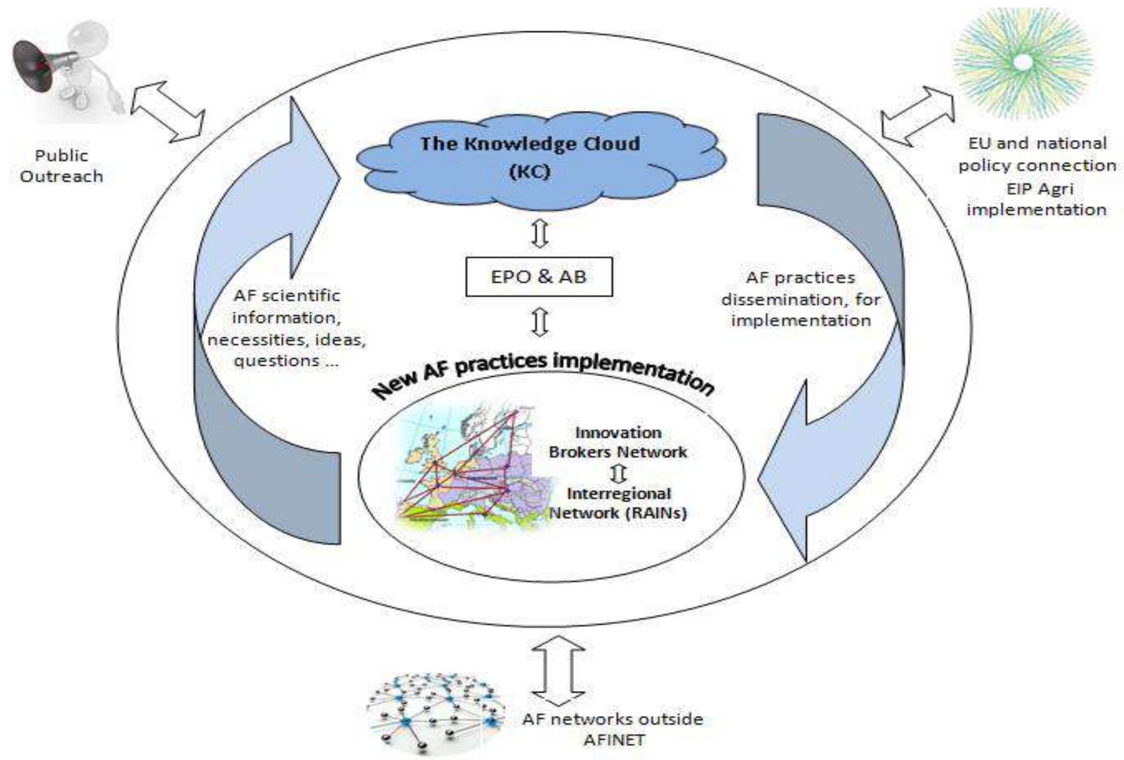


Figure 1: AFINET project concept.

Materials and methods

Nine regional agroforestry networks (RAINs) were developed during the first year of the AFINET project between June and September 2017. A multi-actor approach was used to integrate different actors from a bottom-up perspective. Each meeting was organized through carefully designed and balanced subgroups to which key questions were asked dealing with main gaps and challenges facing agroforestry implementation. The questions were discussed by using the storm of ideas techniques and summarized with post-its on walls. The meetings were facilitated by the innovation brokers.

The selection of the components of the RAINs was carefully conducted following the criteria that at least a 30% of farmers/practitioners should be present as well as the following categories: private partners (i.e. SMEs, tree nurseries, private advisors…), multipliers (i.e. sector and professional associations), researchers and policy makers and administration. All answers were carefully considered by the innovation brokers and partners and summarized as part of a project deliverable.

Results

AFINET meetings had over 30% of farmers (36%) and 26% of researchers; together with the group of advisors and multipliers this makes an excellent composition of the RAIN (22% advisors and multiplers, 7% private partners, 6% policy makers and 3% governmental organizations). Table 1 shows the main gaps and bottlenecks found by all the actors involved in the nine RAINs. Gaps were grouped in four categories: (1) Communication to different types of stakeholders (4 points), (2) Technical aspects (10 points), (3) Economic aspects, Chain development and Commercialization (7) and (4) Administrative and legal aspects.

Discussion

EIP-Agri aims to fill the gap between knowledge and implementation, and following what the actors of the RAINs have highlighted, this is indeed important for extending agroforestry as suggested Mosquera-Losada et al. (2017) in the AGFORWARD policy recommendations. Technical aspects are indeed important to foster agroforestry but it is also necessary to address other aspects more related to socioeconomy (value chain), policy and education.

Table 1: Summary of common bottlenecks, problems or challenges amongst the 9 different regions (AF = agroforestry).

Communication, Dissemination and Awareness raising	**TOTAL**	**Economic aspects, Chain development and Commercialization**	**TOTAL**
Farmer awareness of AF benefits (environmental and financial)	6	Better view on the demand, supply & marketing opportunities for AF products (e.g. Fruits, nuts, poplar wood, new crops)	9
General public AF awareness (high quality products / ecosystem services)	5	Lack of information on cost/benefit analysis of AF systems as compared to monocrops	8
Lack of specialized training on AF including technical, economical and legal/policy aspects.	5	Finding the right tree/ crop/ livestock association to improve profitability	6
Lack of case studies dissemination, best practice examples, experimental farms	4	Lack of valorization of AF products	6
Technical aspects/ management		Valorization of the ecosystem services AF systems provide	5
Information on appropriate species/varieties choice (combination animal, tree, crop)	8	Label/certificate/branding AF for high quality and low impact products	5
Lack of practical guidelines (e.g. pruning, grafting, tree spacing, fertilization, treatments, AF management)	7	Cooperation development for marketing AF products	5
Effective seedling/tree protection (effective and economic)	7	**Administrative and Legal aspects**	
Lack of pilots and demonstration sites	5	Lack or inadequate financial or policy measures to support AF	7
Nutritional value & medicinal function of fruits, pastures, tree fodder	4	Lack of clarity about tree planting under the CAP and its implications	5
Cooperative use of machinery/animals for management	4	Lack of recognition of AF and no legal definition	3
Animal stocking rates in AF systems	3	Subsidy system & legislation designed for big companies while average farms are small	3
Lack of advisors and officers (from the administration) specialized on AF	3	Incompatible policies	3
Lack of knowledge on how AF can help with water management, droughts and climate change adaptation	2		
Lack of specialized human labour	1		

Acknowledgements

This work was funded through the AFINET (www.afinet.eu) project from the European Union´s H2020 Research and Innovation Programme under grant agreement no 727872 and the Xunta de Galicia (Consellería de Cultura, Educación e Ordenación Universitaria (‘’Programa de axudas a etapa posdoutoral DOG n8122, 29/06/2016 p.27443, exp: ED481B 2016/0710’’)). The views and opinions expressed in this article are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

References

Mosquera-Losada MR, Santiago Freijanes JJ, Pisanelli A, Rois M, Smith J, den Herder M, Moreno G, Lamersdorf N, Ferreiro-Domínguez N, Balaguer F, Pantera A, Papanastasis V, Rigueiro-Rodríguez A, Aldrey JA, González-Hernández P, Fernández-Lorenzo JL, Romero-Franco R, Lampkin N, Burgess PJ (2017) Deliverable 8.24: How can policy support the appropriate development and uptake of agroforestry in Europe? https://www.agforward.eu/index.php/en/how-can-policy-support-the-uptake-of-agroforestry-in-europe.html (accessed 06/05/2018).

COMBINING ORNAMENTAL TREE AND FORAGE CROP PRODUCTION USING BOTH FIELD EXPERIMENTS AND MODELLING APPROACH IN THE NETHERLANDS

Erdem F[1*], Hoekstra N[2], Luske B[2], Crous-Duran J[3], Hautier Y[4], Van Eekeren N[2]

(1) Louis Bolk Institute, Bunnik, the Netherlands / Utrecht University, Utrecht, the Netherlands (2) Louis Bolk Institute, Bunnik, the Netherlands (3) Forest Research Centre, School of Agriculture, University of Lisbon, Lisbon, Portugal (4) Research group Ecology and Biodiversity, Utrecht University, Utrecht, the Netherlands

*Corresponding author: frans.erdem@live.nl

Abstract

As a result of a growing need for sustainable agriculture, a silvopastoral agroforestry system combining ornamental trees and forage grass was established in North Brabant, the Netherlands. While the potential of increased benefits is present for this combined system over traditional cultivation, the use of ornamental trees in agroforestry systems is novel and research on its effectiveness is therefore required. The objective of this study was to compare this agroforestry system with current intensive crop cultivation in terms of yield, economic viability, and environmental impact. Research consisted of (1) a field experiment comparing single and double tree rows for two ornamental trees in an alley-cropping setup and (2) modelling using Yield-SAFE to determine potential yield outputs. As the field experiment is currently in progress, only the yield-SAFE results are discussed. Increased awareness of issues with the application of ornamental trees could improve general application of agroforestry in agriculture.

Keywords: ornamental trees; forage grass, yield-SAFE, silvopastoral

Introduction

Agroforestry can provide both economic and ecological benefits as a result of interactions among its components. These include higher productivity through complementary nutrient use, enhanced soil quality, pest and disease control, and increased biodiversity. Silvopastoral agroforestry, which combines tree production with pasture and frequently includes foraging animals, is one of the most popular systems in Europe (Mosquera-Losada et al. 2012; den Herder et al. 2017). Trees in these systems are often used for acquiring fruit, timber, or fodder for animals.

In North Brabant, the Netherlands, cultivation of ornamental trees for planting in communal areas is a major contributor to the local economy. However, several developments have led to a less favourable market, such as rising land costs and decreasing profits from grown trees. Furthermore, high use of pesticides and nitrate leaching degrade the environment, which emphasises the need for more sustainable approaches. As the region is also home to dairy farmers, a silvopastoral agroforestry system combining ornamental trees with forage grass is explored in order to utilize the available land more efficiently and mitigate current shortage of agricultural lands.

This combined cultivation could potentially create benefits in terms of production and environmental impact not present in current monocultural systems. However, the use of ornamental trees in an agroforestry system is novel, and certain aspects of ornamental tree cultivation may cause difficulties. For instance, the production cycle of these trees is much shorter than trees in other agroforestry systems, ranging from four to six years. Additionally, ornamental trees are harvested as a whole, including the roots (Kees van Iersel, personal communication, December 4, 2017). Research on the effectiveness of agroforestry systems including ornamental trees is therefore necessary.

The objective of this study was to compare a novel agroforestry system combining the production of ornamental trees with forage grass with current intensive crop cultivation. Different setups for the agroforestry system were explored, including variable tree density and tree species. Product yields, economic viability, and environmental impacts were compared between these systems. Research is twofold: one field experiment which was established in April 2018 for a duration of three years, and a modelling section with use of Yield-SAFE to determine potential yield outputs of the system's components.

Materials and methods

Field experiment

The field experiment started in April 2018. The elm cultivar 'Columella' (*Ulmus* 'Columella') and honey locust cultivar 'Skyline' (*Gleditsia triacanthos* 'Skyline') were selected for their tolerance for pests and wind, deep root development and small crown for minimizing tree-grass competition, and marketability (Hiemstra 2012; Boomkwekerij Udenhout 2016; Van Den Berk Boomkwekerijen 2018). Perennial ryegrass was selected as crop species for its high quality and palatability as pasture grass (Smit 2005). The field experiment was designed in agreement with participating stakeholders as well as using established literature of optimal agroforestry design. The resulting experimental design will be comparing single and double tree rows for the two different tree species in an alley-cropping setup.

Tree, grass, and soil characteristics are to be measured, as well as interactions between these components. Tree characteristics include trunk circumference, tree height, diameter at breast height (dbh), crown spread and density, branching height, and pest abundance. For grass these are yield and nutritional composition. Soil measurements include dry matter, soil organic matter, soil nutrient content, and nitrogen level. Interactions are measured by light and water competition, and root distribution. Additional measurements are time management and a cost-benefit analysis.

Modelling with Yield-SAFE

The parameter-sparse model Yield-SAFE (van der Werf et al. 2007) was chosen as an accessible method for obtaining yields using climate and soil data. The updated version of Yield-SAFE as part of the AGFORWARD project will be used as this version allows modelling of grasses (Palma et al. 2016). Yield-SAFE was used to model and predict the performance of the different systems in terms of yield, profit, nutrient balance, and make long term predictions of system development.

The model predictions will be compared to data acquired from field experiments. As the field experiment has only started and no results are yet available, only the results of the Yield-SAFE model will be discussed.

Future prospects

Currently, no results can be presented yet. In the current research we are starting to address the lack of research and information on the application of agroforestry in the ornamental tree production sector, and aim to assist the transitioning of current ornamental tree farms into agroforestry systems. Whereas some of the issues are very similar to other agroforestry systems, in this system we also face a number of different challenges and opportunities, for example issues in relation to pest control in trees and the harvesting of tree roots. Increased awareness and knowledge on these issues may also inform the development of agroforestry systems in general.

References

Boomkwekerij Udenhout (2016) Bomenboek 10e editie. Rutten's drukkerij Udenhout, Udenhout.

den Herder M, Moreno G, Mosquera-Losada MR, Palma JHN, Sidiropoulou A, Santiago Freijanes JJ, Crous-Duran J, Paulo J, Tomé M, Pantera A, Papanastasis V, Mantzanas K, Pachana P, Papadopoulos A, Plieninger T, Burgess PJ (2017) Current extent and trends of agroforestry in the EU27. Agriculture Ecosyst Environ 241: 121–132.

Hiemstra JA (2012) De juiste boom, een samenvatting van 15 jaar onderzoek naar de gebruikwaarde van straatbomen.

Mosquera-Losada MR, Moreno G, Pardini A, et al (2012) Past, Present and Future of Agroforestry Systems in Europe. In: Nair PKR, Garrity D (eds) Agroforestry - The Future of Global Land Use. Springer, Dordrecht, pp 285–312.

Palma JHN, Graves AR, Crous-Duran J, Paulo JA, Oliveira TS, Garcia de Jalon S, Kay S, Burgess PJ (2016), Keeping a parameter-sparse concept in agroforestry modelling while integrating new processes and dynamics: New developments in Yield-SAFE. III EURAF Conference, Montpellier, France.

Smit HJ (2005) Perennial ryegrass for dairy cows : Effects of cultivar on herbage intake during grazing. Wageningen University, The Netherlands. http://library.wur.nl/WebQuery/wurpubs/fulltext/121654 (accessed 18/04/2018).

Van Den Berk Boomkwekerijen (2018) Europese Bomenfilter. https://www.vdberk.nl/bomen/ (accessed 12/02/2018).

van der Werf W, Keesman K, Burgess P, Graves A, Pilbeam D, Incoll LD, Metselaar K, Mayus M, Stappers R, Keulen H, Palma J, Dupraz C (2007) Yield-SAFE: A parameter-sparse, process-based dynamic model for predicting resource capture, growth, and production in agroforestry systems. Ecol Eng 29: 419–433.

BREEDING DURUM WHEAT FOR AGROFORESTRY: WHAT TO LOOK FOR?

Gosme M[1*], Panozzo A[2], Desclaux D[2]

(1) SYSTEM, INRA, CIRAD, Montpellier SupAgro, CIHEAM, Montpellier, France (2) DIASCOPE, INRA, Mauguio, France

*Corresponding author: marie.gosme@inra.fr

Abstract

Current varieties of cereals have been selected for conventional agriculture, in full sun conditions. It might be possible to increase crop yield in agroforestry conditions through plant breeding. A total of 31 genotypes (10 pure lines, 14 populations and 7 genetic resources) of durum wheat were tested over three years in two Mediterranean sites in both agroforestry and full sun control. As was expected, yield was reduced in most cases (except in 2015), but the reduction ranged from 8% to 80% depending on the genotypes. In the tested conditions, genetically diverse cultivars (populations) were not better adapted to agroforestry conditions than pure lines. Although no variety performed consistently well in agroforestry throughout all sites and years, the responses of genotypes to the presence of trees were diverse, indicating that selection for agroforestry might be possible. Future breeding programs should focus on improving durum wheat fertility in the shade.

Keywords: alley cropping; *Triticum durum*; shade tolerance; screening

Introduction

Agroforestry, i.e. a land use that combines agriculture and forestry, including the agricultural use of trees (van Noordwijk et al. 2016), provides diverse ecosystem services (Torralba et al. 2016) and as such attracts more and more attention from scientists and some pioneering farmers. However, when considering only crop yield, agroforestry usually results in a decrease compared to the pure crop because of the competition for resources between the crop and the trees (Cannell et al. 1996; Jose et al. 2004). However, as the current varieties of durum wheat were selected for conventional agriculture (Wolfe et al. 2008), it is possible that there is room for improving the performance of the crop in agroforestry conditions through plant breeding. Furthermore, it is often claimed that genetic diversity improves the resistance of crops to biotic and abiotic stresses (Reiss and Drinkwater 2017), so we wanted to test if population varieties were more adapted to agroforestry than pure line varieties. The aim of this work was thus to assess the performance of several varieties of durum wheat (elite pure lines, populations and genetic resources) in different agroforestry conditions as well as in full sun conditions, in order to (i) test the hypothesis that genetically diverse varieties are less negatively impacted by agroforestry conditions than pure lines, (ii) characterize desirable traits of the crop for cultivation in agroforestry systems and (iii) identify interesting varieties to be used as parents in future plant breeding programs for agroforestry.

Materials and methods

The experiment was conducted in two sites over three years (2014-2015, 2015-2016 and 2016-2017, subsequently only the year of harvest is indicated). The first site was located at INRA Melgueil experimental station, South-East of Montpellier in France, which is managed organically by INRA personnel. The second site was located in Restinclières Agroforestry Platform (43°42N, 3°51E), North of Montpellier, which is managed by a conventional farmer. In each site, durum wheat varieties were sown in agroforestry (AF) and full sun (FS) conditions.

Table 1: Proportion of light (sum over the period) available to the crops in agroforestry in comparison with the full sun condition at different periods and different sites. M: measured with light sensors, C: calculated through analysis of hemispherical photographs.

Site	**Period**	**2015**		**2016**		**2017**	
		Dates	Proportion light (%)	Dates	Proportion light (%)	Dates	Proportion light (%)
Restinclières	Before budbreak	12 Jan 15-9 Apr 16	M: n.a. C: 55%	2 Nov 15-1 Mar 16	M: 55% C: 70%		
	After budbreak	9 Apr 16-30 Jun 16	M: 41% C: 40%	1 Mar 16-6 Jul 16	M: 50% C: 42%		
INRA station	Winter	19 Dec 14 30 Mar 15	M: 65%	18 Nov 15-30 Mar 16	M: 62%	3 Dec 16-30 Mar 17	M: 62%
	Spring	1 Apr 15-26 Jun 15	M: 70%	1 Apr 16-25 Jun 16	M: 75%	1 Apr 16-26 Jun 17	M: 70%

The plots used for the experiment contained different tree species, creating different shade intensity and dynamics (Table 1), depending on tree size and type (evergreen/deciduous). In Restinclières, the agroforestry plot in 2015 contained poplars planted in 1999 with 13 m between tree rows and 6 m between trees along the row. In 2016, it contained ash trees planted in 1995 in a 13m x 4m pattern. At INRA, the agroforestry plot contained olive trees planted in 2003 in a 6m x 5m pattern. A total of 31 durum wheat genotypes (10 elite pure lines (PL), 14 populations (POP) and 7 genetic resources (GR), chosen for their phenotypic variability) were tested over the three years, with two replicate microplots in each condition at INRA and 3 replicates in Restinclières. In each microplot, the yield and yield components (plants/m², tillers/plant, spikes/tiller, grains/spike and thousand kernel weight) were measured. Relative yield and yield components were computed as the ratio of the value in agroforestry (averaged for the 2 or 3 microplots of the genotype in a given site-year) on the value in full sun (averaged in the same manner). Data were analysed first with mixed models using package lme4 of R statistical language, considering the genotype as random effect, to test the effect of the conditions (AF, FS), for each site and year separately (INRA 2015-2016-2017, Restinclières 2015 and 2016) on each of the yield components. The two modalities were then compared using Tukey contrasts using package multcomp of R statistical language. The effect of the type of cultivar on the relative components of yield was tested with two-way anovas (conditions, type, and double interactions). In order to study the possibility to predict the suitability for cultivation in agroforestry conditions of a cultivar, we fitted a Partial Least Squares Regression with the components of yield in agroforestry, full sun and as relative values as predictor variables and the yield in agroforestry and the relative yield as response variables. In order to compare varieties in terms of adaptation to cultivation in agroforestry conditions, we computed the average, for each variety, of the yield in full sun expressed as a percentage of the mean yield of the site-year in full sun and the average, for each variety, of the yield in agroforestry conditions expressed as percentage of the yield in full sun conditions.

Results

Due to floods in autumn 2014, wheat sowing was delayed until December 2014 at INRA experimental station and January 2015 in Restinclières. In this latter site, the farmer could not treat the experiment with the rest of his wheat plots so no herbicides or fertilizers were applied. Therefore in this site-year, wheat yield was very low (mean over all varieties and conditions = 0.41 tons of grain dry matter per hectare) compared to the other site-years (1.25 in Restinclières in 2016, 2.45, 1.78 and 2.17 tons of grain dry matter per hectare at INRA in 2015, 2016 and 2017 respectively).

Effect of agroforestry on yield components of durum wheat

Agroforestry conditions significantly reduced grain yield compared to full sun conditions, except in 2015, were grain yield was higher in agroforestry than full sun (significantly so in Restinclières). Relative yields were (mean ± standard deviation) 1.27±0.44, 0.54±0.28, 0.67±0.37, 1.55±0.96 and 0.29±0.09 at INRA in 2015, 2016, 2017, Restinclières 2015 and 2016 respectively. The yield component that was most negatively impacted by agroforestry was the number of grains per spike (in average -31% in agroforestry compared to full sun) and the number of tillers per plant (-25%) (Figure 1). For these two yield components, the value in agroforestry was always significantly lower than in full sun, except in Restinclières 2015 for the number of tillers/plant and at INRA in 2015 for the number of grains per spike, where the difference was not significant. For the other yield components the effect of agroforestry was less clear (Table 2).

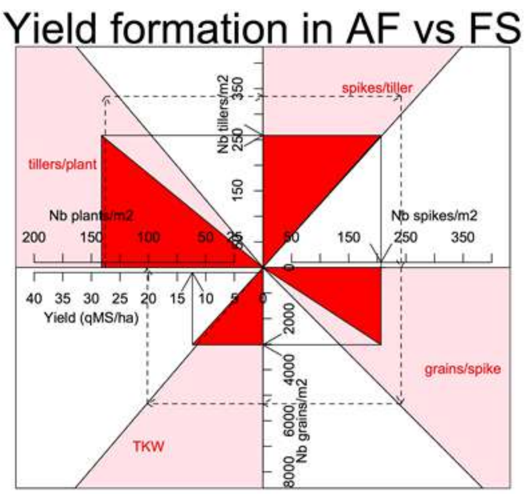


Figure 1: Yield formation in agroforestry (red angles and solid lines) vs full sun (pink angles and dashed lines), average over all sites, years and genotypes.

Table 2: Effect of agroforestry conditions (AF>FS, AF<FS or no significant effect) on yield components in each site-year (I=INRA site, R=Restinclières Estate site, 15-17=years 2015-2017)

site-year component	I15	I16	I17	R15	R16
plants/m2	>	-	>	>	-
tillers/plant	<	<	<	-	<
spikes/tiller	-	>	<	-	-
grains/spike	-	<	<	<	<
TKW	-	>	-	>	-
Yield	-	<	<	>	<

Effect of genetic diversity on relative yield components and relative yield

There was no effect of the type of variety (pure line, population or genetic resource) on relative number of plants/m^2, tillers/plant nor spikes per tiller. There was a significant effect of the type on the relative TKW only at INRA in 2016 with GR>(PL~POP) and in Restinclières in 2016 (PL>POP); and a significant effect on the relative yield only at INRA in 2017, with POP significantly higher than PL but GR not significantly different from POP nor PL.

Indicators of suitability for cultivation in agroforestry

The PLSR results showed that the variables most correlated with yield in agroforestry and relative yield were the number of grains per spike and the relative number of grains per spike, respectively (Figure 2).

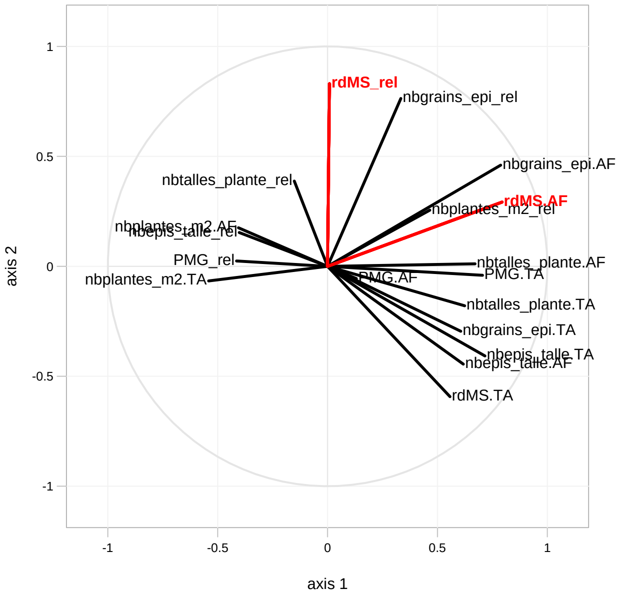


Figure 2: Circle of correlations of the predictor variables (in black) and response variables (in red).

Interesting genotypes for further breeding programs

Due to the experimental problems in 2015 (floods in autumn 2014 that delayed sowing), this year was removed from the subsequent analysis. There was a high variability in the sensitivity of cultivars to agroforestry conditions: considering both sites together, the reduction of yield in AF compared to FS ranged from -8.6% to -79.6% depending on the variety. The performance of each cultivar was considered along two axes: yield in full sun (as a percentage of the mean of all varieties in a given site-year) and relative yield (yield in agroforestry as a percentage of yield in full sun) (Figure 3). Interesting varieties for a future breeding program would have both high yield in full sun and low yield reduction in AF. Based on the result from INRA experiment, these would be POP PROT, POP HR, DAKTER and "POP F2 leg Salernes". Unfortunately, except for POP HR, which has a good relative yield (but a low yield in FS) in Restinclières, the varieties that are identified as interesting in Restinclières (Claudio and Pop Algérie 3) are not the same as at INRA.

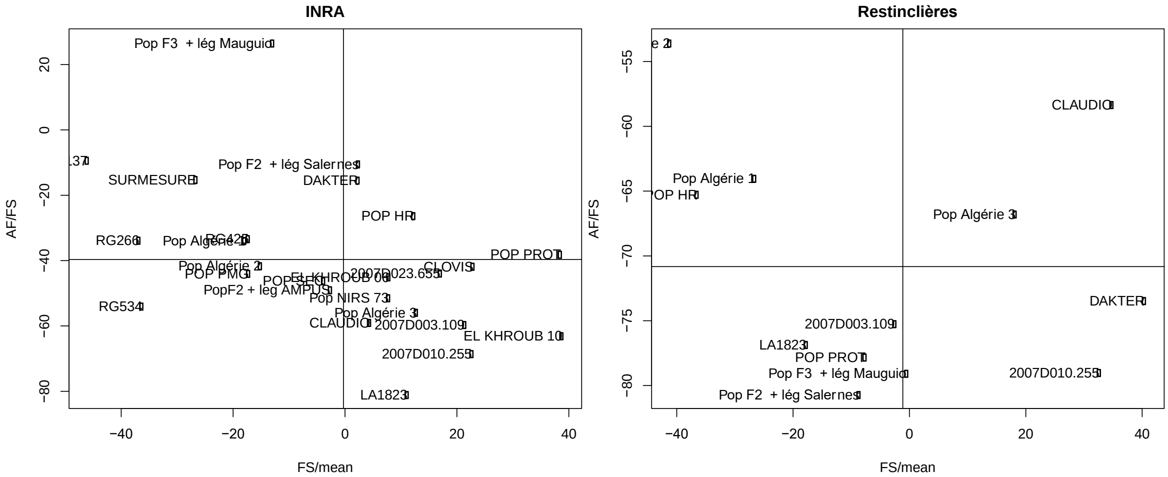


Figure 3: "Performance" of each variety in terms of yield in full sun (expressed as a percentage of the mean yield of the site-year in full sun) and yield in agroforestry (expressed as a percentage of the yield in full sun conditions of the given variety in the given site-year). Horizontal and vertical lines indicate the overall means, dividing the map into 4 groups: 1: high yield in full sun and low reduction in AF; 2: high yield in full sun and high reduction in AF; 3: low yield in full sun and low reduction in AF; 4: low yields in all conditions. Data from 2015 were removed prior to the analysis.

Morphological measurements seem to indicate that plant height and distance from last leaf to spike might be useful for discriminating between the groups, but further analyses are needed to confirm this result.

Discussion and conclusion

As was expected, yield was reduced in most cases (in 2016 and 2017, 90% of the tested genotypes had a relative yield (AF/FS) lower than 1), however, in 2015, 71% of the genotypes had a relative yield higher than 1, indicating that in some conditions (e.g. late sowing), agroforestry can improve yield. Yield reduction ranged from 8% to 80% depending on the genotype. Contrary to our hypothesis, genetically diverse cultivars (populations) were not better adapted to agroforestry conditions than pure lines: except at INRA in 2017, where populations had a high relative yield, populations did not yield significantly better than pure lines and did not have higher yield components. The number of grains per spike was the component of yield that was most negatively impacted by agroforestry and it seems to be a relevant indicator of suitability of plants for cultivation in agroforestry. This may be due to light reduction, which is known to affect cereal fertility. Future breeding programs should focus on improving wheat fertility in the shade. The variability of the genotypes' responses to the presence of trees indicates that selection for agroforestry might be possible. The two agroforestry designs were totally different: the plants were submitted to heavy and constant shade at INRA site (olive trees are evergreen), whereas in Restinclières, the shade varied over time, which might explain why none of the genotypes tested in this experiment performed consistently well in all sites and years. Further analyses are needed in order to disentangle the effects of agroforestry from the effects of the specific sites and years.

References

Cannell MGR, Van Noordwijk M, Ong CK (1996) The central agroforestry hypothesis: the trees must acquire resources that the crop would not otherwise acquire. Agrofor Syst 34: 27–31.

Jose S, Gillespie AR, Pallardy SG (2004) Interspecific interactions in temperate agroforestry. Agrofor Syst 61:237–255.

Reiss ER, Drinkwater LE (2017) Cultivar mixtures: a meta-analysis of the effect of intraspecific diversity on crop yield. Ecol Appl. doi: 10.1002/eap.1629.

Torralba M, Fagerholm N, Burgess PJ, Moreno G, Plieninger T (2016) Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. Agric Ecosyst Environ 230: 150–161.

van Noordwijk M, Coe R, Sinclair F (2016) Central hypotheses for the third agroforestry paradigm within a common definition. World Agroforestry Centre (ICRAF).

Wolfe MS, Baresel JP, Desclaux D, Goldringer I, Hoad S, Kovacs G, Löschenberger F, Miedaner T, Ostergard H, Lammerts van Bueren ET (2008) Developments in breeding cereals for organic agriculture. Euphytica 163: 323–346.

BIOMASS PRODUCTION AND CONCENTRATION OF ROSMARINIC ACID IN *MELISSA OFFICINALIS* L. ESTABLISHED UNDER *PRUNUS AVIUM* L.

Mosquera-Losada MR[1*], Ferreiro-Domínguez N[1, 2], Romero-Franco R[1], González-Hernández MP[1], Rigueiro-Rodríguez A[1]

(1) Department of Crop Production and Engineering Projects, High Polytechnic School, University of Santiago de Compostela, 27002, Lugo, Spain (2) Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda s/n, 1349-017 Lisbon, Portugal

*Corresponding author: mrosa.mosquera.losada@usc.es

Abstract

The production of medicinal plants could be combined with the production of timber from high value trees as *Prunus avium* L. because many medicinal plants are characterised by its capacity to growth under a partial shade. This type of agroforestry practice called silvoarable or forest farming (depending on tree density) could increase the economic and environment benefits of farms. The aim of this study was to evaluate the effect of two tree densities (1333 and 666 trees ha^{-1}) and the fertilisation with sheep manure on the biomass production and the concentration of rosmarinic acid in *Melissa officinalis* L. established under *Prunus avium* L. in Galicia. The results of this experiment did not show a negative effect of *Prunus avium* L. shade on the *Melissa officinalis* L. biomass production. Moreover, the high tree density increased the concentration of rosmarinic acid in *Melissa officinalis* L. probably due to the delay of the flowering caused by the tree. This result is very important from a management point of view because the harvest period could be delayed without decreasing the concentration of active components in the medicinal plants, improving farmer time organization.

Keywords: intercropping; tree density; fertilisation; medical plants; active components

Introduction

About 80% of the people in the world use medicinal plants, being mostly harvested without control, which may reduce the natural populations (Rao et al. 2004). However, in the tropics, many medicinal plants are planted and its natural regeneration is carefully placed in agroforestry systems, mainly due to its capacity to grow in partial shade conditions. In this context, medicinal plants could be intercropped with high value trees such as *Prunus avium* L. This tree species is characterised by a low radiation interception for the understory and a fast growth rate with better financial returns (3000 € m^{-3}) compared with other more extended used tree species in the Galicia region (NW Spain) where this experiment was established (Horgan et al. 2003; Chifflot et al. 2006).

When medicinal plants are intercropped with trees it is important to evaluate the biomass production of the medicinal plants but also the quality and amount of the active components for which the medicinal plants are valued. The production of active components is not directly related to the plant biomass increase and depends among other factors on the edaphoclimatic conditions but also on the duration of the shade effects generated by the trees (Rao et al. 2004). The aim of this study was to evaluate the effect of two tree densities (1333 and 666 trees ha^{-1}) and the fertilisation with sheep manure on the production biomass and the concentration of rosmarinic acid in *Melissa officinalis* L. established under *Prunus avium* L. in Galicia.

Materials and methods

The experiment was established in Boimorto (A Coruña, Galicia, NW Spain) on a plantation of *Prunus avium* L. managed by the Bosques Naturales company. Bosques Naturales is a forestry company focused on the management, maintenance, monitoring and research of high-value hardwood species plantations, mainly walnut and cherry. The plantation of *Prunus avium* L. was carried out in 2008. Initially, the plantation was a mixed stand which was managed to establish *Prunus avium* L. at the final densities of 6 m x 1.25 m and 6 m x 2.5 m, equivalent to 1333 and 666 trees ha^{-1}, respectively. In November 2015, after the soil preparation, *Melissa officinalis* L. was planted in-between tree rows following a randomized block design with three replicates. Medicinal plants were planted in 1.75 m-wide alleys, at 2.12 m distance from the base of the trees. Distance between plants rows was 0.7 m and distance between plants within a row was 0.4 m. Medicinal plants were planted in one of the alleys, whilst the other alley remained uncropped to allow access for machinery for annual pruning and phytosanitary application to the trees. Moreover, medicinal plants were protected with a plastic mesh. The total number of treatments was four because the *Melissa officinalis* L. was established under *Prunus avium* L. planted at two tree densities (1333 and 666 trees ha^{-1}) without fertilisation and with fertilisation (5 t ha^{-1} of sheep manure applied at the beginning of the experiment).

Melissa officinalis L. was harvested in July 2016 and 2017. During the harvests the orientation of the plants in the plot was taking into account. In each plot the central plants and the plants with North orientation (North-Center) were separated from the plants with South orientation (South). The plants were weighed fresh in the field. The mortality of the plants was also recorded. In the laboratory, a subsample of the plants was weighed fresh, dried (36-38ºC) and weighed dry to estimate the dry matter production. The concentration of rosmarinic acid in the leaves of *Melissa officinalis* L. was determined through an UV-V spectrophotometry analysis (RFE, 2002). In this study, the medicinal plants production per hectare was calculated considering the area occupied by the trees and assuming that the medicinal plants were established in all alleys of the plot.

Data were analysed using ANOVA and differences between averages were shown by the LSD test, if ANOVA was significant. The statistical software package SAS (2001) was used for all analyses.

Results

Figure 1 shows that the production of *Melissa officinalis* L. was not significantly modified neither by the tree density, nor the orientation of the medicinal plants in the plots, nor by the fertilisation ($p>0.05$).

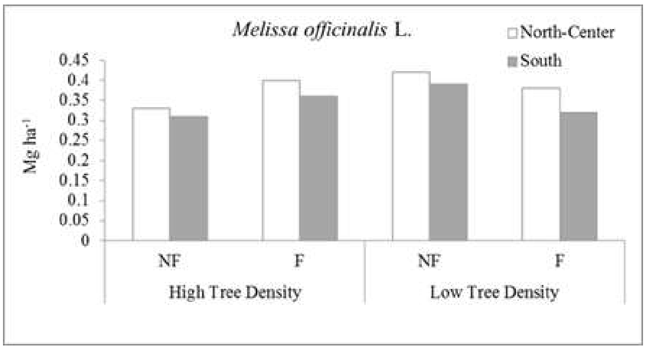


Figure 1: Biomass production of *Melissa officinalis* L. (Mg dry matter ha^{-1}) under *Prunus avium* L. established at different tree densities (high tree density: 1333 trees ha^{-1} and low tree density: 666 trees ha^{-1}) in Galicia (NW Spain) in July 2016. NF: no fertilisation, F: fertilisation with 5 t ha^{-1} of sheep manure. North-Center and South indicate the orientation of the medicinal plants in the plots.

In July 2016, the concentration of rosmarinic acid in the leaves of *Melissa officinalis* L. was higher in the high tree density (1333 trees ha^{-1}) compared with the low tree density (666 trees ha^{-1}) ($p<0.05$) (Figure 2).

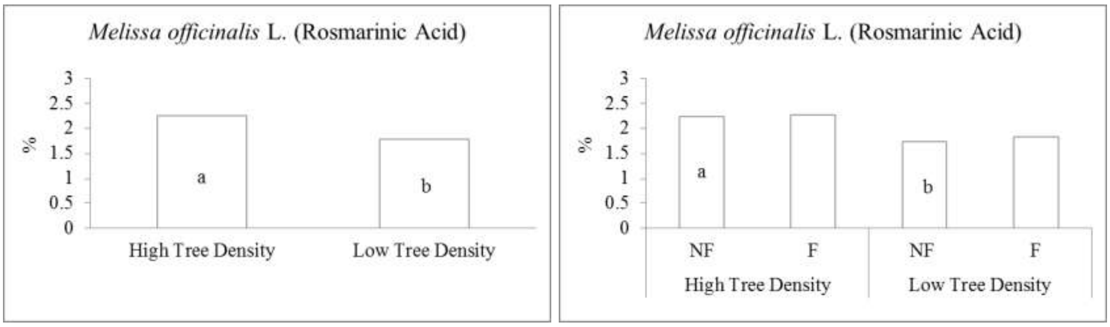


Figure 2: Concentration of rosmarinic acid in *Melissa officinalis* L. (%) under *Prunus avium* L. established at different tree densities (high tree density: 1333 trees ha^{-1} and low tree density: 666 trees ha^{-1}) in Galicia (NW Spain) in July 2016. NF: no fertilisation, F: fertilisation with 5 t ha^{-1} of sheep manure. North-Center and South indicate the orientation of the medicinal plants in the plots. Different letters indicate significant differences between treatments.

The results obtained in the harvest of July 2017 are not shown because the production was very low probably due to drought registered during 2017, being this year the driest year of the last 20 years.

Discussion

The biomass production of *Melissa officinalis* L. obtained in this study (0.31-0.42 Mg DM ha^{-1}) in July 2016 was lower than the biomass production estimated by Douglas (1993) in different areas of New Zealand (0.8 Mg DM ha^{-1}) and by Mihajlov et al. (2013) (0.5 Mg DM ha^{-1}) in the first harvest after the establishment of this medicinal plant in a region of Macedonia. The differences found between our experiment and the studies of these authors could be explained because the experiments were carried out in areas with different climate conditions but also because in our study the land occupied by the trees was discounted.

In this experiment, the biomass production of *Melissa officinalis* L. was not modified by the tree density and the orientation of the medicinal plants in the plots probably because this species is well adapted to partial shade (Canter 2003). These results indicate that this medicinal plant could be intercropped with high value trees as *Prunus avium* L., as long as the management of the plantation, mainly the pruning of branches, is adequate to allow the light inputs to the understory. Moreover, the biomass production of *Melissa officinalis* L. was not affected by the fertiliser applied to the soil probably due to the fertiliser dose was very low to modify the chemical soil properties which remained to be very poor in all plots because the Galician soils are characterised by its low fertility. The pH of the natural Galician soils is generally below 5 when fertilisers and lime are not applied to the soil, mainly due to the rainfall regime and crop extraction (Mosquera-Losada et al. 2017).

Finally, in this study the concentration of rosmarinic acid in *Melissa officinalis* L. (1.28-2.78%) was higher than the minimum required by the European Pharmacopoeia (1%) to process the plant. Moreover, the values of rosmarinic acid were within the interval defined in previous studies (0.5-6.8%) in which it is described that the concentration of this active component in *Melissa officinalis* L. varies with the geographical area and the harvest time (Lamaison et al. 1990; Zgorka and Glowwiak 2001; Wang et al. 2004). In any case, the rosmarinic acid was higher in the high tree density (1333 trees ha^{-1}) compared with the low tree density (666 trees ha^{-1}) probably due to the delay of the flowering period caused by the shade conditions generated by trees. If a delay in flowering happens generally the concentration of this active component is higher because there is more time to accumulate it. This result is very important from a management point of view because the harvest period could be delayed without decreasing the concentration of active components in the medicinal plants, improving farmer time organization.

Conclusion

No negative effect of *Prunus avium* L. shade was found on the *Melissa officinalis* L. biomass production, which makes high value tree plantation an optimum place to combine with medicinal plants. The higher concentration of rosmarinic acid in *Melissa officinalis* L. associated to the high tree density could be explained by the delay of the flowering which improves the farmer time organization to harvest the different plots because the harvest period can be delayed without decreasing the concentration of active components in the medicinal plants.

Acknowledgements

We are grateful to European Commission (AGFORWARD FP7-contract 613520), XUNTA DE GALICIA (Consolidation funds and Consellería de Cultura, Educación e Ordenación Universitaria ("Programa de axudas á etapa posdoutoral DOG nº122, 29/06/2016 p.27443, exp: ED481B 2016/0710")) and Bosques Naturales company (https://bosquesnaturales.com/).

References

Canter PH (2003) The catwalk of CAM, fad and fashion in complementary medicine. FACT 8: 167-168.

Chifflot V, Bertoni G, Cabanettes A, Gavaland A (2006) Beneficial effects of intercropping on the growth and nitrogen status of young wild cherry and hybrid walnut trees. Agrofor Syst 66: 13–21.

Douglas M (1993) Lemon Balm - Melissa officinalis. http://web.archive.org/web/20040203012633/http://www.crop.cri.nz/psp/broadshe/lemon.htm (accessed 26/04/2018).

Horgan T, Keane M, McCarthy R, Lally M, Thompson D (2003) A Guide to Forest Tree Species Selection and Silviculture in Ireland. COFORD, Dublin.

Lamaison JL, Petitjean-Freytet C, Carnat A (1990) Rosmarinic acid, total hydroxycinnamic derivatives and antioxidant activity of *Apiaceae*, *Borraginaceae* and *Lamiceae* medicinals. Annales Pharmaceutiques Francaises 48: 103–108.

Mihajlov L, Ilieva V, Markova N, Zlatkovski V (2013) Organic Cultivation of Lemon Ballm (Melissa officinalis) in Macedonia. J Agri Sci Technol 3: 769-775.

Mosquera-Losada MR, Amador-García A, Muñóz-Ferreiro N, Santiago-Freijanes JJ, Ferreiro-Domínguez N, Romero-Franco R, Rigueiro-Rodríguez A (2017) Sustainable use of sewage sludge in acid soils within a circular economy perspective. Catena 149: 341–348**.**

Rao MR, Palada MC, Becker BN (2004). Medicinal and aromatic plants in agroforestry systems. Agrofor Syst 61: 107-122.

RFE (Real Farmacopea Española) (2002) Agencia Española del Medicamento. 2nd Edition, Ministerio de Sanidad y Consumo, Madrid, Spain.

SAS (2001) SAS/Stat User's Guide: Statistics. SAS Institute Inc., Cary, NC, USA.

Wang H, Provan GJ, Helliwell K (2004) Determination of rosmarinic acid and caffeic acid in aromatic herbs by HPLC. Food Chem 87: 307–311.

Zgorka G, Glowniak K (2001) Variation of free phenolic acids in medicinal plants belonging to the Lamiaceae family. Journal of Pharmaceutical and Biomedical Analalysis 26: 79–87.

BREEDING FOR AGROFORESTRY: IS IT ONLY BREEDING FOR SHADE?

Panozzo A[1], Desclaux D[1*]

(1) DiaScope- Inra – Domaine de Melgueil- 34130 Mauguio, France

*Corresponding author: dominique.desclaux@inra.fr

Abstract

As most of the crop varieties used by farmers were selected in full sun conditions, crop breeding programs looking at agroforestry-adapted cultivars are often reduced as programs for shade-tolerant cultivars. Implementing a breeding program for the understorey crops requires a large surface of agroforestry (AF) design. We evaluated the relevance of a pre-breeding test in a greenhouse (limited area, artificial shade) which may allow to screen a great number of varieties for their adaptation to shade. The artificial shelter test helped to select some interesting genotypes adapted to AF systems but it also may conduct to select uninteresting ones or to reject some others that could be AF adapted. The presence of the trees in the field is not adequately simulated by articificial shade effect in the greenhouse. Numerous others effects occuring in the field like belowground interaction between plants and between plants and trees may have a greater effect on some genotypes than the shade.Thus selecting shade-tolerant varieties is not equal as selecting agroforestry-adapted varieties.

Keywords: greenhouse; field; crop; durum wheat; PAR

Introduction

Several authors assessing light competition in temperate agroforestry systems concluded that the success of agroforestry depends on the selection of shade-tolerant varieties (Artru et al. 2017; Ehret et al. 2015; Friday et al. 2002; Barro et al. 2012). Implementing a breeding program for the understorey crops requires a large surface of agroforestry system to evaluate a wide range of varieties. The main idea of this study is to evaluate the possibility of a pre-breeding test in a greenhouse (limited area) which may allow to screen a great number of varieties for their adaptation to shade. As light is likely to be the principal limiting resource for understorey crops, previous studies tested the effect of artificial shade on crop growth and yield by using different shading materials and for variable periods. Artru et al. (2017) monitored winter wheat growth and productivity under artificial shade provided by camouflage shade-netting, to reproduce a rapidly fluctuating sun/shade pattern. Varella et al. (2011) investigated whether wooden slatted structures reproduced well the daily periodic light fluctuation and the spectral composition observed under trees, in comparison with conventional plastic shade-cloth. In order to mimic the increasing leaf area of walnut trees, Dufour et al. (2013) added overlapping shade cloth during durum wheat growing season. The success of the selection process, according to Varella et al. (2011), depends on the accuracy with which the artificial shade mimics the light environment and the plant responses to it. The aim of the present work was to assess the appropriateness of a permanent shading cloth over durum wheat plants grown in pots (1 plant/pot) inside a greenhouse to be used as pre-breeding test for selecting shade-tolerant genotypes. The main questions were:

- Is the greenhouse environment able to represent the field environment?
- Does the permanent shading cloth in the greenhouse mimic the shade effects determined by olive trees rows in an agroforestry system?
- Is shade the only limiting factor for crop yield in AF system?

Materials and methods

The experiments were conducted at INRA station DiaScope in Mauguio, France (43º35'N, 3º45'E) in 2016 and 2017. 25 genotypes of durum wheat were tested each year in two experimental trials: (i) Field: two treatments: open field without trees (Control) or agroforestry system with natural shade provided by olive trees in an alley cropping design (AF); (ii) Greenhouse : two treatments: without (Control) or with artificial shade (Shade).

Experimental design. **In the field**, 11 populations of durum wheat (*Triticum turgidum durum*) and 14 pure lines were sown (sowing density = 350 seeds/m^2) each year around mid-November (just after olive harvesting) in two experimental conditions: in open field without trees (Control, Figure 1-left) and between trees in an olive orchard (AF: Figure 1-right). AF was a 6x6m design olive orchard and trees have been yearly pruned from 2012. In each treatment, a randomized block design was implemented with two plots (reps) per genotype. Each plot was 1.55 m wide and 10 m long. Each treatment then hosted 50 plots of durum wheat in an annual rotation with legumes crops.

Figure 1: Pictures of the Control treatment (left) and the olive trees/d. wheat AF intercropping treatment (right).

The "pre-breeding test" was implemented inside **a greenhouse** (rigid PVC walls (ONDEX Bio 2 Cristal) and a ground surface of 83 m²). Inside the greenhouse, the same 25 durum wheat varieties were cultivated in pots (one plant/pot) and subjected to two treatments: Control and Shade. Shade effect was created by placing pots under a shelter from sowing to harvesting, three repetitions/treatment (Figure 2). Neither fertilizer neither protection products were used, as in the field trial. The maximal temperature threshold of the greenhouse was set at 25 °C during day hours and at 22 °C during night hours. An irrigation system (capacity of 2 litres/hour) run 10 minutes per two days/week from sowing to harvesting.

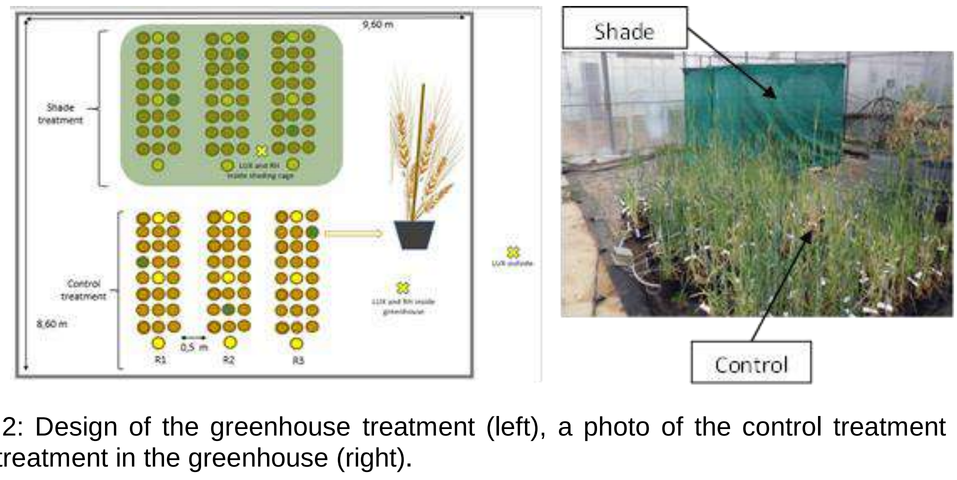


Figure 2: Design of the greenhouse treatment (left), a photo of the control treatment and the shade treatment in the greenhouse (right).

Data collecting. Photosynthetic Active Radiations (PAR) were recorded in the greenhouse via a Luxmeter (Voltcraft-DT 8820) and in the field by pyranometers SP-LITE in the two treatments. The average PAR levels in the greenhouse (Shade) and in the field (AF) treatments were respectively 320 and 250 µmol/m^2/s. Compared to the Controls, these data represent a reduction of PAR equal to 57% in the greenhouse and 50% in the field. Concerning the temperature, no significant differences were found between the two control treatments (greenhouse and field) in the one hand, and the two shade treatments in the other. At maturity the yield and its components were measured for each genotype and repetition.

Results and discussion

Representativity of the greenhouse experience. To assess the representativity of the greenhouse experimentation, the mean yield and yield components of each genotype observed in the greenhouse Control treament were compared to those measured in the field Control (Figure 3). Considering the yield (grains dry matter/plant), the production in the greenhouse was higher than in the field (different scale axis) because of the absence of competition between plants. However, there is a general good correlation between the yield obtained in the greenhouse control treatment and those obtained in the field control treatment (Figure 1, left). The two highest yielding genotypes in the greenhouse reached also the highest results in the field. As the same time, the genotypes with the lowest grains dry matter/plant were also the same in the greenhouse and in the field. However, for some genotypes (outside the ellipse) the greenhouse results do not fit well with the performances reached in the field. Two reasons to explain it: for some of them, the yield was reduced by weeds present in the field in 2016, for others that are populations, the within-cultivars heterogeneity can not be well represented by the choice of 1 plant per pot in the greenhouse!

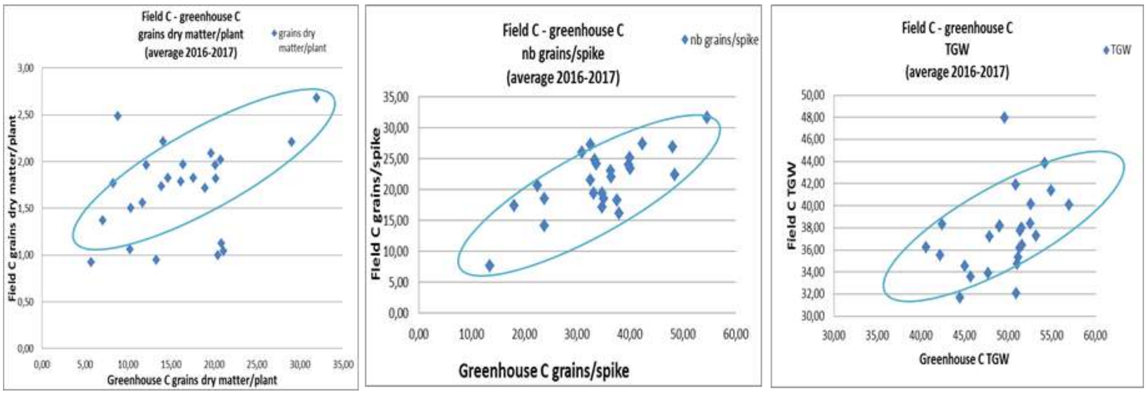


Figure 3: Correlation between Greenhouse Control and Field Control for yield, number of grains per spike and thousand grain weight (TGW)). A point represents the mean of the two years and two reps data for one genotype (without years effect)

Considering the number of grains/spike and the thousand grain weight (TGW), the correlations are higher (same scale axis). The genotypes showing the highest number of grains/spike were the same in the greenhouse and in the field as were the genotypes with the lowest rate. Concerning TGW, the two points outside the ellipse are two durum wheat populations. We can therefore conclude that the Control greenhouse experiment is able to represent the results of field Control, mainly for the pure lines genotypes.

Rank of the genotypes in the shade treatments. The mean yield and yield components of each genotype observed in the greenhouse Shade treament were compared to those measured in the olive tree orchard (AF treatment; Figure 4).

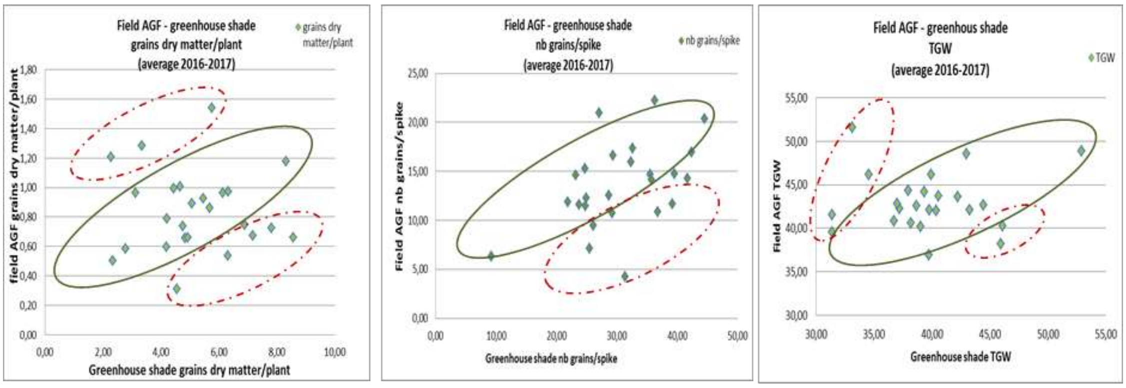


Figure 4: Correlation between Greenhouse shade and Field AF treatments for the yield (grain dry matter/plant), the nb of grains/spike and the thousand grains weight

The correlations between the greenhouse (shade) and field (AF) treatments are lower compared to those obtained for the two control treatments: the three highest yielding genotypes in the field were not the highest in the grenhouse (red ellipse above the green), and some others reaching the best yields in the greenhouse were under the mean in the field (dashed ellipse over the full line one). However, for some genotypes, the results obtained in the greenhouse shade treatment fit well the results obtained in the field AF treament (full line ellipse). Almost the same remarks can be made for the considered yield components (grains/spike or TGW). The points out of the full line ellipse are not all coming from populations. For these genotypes we might suppose that light was not the major or not the only limiting factor determining yield results.

In the greenhouse, the choice of growing each plant in a single pot avoided not only the belowground interaction with olive trees, but also any effect due to competition with neighboring durum wheat plants. In this way, the factor “light” was isolated from all possible belowground interactions. We may suppose that when field performances are well simulated by the greenhouse shade test, for these genotypes light is really the major limiting factor reducing yield. Considering the yield, genotypes situated in the bottom right part of the graphic (Figure 4; high level in the greenhouse, low level in the field), seem to be more sensitive than others to limiting factors other than light encountered in AF field conditions, such as belowground interaction/competition for water and nutrients. On the other hand, the three best yielding genotypes in the field, showing a low yield in the greenhouse (top left part of Figure 4) seem to have been more affected than other genotypes by the permanent shade effect of the shelter in the greenhouse. The PAR reduction in the shade greenhouse treatment was higher than in AF treatment and it seems that some genotypes cannot afford such level of light reduction.

Conclusion

As most of the crop varieties used by farmers were selected in full light conditions, crop breeding programs looking for shade tolerant traits are necessary to select cultivars adapted to agroforestry (Retkute et al. 2015). As the test implemented in greenhouse conditions without shade gives the same genotypes ranking than the full sun field test, we may conclude that the greenhouse is representative of the outdoor conditions and may be of interest to select the high-yielding varieties and eliminate the low-yielding ones. Moreover it requires less surface and therefore allows an economic gain. However, considering the selection for Agroforestry adaptation, permanent shelter in a grenhouse may help to identify some genotypes; but for some others, we conclude that the presence of trees in the field cannot be simulated by only shade effect in the greenhouse. Numerous others effects occuring in the field like belowground interaction between plants and between plants and trees may have a greater effect on some genotypes than shade. Therefore, by using the greenhouse shelter test, a breeder may reject some interesting varieties or select others varieties that might not be the best in the field. Thus selecting for shade-tolerant varieties is not equal as selecting for agroforestry-adapted varieties.

References

Artru S, Garré S, Dupraz C, Hiel MP, Blitz-Frayret C, Lassois L (2017) Impact of spatio-temporal shade dynamics on wheat growth and yield, perspectives for temperate agroforestry. Eur J Agron 82: 60-70.
Barro RS, Costa Varella A, Lemaire G, Borges de Medeiros R, Carlos de Saibro J, Nabinger C, Villamil Bangel F, Justin Carassai I (2012) Forage yield and nitrogen nutrition dynamics of warm-season native forage genotypes under two shading levels and in full sunlight. Revista Brasileira de Zootecnia 41: 1589-1597.
Dufour, Metay A, Talbot G, Dupraz C (2013) Assessing light competition for cereal production in temperate agroforestry systems using experimentation and crop modelling. J Agron Crop Sci 199: 217-227.
Ehret M, Graß R, Wachendorf M (2015) The effect of shade and shade material on white clover/perennial ryegrass mixtures for temperate agroforestry systems. Agrofor Syst 89: 557-570.
Friday JB, Fownes JH (2002) Competition for light between hedgerows and maize in an alley cropping system in Hawaii, USA. Agrofor Syst 55: 125-137.
Retkute R, Smith-Unna SE, Smith RW, Burgess AJ, Jensen OE, Johnson GN, Preston SP, Murchie EH (2015) Exploiting heterogeneous environments: does photosynthetic acclimation optimize carbon gain in fluctuating light? J Exp Bot 66: 2437-2447.
Varella AC, Moot DJ, Pollock KM, Peri PL, Lucas RJ (2011) Do light and alfalfa responses to cloth and slatted shade represent those measured under an agroforestry system? Agrofor Syst 81: 157-173.

AGROFORESTRY SYSTEMS AND INNOVATION IN EXTRA-VIRGIN OLIVE OIL CHAIN IN CENTRAL ITALY

Pisanelli A[1*], Consalvo C[1], Martini E[2], Lauteri M[1], Camilli F[3], Paris P[1]

(1) Istituto di Biologia Agro-Ambientale e Forestale, Consiglio Nazionale delle Ricerche, Porano (TR), Italy (2) Alta Scuola, Associazione Culturale e Scientifica, Orvieto (TR), Italy (3) Istituto di Biometeorologia, Consiglio Nazionale delle Ricerche, Firenze, Italy

*Corresponding author: andrea.pisanelli@ibaf.cnr.it

Abstract

Although agroforestry systems are being acknowledged by relevant international policies, their adoption at EU farm levels is still hampered mainly due to lack of knowledge and expertise. In order to increase knowledge and awareness among stakeholders about agroforestry systems, the Agroforestry Innovation Network project (AFINET), funded within the EU H2020 research and innovation programme, has created Regional Agroforestry Innovation Networks (RAINs) in 9 EU countries focusing on different agroforestry practices.

This paper reports the activities carried out in the first RAIN meeting organized in Italy where AFINET project is focused on the multipurpose olive tree systems in the territory around Orvieto Municipality, Umbria Region, Central Italy. Stakeholders participating at the meeting perceived that the most relevant opportunities are related to the adoption of good practices, the implementation of cooperation among stakeholders, the enhancement of EU policies, the improvement of marketing of the extra-virgin olive oil.

Keywords: olive oil value chain; stakeholder knowledge; participative approach; innovation

Introduction

Global and European policies acknowledge the role that agroforestry can play to promote multifunctional agriculture providing products and delivering additional, highly important, ecosystem services. Nevertheless, it is also recognised that several constraints such as the lack of knowledge and expertise of farmers, land users and policy makers concerning agroforestry systems establishment and management hamper the adoption of agroforestry systems (Camilli et al. 2017).

In order to fill this gap, the European research project AFINET, Agroforestry Innovation Networks (http://www.eurafagroforestry.eu/afinet), 2017-2019, was funded within the EU's H2020 research and innovation programme. AFINET acts at EU level in order to direct research results into practice and promote innovative ideas to face challenges and solve practitioners' problems. To achieve such a result, AFINET proposes an innovative methodology based on the creation of a European Interregional Network, linking different Regional Agroforestry Innovation Networks (RAINs). RAINs are working groups created in nine strategic European regions (Spain, UK, Belgium, Portugal, Italy, Hungary, Poland, France and Finland), interconnected and managed by the figures of the Innovation Brokers. RAINs represent different climatic, geographical, social and cultural conditions and enclose a balanced representation of the key actors with complementary types of expertise (farmers, policy makers, advisory services, extension services, etc.). Through AFINET, each project partner will organize six RAIN meetings throughout three years of activities.

The Italian RAIN is focused on multipurpose olive tree systems in the territory around Orvieto Municipality, Umbria Region, Central Italy. Umbria can be considered one of the most interesting regions because of the high quality production of both olive and extra-virgin oil and the linkage of oil production with local culture and environment. The area around Orvieto

Municipality is rich in olive orchards representing one of the most common land use practice (Martini 2010). Olive trees are still managed traditionally, often in marginal sites, with minimal mechanization and relatively low external inputs such as chemical treatments in comparison to other crops. The presence of permanent crops (olive trees) guarantees a partially tree cover reducing hydrogeological risk. Soil management usually keeps natural grassing reducing soil carbon emission and increasing soil fertility (Bateni 2017). Intercropping with cereals and/or fodder legumes and livestock can also be practiced in olive orchards, increasing the complexity of the olive tree multifunctional system. Moreover, olive orchards can be managed as agroforestry systems since they can be intercropped with arable crops (cereals, legumes) and/or combined with livestock (sheep, poultry).

The RAIN network includes the whole extra-virgin olive oil chain, from olives production on farm, to the olive processing, the olive oil and oil residues production, at the mill. The RAIN is expected to improve the management of olive orchards, promoting the adoption of agroforestry solutions and practices.

This paper reports the results obtained during the first RAIN meeting participated by the stakeholders of the local olive oil sector and the results from the online questionnaire sent to stakeholders to elicit the main agroforestry challenges to face in order to improve the local olive oil value chain.

Materials and methods

A description of the olive oil value chain in Umbria region was carried out consulting available bibliography. A network of local stakeholders including farmers, consultants, oil mill managers, researchers, policy makers and citizens was invited to be part of the Italian RAIN. The first RAIN meeting was organised the 15th September 2017 at the Orvieto Municipality, Umbria region. During the meeting, AFINET project and its objectives were presented together with the RAIN approach and methodology. A participative exercise was then implemented involving the participants. Stakeholders were invited to form three groups and join three tables of discussion in order to identify bottlenecks, knowledge gaps and challenges affecting the local olive oil supply chain. Each table had a panel indicating a specific issue related to the olive oil chain: climate and environment, socio-economy and policy. Each group of participants moved from a table to another in order to take part to the discussion of all the three issues. A facilitator at each table introduced the participative exercise and invited the stakeholders to discuss the issue reported on the panel. Then, each stakeholder was asked to attach on the panel three post-it with the main constraints and three post-it with the main opportunities related to the table issue.

After the first RAIN meeting, an online questionnaire was submitted to the stakeholders who were asked to score (from 1, less important; to 6, very important) the agroforestry challenges to be implemented in order to improve the local olive oil value chain.

Results

The regional olive oil chain, involves about 30,000 farms growing olive trees in about 27,000 ha, and 270 oil mills; in 2014 the olive oil production was estimated to be about 3,152 tons (with a reduction of about 45% compared to 2013). In Umbria Olive trees are cultivated in the whole region and 5 Protected Designations of Origin (DOP) are represented: Colli Assisi Spoleto, Colli Martani, Colli Amerini, Colli del Trasimeno and Colli Orvietani. The main strength points of olive oil chain in Umbria are: i) high landscape value of olive orchards; ii) high quality level of the olive oil; iii) great awareness and expertise of farmers and oil mill managers; iv) high cultural and traditionally value. On the other side, the main weak points of the olive oil chain in Umbria are: i) high productive costs; ii) low intensive management practices; iii) small-scale farm dimension.

Twenty seven stakeholders participated at the first RAIN, including farmers (12), multipliers such as members of trade associations and citizens (8), researchers (6) and policy makers (1).

According to the results of the participative exercise, stakeholders perceive that most of the bottlenecks and opportunities are related to good practices and innovation, cooperation among stakeholders, European policies, marketing of the extra-virgin olive oil, environment and climate.

In Figure 1 bottlenecks and opportunities are reported separately in each category. It is interesting to see that, cooperation, marketing and environment are perceived more as opportunities than bottlenecks. On the contrary policy issues are perceived more as negative constraints than an opportunity. Good practices seem to be perceived both as opportunity and bottleneck probably because farmers recognize the potential benefits of agroforestry but they also perceive their management complexity.

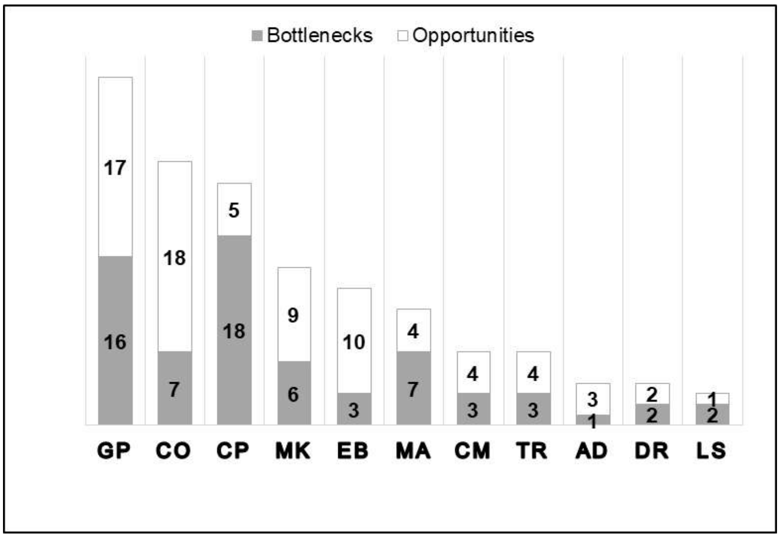


Figure 1: Frequency of bottlenecks and opportunities within each category as perceived by the stakeholders. GP: good practice; CO: cooperation; CP: community policy; MK: marketing; EB: environment; MA: management; CM: communication; TR: training; AD: abandonment; DR: drought; LS: landscape.

Sixteen stakeholders responded to the online survey. All the agroforestry challenges were scored higher than 5.0 (Table 1). Most of the challenges should be addressed to improve the management of agroforestry systems, identifying best management practices to optimize production and environmental benefits and increase the knowledge about tree, crops and animal combination. The need to implement demonstrative fields, to educate consumers and land users about the benefits of agroforestry emerged also as key innovations. Moreover, the value chain of agroforestry products needs to be improved, in particular for the aspects concerning the profitability of specific agroforestry systems. Finally, European policy should be improved in order to facilitate farmer's uptake of agroforestry measures.

Table 1: results of the online survey carried out to score the different challenges that should be implemented in order to contrast the bottlenecks of the olive oil value chain.

Challenges	Average score
More information on optimal tree/crop/livestock combinations, in order to maximize productivity, soil improvement etc.	5.81
Gather more information on fodder trees and nutritional value of nuts and fruits for specific animal species.	5.69
Search ways to improve the profitability of agroforestry systems in the short term.	5.69
Informing consumers and society in general about agroforestry and its benefits (both environmental and economic)	5.56
Access to case studies: showcasing farms which demonstrate good agroforestry practices	5.56
More information on the costs and benefits of specific agroforestry systems	5.44
Better understanding of the value chain (supply, demand and marketing opportunities) of agroforestry products (e.g. nuts, fruits, wood products)	5.44
Develop specialized machinery for agroforestry systems	5.31
Development of practical guidelines/best management practices for tree and tree understory management	5.25
Improving policy support tools to promote agroforestry	5.13
Reducing legislative uncertainty with regard to tree planting on agricultural land	5.07
More knowledge on suited varieties or fruit and nut production in agroforestry systems	5.06

Conclusion

The main strengths of the olive oil production sector in the Orvieto area, as emerged from the RAIN meeting discussion are: high quality of the product (extra-virgin olive oil), the linkage with local cultural traditions; the effects of olive orchards on biodiversity preservation; their influence on landscape fragmentation resulting in a valuable mosaic of co-existing elements, such as hedgerows, woodlots, herbaceous crops; soil erosion control; the use of intercropping, understory grazing and grassing down; high professional competence of the stakeholders. On the other side, the weaknesses are: high production costs; management complexity; small farm size; climate changes affecting vulnerability to pests and diseases. Furthermore, in order to compensate the high cost of oil production the RAIN intends to identify innovative uses of the residues of olive trees cultivation and olives processing, thus making the extra-virgin olive oil production sustainable.

According to the local stakeholders' opinion, in order to contrast bottlenecks and exploit opportunities of the olive oil supply chain, the possible innovations that should be taken into account are:

i) To introduce best practices: testing and experimenting innovative agroforestry systems introducing different crop/animals species and varieties;

ii) To improve the management of the olive orchards: encouraging and increasing the organic production;

iii) Valorization of olive processing residues: identifying and testing innovative products (bio-materials, olive paste as example);

iv) To raise the awareness among consumers: educating people about the benefits of olive oil consumption, creating networks among stakeholders, improving marketing and commercialization.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727872

References

Bateni C (2017) Soil carbon stock in olive groves agroforestry systems under different management and soil characteristics. Master in Environmental Management of Mountain Areas Thesis Faculty of Science, university of Bolzano.

Camilli F, Pisanelli A, Seddaiu G, Franca A, Bondesan V, Rosati A, Marcos Moreno G, Pantera A, Hermansen JE, BurgessPJ (2017) How local stakeholders perceive agroforestry systems: an Italian perspective. Agrofor Syst https://doi.org/10.1007/s10457-017-0127-0.

Martini E (2010) Paysage et Environnement de l'Olivier dans la Region d'Umbria (Stratégie de Marketing et de Promotion). Fête de l'Olivier à Meknes – 2° édition: Meknes (Maroc), 17-19 Juin 2010. KNOLEUM, paysages de l'olivier: Etudes conduites par les 6 partenaires du projet Interreg III B Knoleum concernant la filière olévicole.

BIO-MULCH: AN EFFECTIVE TOOL OF WEED SUPRESSION IN ALLEY CROPPING

Vityi A[1*], Kiss Szigeti N[1], Marosvölgyi B[1], Schettrer P[2]

(1) University of Sopron Co-operational Research Centre Nonprofit Ltd, Sopron, Hungary (2) Kék Duna Agricultural Co-operative, Fajsz, Hungary

*Corresponding author: vityi.andrea@uni-sopron.hu

Abstract

In alley cropping systems mechanical weed management might face obstacles within the tree rows. The aim of the experiment carried out within the frame of the AGFORWARD project in a silvoarable agroforestry system with timber trees (*Paulownia* sp.) intercropped with alfalfa was to test if raw biomass mulch can be used for weed suppression purposes in a technically and economically successful way. Based on the results, mulching with locally available fresh biomass can be effectively used for weed control purposes and provides additional advantages such as the improvement of soil fertility, microclimate and water management.

Keywords: alley cropping; weeds; silvoarable

Introduction

In alley cropping systems mechanical weed management might face obstacles within the tree rows (because of the lack of space, presence of cultivated plants, etc.), and as a consequence, unit labour cost of weed control is often higher than in monocultures. Use of herbicides is not recommended, due to potential damage to the trees. Straw cover is a possible method of weed control, but its effectiveness depends on local circumstances (e.g. not effective in windy areas), and its removal is required during winter as it attracts rodents. The experiment was carried out within the frame of AGFORWARD project, in a silvoarable agroforestry system with timber trees (*Paulownia* sp.) intercropped with alfalfa (Vityi et al. 2015). The aim was to test if raw biomass mulch can be used for weed suppression purposes in a technically successful and economically viable way.

Materials and methods

Herbaceous flora of the tree rows and a part of the first harvest of the crop (*Medicago sativa*) were used to mulch the tree rows (note, it is important to harvest weeds before flowering, otherwise mulching will lead to the spread of weeds within the tree rows). The use of bio-mulch was tested in three of the six tree rows planted in the experimental agroforestry system (see map in Table 1). Tree rows with motormanual weed control were the control. Herbaceous cover was made in early May 2016 and 2017 in order to test effectiveness during the most intensive growing period of the year. Weeds were cut using a motor-manual method, while alfalfa was harvested mechanically and spread manually in the tree rows. The thickness of bio-mulch layer is crucial. In the experiment the thickness of biomass cover was 10 cm and material harvested closest to tree rows was used due to economic reasons. The recorded parameters were: i) weed percentage cover (from May to July 2016 and 2017), ii) labour time and costs of covering the surface for weed control and iii) annual growth of trees in mulched rows and the control rows without bio-mulch (based on measurements carried out at the end of growing seasons of 2015, 2016, and 2017).

Table 1: Description of the experimental site.

Area	2 ha
Co-ordinates	46°40’51.41”N, 18°92’71.98”E
	
Map of system	
Mean monthly temperature	12.5 °C
Mean annual precipitation	429.2 mm
Soil type	WRB classification: Phaenozem
Soil texture	Clay loam
Additional soil characteristics	Plasticity according to Arany (K_A): 52; Humus content 3.6%; Groundwater 3.8-4.4 m below soil surface. Topsoil: loam/clay loam; subsoil: clay loam or clay with gleyic colour pattern (stagnic gley)
Aspect	North-West/South East
Tree species	*Paulownia tomentosa (var. CE.), number of trees: 126*
Date of tree planting	2013
Intra-row spacing	14 m
Inter-row spacing	5 m
Crop species	*Triticale* (*Medicago sativa*)
Crop management	Fertilization once per year, harvest 4-5 times per year No herbicides applied
Crop products	Fodder

Results

The bio-mulch effectively suppressed weeds for approx. 60 days and resulted in a reduction of two weed-cutting periods during the growing season. By the end of the second month, the percentage of weed cover in treated rows was 25% less than the non-covered rows. Also the number of weed species and their density decreased significantly (Figure 1).

Figure 1: Change of weed pattern in tree rows in relation to time (1: 3rd week, 2: 5th week, 3: 8th week) and control rows without bio-mulching (4) (Photo: Péter Schettrer).

The results of tree development show a significant difference in diameter growth for rows covered with bio-mulch (alfalfa and weed), compared to non-covered rows ($t<0.05$; $p=0.048835$). As trees were managed equally, the difference may be attributable to the effect of the different weed management (Figure 2).

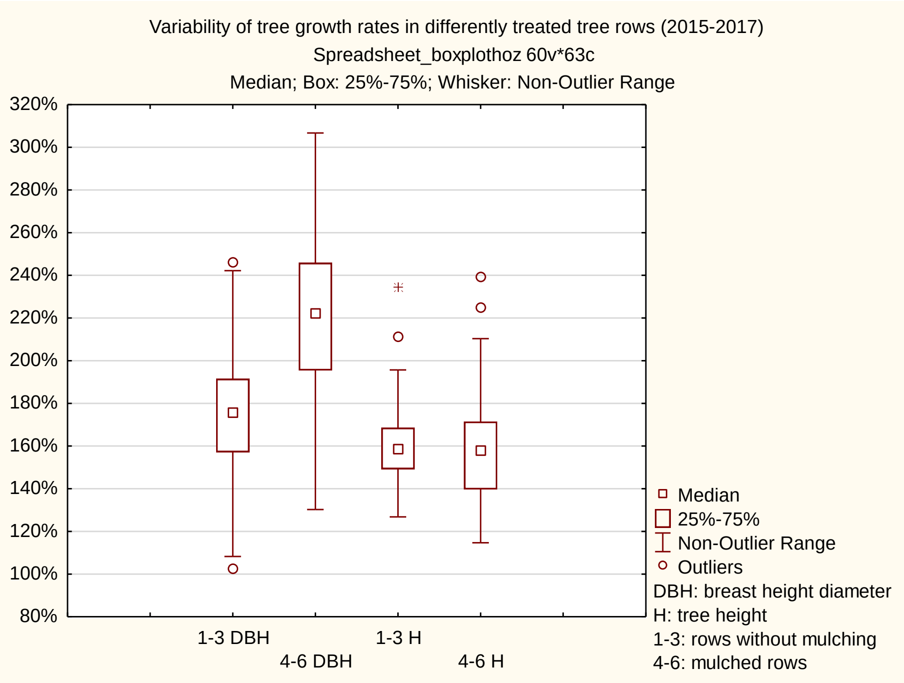


Figure 2: Effect of bio-mulching on tree growth rates in growing seasons 2016 and 2017

Evaluation of the test results and conclusion

Based on the results, mulching with locally available fresh biomass can be effectively used for weed control purposes. Furthermore, improved water use efficiency may be improved due to a reduction in soil evaporation within the tree rows. The key advantages of the method are improvement of soil fertility, microclimate and water management. Besides, this practice is environment-friendly and thus applicable in organic production systems as well.

Acknowledgement

The authors would like to thank the forestry company who participated in this transdisciplinary exercise. We acknowledge the support of the European Commission through the AGFORWARD FP7 (contract 613520) and AFINET H2020 (contract 727872) research projects.

References

Vityi A, Marosvölgyi B, Kiss A, Schettrer P (2015) System report: Alley Cropping in Hungary. AGFORWARD (613520) http://agforward.eu/index.php/hu/szantofoeldi-agroerdeszeti-rendszerek-magyarorszagon.html (accessed 21/04/2018).

EFFECTS OF SHADE ON BLACK CURRANT PHYSIOLOGY AND PRODUCTIVITY

Wolske E[1*], Branham B[1], Wolz K[2]

(1) Department of Crop Science, University of Illinois, Champaign-Urbana, United States (2) Savanna Institute, Madison, United States

*Corresponding author: ewolske2@illinois.edu

Abstract

Multifunctional Woody Polycultures have been proposed as a more ecological-friendly system of production agriculture that relies on woody perennials grown within a mix of other perennial crop species. However, little research has been conducted on productive shade tolerant crops that can fill the understory niche in these systems. An experiment was conducted on *Ribes nigrum* L. cv 'Consort' to measure the yield response to various levels (0, 35%, 45%, 65%, and 85%) of artificial shade. The study was located at the University of Illinois Urbana-Champaign. This 2-year experiment was initiated in 2016 on 4-year-old black currants. In 2016, there was a 5% reduction in yield from 65% shade, with 85% shade reducing yield by 28%. In 2017, yield was reduced 11% at 65% shade and 57% at 85% shade. Based upon these results, black currants can produce excellent yields under partial shading making them a potentially valuable edible understory crop.

Keywords: shade tolerance; black currant; *Ribes nigrum*; understory; multifunctional woody polycultures

Introduction

Multifunctional woody polyculture is a potential alternative to current agricultural production system. The benefits of MWP systems include reduced soil erosion and nutrient runoff, carbon sequestration instead of carbon emission, resiliency to climate fluctuations, and increased biodiversity (Jordan and Warner 2010). Agricultural landscapes can be designed to produce an agricultural product while also providing net ecosystem services and functionality (Lovell and Johnston 2009). In a side-by-side study, Davis et al. (2012) found that the combined yield and ecosystem benefits from a diverse cropping system could meet or exceed the same performance of a less diverse cropping system while using less synthetic agrichemical inputs.

A major limiting factor in a multi-species system is the availability of light due to intercrop competition, which results in a distinct overstory and understory niche. Black currants (*Ribes nigrum*) have the potential to produce a valuable product in the shaded understory niche. The quick growth to maturity, three to five years, makes this perennial crop a good choice in the staggered maturation of the key species in polyculture systems. Additionally, currants naturally occur in understory environments and are known to produce and grow well under shaded conditions (Bratsch and Williams 2009; Djordjevik et al. 2014; Harmat et al. 1990; Šavikin et al. 2013; and Toldam-Andersen and Hansen 1993). However, empirical research has been limited in determining the agricultural potential of black currants grown under the shade of an over-story of larger-sized fruit and nut trees.

An effective multifunctional woody polyculture system will require crops that produce adequate yield under partial shade. Black currants have potential as an understory crop, with healthy, marketable, good-yielding fruit and shade tolerance. However, there is a paucity of research on the effects of shade on black currant physiology and agricultural potential in the Midwestern US. The objectives of our research were to study the impact of shade on black currant growth and yield.

Materials and methods

This study was conducted in 2016 and 2017 on the Woody Perennial Polyculture project site at the University of Illinois Fruit Farm in Urbana, Illinois. Soil types present are a Flanagan series (fine, smectitic, mesic Aquic Argiudolls) and a Thorp series (fine-silty, mixed, superactive, mesic Argiaquic Argialbolls). The existing site had east-west orientation with 4-year old Ribes nigrum L. cv 'Consort' set at 1.2 m spacing between plants and 4.8 m spacing between rows. Plants were fertilized in spring 2016 with urea at a rate of 112 kg N/ha and in spring 2017 with poultry manure at a rate of 112 kg N/ha, because the site is being converted to organic production. Disease was treated with applications of mineral oil (Ultra-Pure, BASF Corporation, NC, USA) applied as needed from mid-May until mid-August. Weeds were removed in a 1.2 meter band around plants using glyphosate, dicamba, and light tillage in 2016 and with light-tillage only in 2017. Pruning was done during dormancy to select roughly four 1-year stems, four 2-year stems, and four 3-year stems for an average of 10-12 stems per plant post-pruning.

Four artificial shade treatments were used with one open control. Shade netting at stated levels of 20% white, 30% black, 50% black, and 70% black (Dewitt Company, Sikeston, Missouri, USA) were placed over six currant plants. Shade cloth PAR values were measured at 37%, 45%, 65%, and 83% respectively and are reported as 35%, 45%, 65%, and 85%. Metal conduit was used to create a gothic frame structure 3 m wide and 1.8 m high in the center and slanting down to 0.9 m at the edges. The shade structure extended past the end plants by 0.9 m. A 90% black shade netting treatment was initially installed in 2016 but was replaced with 37% white shade netting three months after February and before full flower bloom.

Experimental design was a randomized complete block with four blocks. Each shade treatment consisted of six plants, with the outer two plants serving as buffers and data collected from the center four plants. The shade netting was installed in early spring before full leaf out on March 12th in 2016 and removed after leaf fall in late November and was installed in late spring before full flower break on April 13th in 2017.

Treatments were harvested by hand when 95% of the berries were ripe as judged by Brix and visual measurements and before significant berry drop occurred. In 2016, all treatments were harvested on July 5th. In 2017, the control and 35% treatments were harvested on June 27th while the 45%, 65%, and 85% treatments were harvested on July 1st and 2nd. Harvest weight was recorded for each of the plants and averaged across plots.

Analysis of variance was performed using JMP Pro (c13, SAS Institute, Cary, NC, USA). Subsamples were averaged across replications before running the analysis. Means were separated using the Tukey-Kramer multiple comparisons test at a significance level of $\alpha=0.05$. Parameter means plus or minus standard deviation by treatment and year are reported.

Results

There was a significant year by treatment interaction, so data are reported separately by year. Averaged across all treatments, the yield in 2017 was 1094 grams per bush while the 2016 yield was 694 grams per bush. In 2016, there was no difference in yield amongst any of the treatments, in 2017, the 85% shade treatment had a lower yield than the control (Table 1). Averaged across both years, the 65% treatment reduced yields by only 8%.

Table 1: Total mean yield of black currant (*Ribes nigrum*) by percent shade treatment and percent reduction from the control for the 2016 and 2017 growing season in Urbana, IL in grams per bush ± standard deviation. Different letters within a column indicate significant differences as determined by Tukey-Kramer multiple comparison test at a rejection level of α=0.05 with LSM values shown where significance was found. NS=not significant. *,**,*** Significantly different at the P=0.05, 0.005, or 0.001 probability level, respectively.

Yield				
	2016		2017	
Treatment	Total (g)	% Reduction	Total (g)	% Reduction
Control	807 ± 277	-	1294 ± 256 a	-
35%	638 ± 197	21	1278 ± 293 a	1
45%	682 ± 79	16	1179 ± 297 a	9
65%	768 ± 210	5	1158 ± 275 a	11
85%	577 ± 98	29	561 ± 119 b	57
LSM	NS		374.4 ***	

Discussion

For the inclusion of woody understory crops in polycultures, the insignificant yield loss found in up to 65% shading proved to be the most interesting result. In 2017, only the 85% shade treatment reduced yield compared to the control (Table 1). Overall yield in 2016 was lower than 2017. This is most likely due to the 4-year-old plants reaching peak maturity and approaching ceiling yields in 2017. The higher yield in 2017 may also be explained by the addition of a two-year-old variety in the vicinity of the trial that went through flowering and may have served as a pollinizer. Also, warmer temperatures at the end of winter season followed by an extended cool spring may have contributed to increased yields in 2017.

The 65% shade treatment shows the greatest potential with minimal yield reduction in both years. This may be due to increased soil moisture or by the plant maintaining biomass allocation to reproduction immediately after developing shade and into the following year. The low yield in the 85% treatment could be caused both by limited carbon capture under reduced solar irradiance and by an increase in disease prevalence. Our results are consistent with the yield loss found by Toldam-Andersen and Hansen (1993) in black currants grown under 50% shade conditions who also reported an 8% reduction in yield for shaded plants. In a similar study on blueberries, Kim et al. (2011) found that blueberries performed well up to 60% shading, where heavier shading reduced yield significantly. Overall, our research indicates that black currants in the Midwest can maintain acceptable yields with up to 65% shade, but yields will be significantly reduced at shade levels above 65%. While the performance of plants under shade netting does not directly correlate to the performance of plants under a shade tree, these results help strengthen the argument for black currants in an understory environment.

Overall, the results of this study indicate that black currants are an excellent understory crop in light to moderate shade conditions. With a phenotypic plasticity homologous to shade species, currants were able to maintain a substantial yield under shade stress. Further, black currant germplasm could be screened to determine the cultivars having the best shade tolerance. These superior cultivars could then be used in a breeding program to further enhance productivity under shade. Black currants may prove useful in polyculture, providing fruit and nut orchard growers with an additional crop in the system that could increase yield and income without requiring additional land resources.

References

Bratsch A, Williams J (2009) Specialty Crop Profile: Ribes (Currants and Gooseberries). VCE Publications 438: https://pubs.ext.vt.edu/438/438-107/438-107.html (accessed 23/04/2018).

Davis AS, Hill JD, Chase CA, Johanns AM, Liebman M (2012) Increasing Cropping System Diversity Balances Productivity, Profitability and Environmental Health. PLoS ONE 7:e47149. doi: 10.1371/journal.pone.0047149

Djordjevic B, Šavikin K, Djurovic D, Veberic R, Mikulič Petkovšek M, Zdunić G, Vulic T (2014) Biological and nutritional properties of blackcurrant berries (Ribes nigrum L.) under conditions of shading nets. J Sci Food Agric 95: 2416–2423.

Harmat L, Porpaczy A, Himelrick D G, and Galletta G J (1990) Currant and Gooseberry Management. Small Fruit Crop Management. Prentice Hall. Englewood Cliffs, N.J.

Jordan N, Warner KD (2010) Enhancing the Multifunctionality of US Agriculture. BioScience 60: 60–66. doi: 10.1525/bio.2010.60.1.10

Kim SJ, Yu DJ, Kim T-C, Lee HJ (2011) Growth and photosynthetic characteristics of blueberry (Vaccinium corymbosum cv. Bluecrop) under various shade levels. Sci Hortic 129: 486–492.

Lovell ST, Johnston DM (2009) Designing landscapes for performance based on emerging principles in landscape ecology. Ecol Soc 14:44

Šavikin K, Mikulič-Petkovšek M, Djordjević B, Zdunić G, Janković T, Djurović D, Veberič R (2013) Influence of shading net on polyphenol profile and radical scavenging activity in different varieties of black currant berries. Sci Hortic 160: 20–28.

Toldam-Andersen TB, Hansen P (1993) Growth and development in black currants (Ribes nigrum). I. Effects of light and leaf-shoot removals on growth distribution and fruit drop. Acta Hortic 352: 237–246.

Session

Social and economic aspects in developing agroforestry

GROWING A FOOD FOREST AS A SUSTAINABLE BUSINESS; SOME PRACTICAL REFLECTIONS ON THE BASIS OF *FOOD FOREST EEMVALLEI ZUID*

Buiter M[1]*, Van Eck W[1], De Waard FJ[1], Derksen E[1], en Lensink B[1]

(1) Stichting Voedselbosbouw Nederland, Lelystad, the Netherlands (www.voedselbosbouwnl.nl)

*Corresponding author: marc.buiter@ziggo.nl

Abstract

In this article we present some practical reflections on the ambition to develop a sustainable business strategy for the design, planting, operation and maintenance of a large-scale food forest. On the basis of our experience with the development of the public *Food Forest Eemvallei Zuid* (30 ha.) in the Netherlands, we discuss a number of strategic options to limit the costs and to optimize the benefits of a food forest that is set up as a professional 'business'. Besides some practical options like a restrained forest management and processing of harvested products before sales, an important strategic option appears to be: co-creation of new arrangements on the analogy of *Community Supported Agriculture* in close cooperation with residents and entrepreneurs from the region. Such arrangements are vital to prevent the evaporation of the added values of a food forest into the bulk mountains of the highly competitive, anonymous world food markets.

Keywords: food forest; sustainable development; business strategy; community supported agriculture

Introduction

Food forests provide many alluring perspectives in the strive for sustainability within our food system. As multi-layered polycultures (see Figure 1), they not only offer the irresistible opportunity to enrich our daily menus with a wide variety of healthy and tasty forest products. Mimicking the development of natural forests, they also provide ecosystem services such as carbon sequestration and biodiversity. While doing that food forests offer great opportunities to reconnect people to the natural world and to broaden and strengthen the social and economic base of local communities. Utilizing the full, versatile potential of a food forest requires a sustainable business strategy. In this article, we share some practical reflections on this ambition on the basis of our experience with the development of a large food forest in the Netherlands.

What is a food forest? A definition …

A food forest is a multi-layered, perennial ecosystem that is designed on the analogy of a natural forest with the objective to produce food. Distinctive characteristics of a food forest are: a canopy of tall trees, at least three other layers of vegetation, rich forest soil and a robust size.To provide for a vigorous, self-sufficient food forest, a 'robust size' equals at least 0.5 hectare in a rich natural environment and at least 20 hectares in an ecological impoverished environment. A food forest provides a habitat to a rich and fast-growing biodiversity.

Figure 1: Nine layers of a food forest

1. Canopy layer
2. Sub-canopy layer
3. Shrub layer
4. Herbaceous layer
5. Ground cover layer
6. Underground layer
7. Climber layer
8. Aquatic/wetland layer
9. Mycelial/fungal layer

Food Forest *Eemvallei Zuid*

On the 5th of July 2017 six parties signed the contract for the realisation of *Eemvallei Zuid (*Figure 2*),* a public natural area of 50 hectares in Oosterwold, the latest suburb of Almere which is a new town in the Netherlands. Since a food forest of 30 hectares will be an integral part of this new natural area in the province of Flevoland, the occasion was also the kick-off of the biggest food forest in Europe thus far. As originator of the project idea, Stichting Voedselbosbouw Nederland is responsible for the design, development, management and economic operation of this food forest.

The festive signing of the contract was the culmination of a complex and prolonged process of consultations and negotiations between on the one hand the province of Flevoland and the municipality of Almere and on the other hand, the initiators: Staatsbosbeheer, Stichting Speelwildernis, Stadsboerderij Almere and Stichting Voedselbosbouw Nederland. Now that this innovative cooperation has been ratified and the accompanying transfer of the landownership to Staatsbosbeheer implemented, the plan is to start planting towards the end of 2018 on the basis of a detailed ecological design for the whole area of *Eemvallei Zuid*. After the planting, the currently bare fields for agriculture will gradually transform into a varied natural area with a large food forest.

Figure 2: The provisional design of *Eemvallei Zuid,* a public natural area of 50 hectares in Almere Oosterwold including a food forest of 30 hectares (the bottle-green parts in the drawing). The lay-out of the area is roughly based on the archaeological traces of the ancient river The Eem, which flew through prehistoric Flevoland.

Business challenges for a large-scale food forest

As part of *Eemvallei Zuid* the food forest will be designed, planted and 'operated' as a recreational forest that is open to the public (see Figure 2). Although there are a number of particulars attached to this case, a sustainable operation of *Food Forest Eemvallei Zuid* poses two big economic challenges that are typical for any food forest that is set up as a professional 'business'. First, there is the challenge to cover the costs of the design, planting and maintenance during the pioneering phase of the food forest, when there is not much to harvest while the trees and shrubs are taking root and maturing. The second economic challenge is to generate sufficient (sources of) income, at least to cover the costs of operation and maintenance, including the biggest head of expenditure in any food forest: the labour-intensive harvesting. In view of the public and recreational character of *Eemvallei Zuid* this challenge also entails the task of safeguarding a substantial part of the forest produce (a/o nuts, fruits and edible leaves) to be sold on the market.

With regard to the first challenge, an explorative analysis of the potential costs and benefits provides ample room for confidence that the management and operation of *Food Forest Eemvallei Zuid* will be economically profitable from 2026 onwards (Stichting 2017). A limited budget for planting material and nature management will be provided by the province of Flevoland. According to the business case of Voedselbosbouw Nederland this budget will be just enough to cover the basic costs during the first eight years after planting.

With regard to the second challenge, there is good reason to be optimistic about the economic sustainability of *Food Forest Eemvallei*. This is mainly because food forests provide a broad spectrum of options to limit the costs and to optimize the sustainable benefits and *Food Forest Eemvallei Zuid* is no exception to that general rule. Below we discuss a number of strategic options for an entrepreneur – in this case: Voedselbosbouw Nederland – to promote a sustainable operation of a food forest.

Strategic options to promote a sustainable operation and maintenance of a food forest

- While designing a food forest **the selection of species and varieties and spatial planning** can be utilized to optimize the profitability. Important factors like growth rate, access to harvestable products, edible parts, taste, options for processing and product prices; all need to be accounted for in this process. Worth knowing in this context is that a food forest is well adapted for the growing of profitable niche products like Japanese wineberry, heartseed walnut, Asian pear, sea kale and wild ginger. To safeguard a substantial part of the harvestable produce that can be sold on the market, it is important to be able to fence off certain parts of the food forest during harvesting periods. This can also be done with natural barriers like hawthorn and blackthorn. Another strategy to safeguard sufficient harvests from the food forest is to select plant species in such a way that there are flowering plants throughout the largest part of the year**.** This strategy is not only valuable to prevent losses due to extreme weather events that can cause crop failures (e.g. late frosts); it also contributes to the aesthetic value of the food forest and to the life support of insects that are critical to the pollination of the forest.

- A **restrained management** is critical to advance the natural succession of a food forest as well as to keep the operational costs within manageable limits. With a view to a smooth succession of the forest system, we plant and welcome pioneering species like poplar, willow, alders, thistles, nettles and sorrel. Common activities in conventional forestry and horticulture like mowing, logging and pruning will therefore be rare in the *Food Forest Eemvallei*. To prevent high harvesting costs the entrepreneur can always keep in mind the option of not-harvesting, especially of low-priced products that are difficult to harvest.

- When market prices of fresh produce are low, the food forest entrepreneur can also choose to **process the harvested products before selling them**. Processed products like marmalades, jams, chutneys, smoothies, ready meals, wines and beers can add a high value to fresh produce from a food forest. This can also be done by, or in cooperation with, an entrepreneur from the local area to whom the food forest entrepreneur sells fresh products or exclusive harvesting rights.

- Besides edible products a 'food forester' can also **produce and sell other useful products like wood, herbs, seeds and planting materials**. To stimulate the natural succession in the *Food Forest Eemvallei* we will plant fast growing pioneers like poplar, willow and alder trees. When these pioneers start to hinder the growth of the slow-growing, edible species such as chestnuts and walnuts, they can be harvested and sold on the (local) wood markets. Likewise, the breeding of (rare) seeds and planting material in a food forest can generate additional income or make expensive purchases from professional breeders redundant.

- **Various educational and recreational services associated with a food forest** can generate additional income besides the selling of food and non-food products. The experience with existing food forests in the Netherlands teaches us that the (potential) demand for such services is high while the supply is limited, to put it mildly. There is a huge appetite, among specialists as well as among the general public, for expert knowledge and serious skills in the fields of (edible) nature, ecology, permaculture, agroforestry and food forests. These days it doesn't take long before an organized tour, workshop, course or master class is fully booked.

- **Innovative arrangements around the production and consumption of food forest products and associated services** can contribute a lot to secure the sale at reasonable prices and conditions. Specially interesting are arrangements on the analogy of *Community Supported Agriculture* in which the food forest entrepreneur delivers produce and provides services like education and recreation to neighbours, local schools, offices, nursing homes and business restaurants in exchange for assistance to planting, harvesting and monitoring activities. New and innovative business arrangements with small and medium sized food enterprises in the region are also worthwhile to explore in depth. Interesting examples in case are exclusive 'harvesting rights' for local brewers, beekeepers, restaurateurs and catering companies in exchange for labour support and/or services like good meals, pollination and the catering of meetings and festivities. There are numerous possibilities to construct such arrangements and these possibilities must and can be explored thoroughly during the first pioneering years of an evolving food forest, when there is not much to harvest yet. These arrangements can also be very helpful to **construct and secure short supply chains in which the total marginal costs of food products and services are being limited** by the restricted number of parties involved and also by the application of rewards in kind.

- While food forests are designed on the analogy of natural forests they are also well equipped to **deliver the associated ecosystem services.** Just like deciduous natural forests, food forests deliver important services in the fields of biodiversity, water management and climate adaptation and mitigation. Nowadays there are slowly increasing opportunities to acquire rewards for specific ecosystem services. Such rewards vary from financial compensations for measures that improve the water retention capacity of the land (e.g. a wetland zone in or near the food forest) to remunerations for carbon sequestration in the biomass and soil of the food forest.

The discussion of the various options above demonstrates clearly that effective economics often require a smart and innovative social organization of the business activities surrounding a food forest. First of all, it appears that an optimal utilization of the versatile business potential of a food forest demands a multidisciplinary approach. An ideal food forest entrepreneur seems to embrace a wide range of professional capacities varying from a high level of ecological know how to various social skills in such distinctive fields as education, networking and hard-core business negotiations. Considered in this way, the most likely candidate for the title 'ideal food forest entrepreneur' may well be a multidisciplinary team rather than a single person or even a couple.

Secondly, in order to prevent the evaporation of the added values of a food forest – such as local, organic produce, various healthy *primary* products, nature conservation – into the bulk mountains of the highly competitive, anonymous world food markets, it is vital that the food forest entrepreneur creates short supply chains to reliable local consuming markets for *special* food forest products and services. Thirdly, processing of fresh food forest produce, in cooperation with local entrepreneurs, can be conditional to capitalize fully on the potential added value of food forest harvests. Lastly, payments in kind and quid pro quo services to 'volunteers' – e.g. free baskets of forest produce, free training and tours, etc. – in exchange for their practical support can be an effective strategy to keep the harvesting costs within manageable limits as well as to connect the food forest to a pool of loyal and satisfied consumers. Especially the last three preconditions add up to the conclusion that every food forest entrepreneur has a high interest in the creation of new social and economic arrangements around the production and consumption of food forest products and associated services, preferably in close cooperation with residents and entrepreneurs from the region.

References

Staatsbosbeheer is the former state forestry service; currently, it is the leading owner and manager of forest land and natural areas in the Netherlands.

Stichting Voedselbosbouw Nederland (2017) Bijlage 12: Business Case Voedselbos. In: Development Plan Eemvallei Zuid Program New Nature; a joint initiative of Staatsbosbeheer, Stichting Voedselbosbouw Nederland, Stichting Speelwildernis and Maatschap Stadsboerderij Almere for the realisation of a new natural area in Almere Oosterwold within the framework of the program New Nature of the province of Flevoland, pp 52-61. Stichting Voedselbosbouw Nederland, Lelystad, the Netherlands.

STAKEHOLDERS' PERCEPTIONS OF THE ENVIRONMENTAL AND SOCIO-ECONOMIC BENEFITS OF AGROFORESTRY SYSTEMS: AN ON ONLINE SURVEY IN ITALY

Camilli F[1]*, Marchi V[1], Pisanelli A[2], Seddaiu G[5], Paris P[2], Franca A[3], Rosati A[4]

(1) Institute of Biometeorology, National Research Council, Florence, Italy (2) Institute of Agro-environmental and Forest Biology, National Research Council, Porano (TR); Italy (3) Institute for the Animal Production System in the Mediterranean Environment, National Research Council, Sassari, Italy (4) Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Centro di ricerca Olivicoltura, Frutticoltura e Agrumicoltura, Spoleto (PG), Italy (5) Dept. of Agricultural Sciences, University of Sassari, Sassari, Italy

*Corresponding author: f.camilli@ibimet.cnr.it

Abstract

This work reports the preliminary results of an online survey on the perceptions/opinions of Italian stakeholders on the environmental and socio-economic benefits of agroforestry systems (AFS). In particular, the study focuses on farmers' opinions. Both farmers and other stakeholders (SHs) show positive opinions regarding the environmental benefits of AFS and think also that they can benefit the farmer image and the landscape (socio-economic benefits). More uncertain opinions seem to regard the positive influence of AFS in preventing fires and in providing economic benefits. In depth analysis of the reasons behind the respondents' choices as well as a focus on other target categories surveyed are needed.

Keywords: agroforestry; environment; farmers; socio-economy; stakeholders

Introduction

Agroforestry is a plethora of land use systems integrating trees (and other woody vegetation), crops and/or grazing animals on the same management unit. Agroforestry is not a novelty in Italy, as it has been long adopted and managed over time, until the advent of modern industrialized agriculture (Perali 2004). In Italy, the combinations of trees and crops and/or livestock have been progressively decreasing during time, especially in some areas of the country, as a consequence of socio-economic dynamics and industrialized agricultural practices (Paris et al. 2001).

Nowadays, such combinations, that can be embodied by agroforestry systems (AFS), are back to the attention of research and policy institutions because of their multifunctional role in providing relevant ecosystem services, such as conservation of biodiversity, protection of soil and water, diversification of productions and maintaining the rural landscape (FAO 2017). As AFS are complex systems, many stakeholders (SHs) should be involved in supporting them. The EIP-AGRI Focus Group on Agroforestry has recently identified, among others, the available knowledge and skills as key factors to enhance the adoption of agroforestry practices in the EU (EIP-AGRI 2017). Recent studies at European and Italian level (García de Jalon et al. 2017; Camilli et al. 2017), elicited the relevance of local SHs' perceptions related to particular AFS. For this reason, it is important to use participatory approaches and methods which help all SHs involved, in particular farmers, to better understand how to effectively design and manage agroforestry systems.

This work presents the results from an online survey conducted in Italy on the perceptions/opinions on AFS of different categories of SHs, focusing on AFS environmental and socio-economic issues. The work compares the responses of farmers (the main actors directly involved in agro-environmental activities) with those of the other SHs included in the sample.

Materials and methods

The survey was performed, as part of the European FP7 AGFORWARD project (2014-2017), between April and June 2016 through an online questionnaire sent to a wide sample of population, grouped according to the following target categories: farmers, agronomy and forestry advisors, extension services, land-use and landscapes planners, policy makers, researchers, tourist operators. The questionnaire was distributed through research institutional websites and other platforms such as the National Rural Network. It was also sent by email all over Italy to several mailing lists of the above cited categories (a mailing list of about 20,000 email addresses was developed) involving: individuals, companies, public authorities, agricultural consortia, national and regional parks, conservation areas, etc. The survey received the approval of the Commission for ethics in research and Bioethics of the National Research Council.

The questionnaire was divided in two parts: the first part was related to the respondents' records (sex, age, education etc.) while the second one was focused on their perceptions/opinions on AFS. The second part was designed following the Likert-type test scheme (Likert 1932), according to which agreement or disagreement are expressed along with a five-value scale: from "completely in agreement" to "completely in disagreement". Questions were grouped in 4 categories regarding the following topics: "Production", "Environment", "Management" and "Socio-economy". The snowball sampling method (Atkinson and Flint 2004) was also applied to make the first respondents to the questionnaire indicate other SHs, in order to get a ripple effect. A descriptive analysis allowed to define the characteristics of the total sample and those of each target category. In order to evaluate the representativeness of the sample, data on farmers obtained by the survey and agricultural census (ISTAT 2010) were compared. Here only some indicators are reported. It has to be underlined that the sample is likely to be biased as farmers working with conventional/intensive agriculture may be underrepresented, being less interested in the topic under investigation. Additionally, people not familiar with email and internet did not receive the questionnaire.

Results

A total number of 654 responses to the questionnaire was obtained: the total of responses by farmers (farmers and agritourism farmers) were 202. The percentages of men and women on the whole sample was 72% and 28%, respectively (Table 1). In Table 1 also the comparison between the ranges of ages are reported. 68% of farmers declared to have AFS in their farms. 57% of farmers, who do not have AFS, claimed to be interested in introducing AFS in their farms.

Table 1: Percentages of women and men in agriculture from the survey and the ISTAT data (2010) and age of farmers from the survey and the ISTAT data (2010).

Survey sample (2016)						
	Agritourism farmers	%	Farmers	%	Total	%
Women	22	30	35	27	57	28
Men	51	70	94	73	145	72
Total	73	100	129	100	202	100
	All famers					
Age	20-35	36-65	>65			
%	18	77	5	100		
2010 Agricultural Census - ISTAT						
Women	7,262	35	371,000	23	378,262	23
Men	13,212	65	1,250,000	77	1,263,212	77
Total	20474	100	1,621,000	100	1,641,474	100
	All famers					
Age	<39	40-64	> 65			
%	18.10	61.50	20.40	100		

Regarding the opinion of farmers on the environmental benefits of AFS (Figure 1), the highest percentages of positive answers (“completely in agreement” and “quite in agreement”) concerned the effects of AFS on the soil fertility, the improvement on carbon sequestration and the water quality. Regarding the latter, the other SHs’ opinions seemed more divided than for farmers. The opinions of farmers and other SHs on the effects of AFS on fire risk tended to be more neutral.

As for socio-economic issues (Figure 2), the answers on the farm image and the landscape are quite positive (both for farmers and the other SHs) but the opinions on commercial and job opportunities, and on tourism, tended to be less positive.

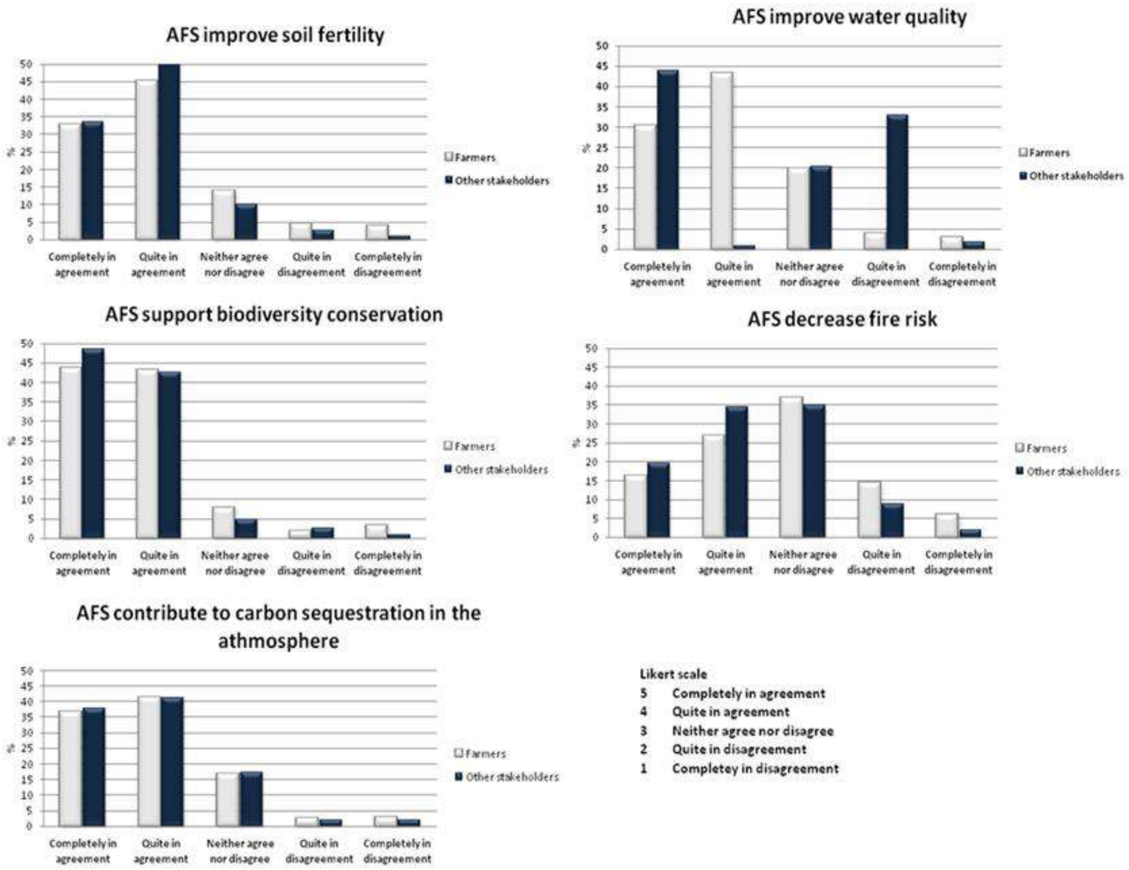


Figure 1: Comparison between farmers’ and other SHs’ opinions on the environmental benefits of agroforestry systems (AFS).

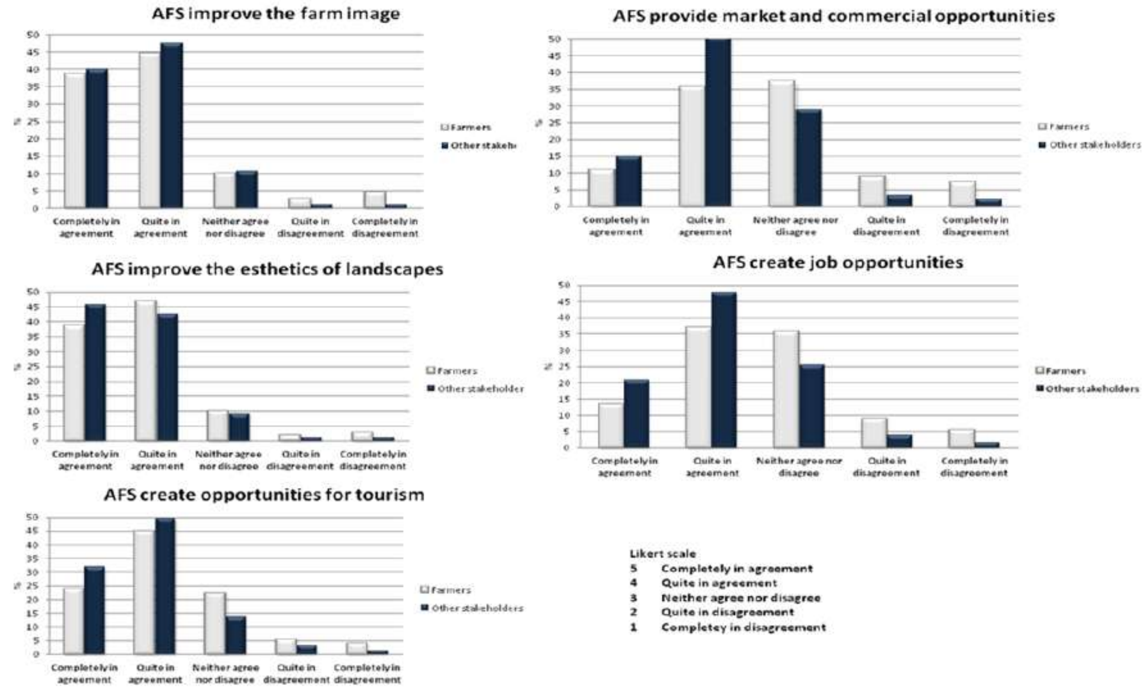


Figure 2: Comparison between farmers' and other SHs' opinions on the socio-economic benefits of agroforestry systems (AFS).

Discussion

This work shows some preliminary data obtained from an online survey on the opinions of different categories of Italian SHs on the environmental and socio-economic benefits of AFS focusing, in particular, on the category of farmers. Firstly, sex and age of the farmers' profile were analyzed. Percentages of women and men are coherent with the data from the Italian 2010 census in agriculture. A higher percentage of women in the agritourism sector can be highlighted, a trend confirmed also by the ISTAT survey (2016) showing that one out of three agritourism farms is run by women. Farmers' age also seems to be representative, even though not all age ranges considered correspond. Farmers over 65 could have been underestimated in our sample, probably because, being less familiar with email, they have not been reached. It is interesting to notice that among those who declare to have no AFS, a quite high percentage (43%) does not seem to be interested in applying AFS in the future. The reasons behind this choice should be investigated. While all the environmental issues showed positive responses of both farmers and other SHs, the responses on fire risk seemed to be less clear. This can be due to the fact that the effects on fires are perceived to a greater extent in cases where AFS coincide with agro-silvopastoral systems, mixed farming systems with crops and livestock (Franca et al. 2012).

The positive responses on environmental benefits of AFS are a relevant result. In fact, as agriculture is a major cause of multiple types of environmental degradation (Clark and Tilman 2017) and farmers are the main actors of this sector, their awareness of the environmental benefits of AFS is an important basis to further promote the leading role of farmers in preserving the environment. Such awareness, if properly worked out, could also be one of the premises to develop effective means for upgrading AFS, the environment and the marketing of AFS products.

However, looking at the responses on socio-economic issues, it seems that, while the answers on farm image and landscape are positive (both for farmers and the other SHs), the opinions on commercial and job opportunities, as well as those on tourism, tend to be less sharply outlined. The more uncertain opinions can be explained by the fact that, despite the positive opinions on the benefits of AFS on farm image and landscape aesthetics, the effects on business opportunities are not perceived as obvious. The reasons why farmers have positively evaluated AFS (see also Graves et al. 2008) should be investigated, if we consider that the application to Agroforestry measures of the Rural Development Plan is very poor (Pisanelli et al. 2014). Are the granted systems not properly chosen by the local administrations? Are the grant levels insufficient for farmers to overcome their economic uncertainties concerning AFS?

The results could suggest the need to better support farmers and other SHs, in particular farm consultants, policy makers, and land planners, in exploiting AFS strengths and opportunities for farm and spatial planning in order to make them effective instruments for products marketing, place branding and promotion.

References

Atkinson R, Flint J (2004) Snowball sampling. In: Lewis-Beck M, Bryman A, Liao T (eds) Encyclopedia of Social Science Research Methods. SAGE Publications, Inc, Thousand Oaks, CA, pp 1044–1045.

Camilli F, Pisanelli A, Seddaiu G, Franca A, Bondesan V, Rosati A, Moreno GM, Pantera A, Hermansen JE, Burgess PJ (2017) How local stakeholders perceive agroforestry systems: an Italian perspective. Agrofor Syst DOI10.1007/s10457-017-0127-0

Clark M and Tilman D (2017) Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice Environ. Res Lett 12 064016.

EIP-AGRI Focus group (2017) Agroforestry: introducing woody vegetation into specialized crop and livestock systems. https://ec.europa.eu/eip/agriculture/en/publications/eip-agri-focus-group-agroforestry-final-report. (accessed 23/04/2018).

FAO (2017) Agroforestry for landscape restoration. http://www.fao.org/3/b-i7374e.pdf (accessed 23/04/2018).

ISTAT–6° Censimento generale dell'agricoltura 2010 (2013) Caratteristiche tipologiche delle aziende agricole. ISBN: 978-88-458-1800-4

ISTAT (Istat Italian National Institute of Statistics) (2016) https://www.istat.it/it/archivio/agricoltura (accessed 23/04/2018).

Franca A, Sanna F, Nieddu S, Re GA, Pintus GV, Ventura A, Duce PP, Salis M, Arca B (2012). Effects of grazing on the traits of a potential fire in a Sardinian wooded pasture, Options Mediterraneennes, Series A: Mediterranean Seminars 103: 307-312.

García de Jalon S, Burgess PJ, Graves A, Moreno G. McAdam J Pottier E, Novak S, Bondesan V, Mosquera-Losada R, Crous-DuranJ, Palma JHN, Paulo JA, Oliveira TS, Cirou E, Hannachi Y, Pantera A,Wartelle R, Kay Sonja, Malignier N, Van Lerberghe P, Tsonkova P, Mirck J, Rois M, Kongsted AG, Thenail C, Luske B, Berg S, Gosme M, Vityi A (2017) How is agroforestry perceived in Europe? An assessment of positive and negative aspects by stakeholders. Agrofor Syst DOI 10.1007/s10457-017-0116-3

Graves AR, Burgess PJ, Liagre F, Pisanelli A, Paris P, Moreno G, Bellido M, Mayus M, Postma M, Schindler B, Mantzanas K, Papanastasis VP, Dupraz C (2008) Farmer Perceptions of Silvoarable Systems in Seven European Countries. In Rigueiro-Rodríguez A, McAdam J, Mosquera-Losada MR (eds) Agroforestry in Europe: Current Status and Future Prospects. Springer Netherlands, pp. 67-86.

Likert R (1932). A Technique for the Measurement of Attitudes. Arch Psychol 140: 1–55.

Paris P, Buresti E, Cannata F (2001) Agroforestry in Italy. Tradition of the practice and research indications on new models. Sino-Italian workshop–forestry and agroforestry for environmental protection and rural development.

Perali A (2004) Dissertation thesis: Evoluzione e situazione attuale dei sistemi agroforestali in Italia (con inventario degli impianti monitorati su Cd-rom). Dipartimento di arboricoltura e protezione delle piante. University of Perugia

Pisanelli A, Marandola D, Marongiu S, Paris P, Rosati A, Romano R (2014) The role of Rural Development Policy in supporting agroforestry systems in EU. 2nd European Agroforestry Conference, Cottbus, Germany.

CARBON FOOTPRINT IN DEHESA AGROFORESTRY SYSTEMS

Escribano M[1], Moreno G[2], Eldesouky A[1], Horrillo A[1], Gaspar P[1], Mesías FJ[1*]

(1) Research Institute of Agricultural Resources (INURA). University of Extremadura. Avda. Adolfo Suarez. s/n – 06007 Badajoz, Spain (2) INDEHESA - Institute for Silvopastoralism Research. University of Extremadura. Plasencia 10600, Spain

*Corresponding author: fjmesias@unex.es

Abstract

Dehesa agroforestry systems (rangelands located in Southwest Spain) are characterised by their semi-arid and often marginal conditions. In this sense, the study of the role of carbon footprint in extensive systems is of great interest by analysing, within a case study framework, the two production systems available in dehesa farms and providing the methodological adjustments required to generate results that are comparable with other livestock systems and species. Results have revealed that sheep meat farms are those with the lowest carbon footprint levels (14.06 kg CO_2eq/kg live weight), followed by meat production farms selling calves at weaning period. Enteric fermentation accounts for 64.10% to 48.99% of the total emissions, and it is linked to the extensification of these systems and to the grazing diet of the animals. The system's own emissions could reach up to 78% in meat production systems. Undoubtedly, feeding is the input that amounts for the highest percentage of off-farm emissions, as it can reach up to 24.90%.

Keywords: carbon footprint, life cycle assessment, extensive production, greenhouse gases

Introduction

Extensive grazing systems located in the Southwest of Spain are characterized by their semi-arid and often marginal conditions with poor soils and scarce and irregular rainfall. These features are behind the low supply of pastures available for livestock use so that proper management is based on the use of reduced stocking rates which imply a minimal animal pressure on the territory. These systems share some of the characteristics defined for extensive animal production systems, such as the limited number of animals per hectare, low productivity per animal and hectare and feeding mainly based on free-range grazing and the use of agricultural by-products.

In this context, the environmental impacts of the agricultural or livestock production depend to a great extent on the production systems, which can be influenced by techniques, harvesting period and other technical issues. This primary phase is seen as the main contributor to the environmental impacts of food, related to biodiversity loss GHG emissions and reduction of soil fertility, among others.

Among livestock food products, meat has the greatest environmental impact. This is due to the inefficiency of animals in converting feed to meat, as 75–90% of the energy consumed is needed for body maintenance or lost in manure and by-products such as skin and bones. There are many processes contributing to major GHG emissions during meat production are: (1) production of feed, (2) enteric fermentation from feed digestion by animals (mainly ruminants), (3) manure handling and (4) energy use in animal houses.

Therefore, analysis of the carbon footprint (CF) in livestock production identifies the production procedures or techniques in which emissions may be reduced using improved efficiencies, estimates the amount and breakdown of GHG emissions and provides a mechanism to track efforts in improving efficiencies and reducing emissions.

Strangely enough, at least when it comes to environmental issues, intensifying animal production is generally advocated to mitigate certain environmental impacts, such as emission of greenhouse gases associated with production of animal-source food (Steinfeld and Gerber 2010). In this regard, the intensification of animal production in feedlots or with changes in their diet allows the early slaughter and has been reported as a strategy adopted in several countries to reduce GHG emissions in the production of beef (Ruviaro et al. 2016).

With that in mind, many consumers are still unfamiliar with carbon footprint information. making it difficult for them to evaluate and compare the different products which are offered. However, meat companies are interested in finding how different product characteristics can influence consumer choices and whether there is a possibility for a price premium if products are differentiated using the carbon footprint attribute. This topic is especially relevant in extensive systems, where environmental values associated to livestock production can be overshadowed by the comparatively higher emissions of these production systems.

The methodology selected in this research is the Life Cycle Assessment (LCA), a quantitative and environmental assessment of a product over its entire life cycle, including raw material acquisition, production, transportation, use and disposal (Khasreen et al. 2009). LCA attempts to quantify the materials and energy consumed, and chemicals emitted to the environment during resource extraction, manufacturing, distribution, use, and end-of-life stages of a product/service.

In this sense, it is of great interest to study the role of CF in extensive systems, analysing, within a case study framework, the different production systems present in dehesa agroforestry systems and providing the methodological adjustments required to generate results comparable with other livestock systems and species.

Materials and methods

Among the different methodologies available to estimate the GHG emissions, Life cycle assessment (LCA) is an internationally accepted, standardized methodology for quantifying the environmental impact of a product, and it has been therefore selected for this research.

CF calculation has been made in accordance with British standard PAS 2050 and the IPCC 2006s' guidelines for national greenhouse gases inventories (IPCC 2006). Also an adaptation of the methodology cited by the Spanish Ministry of Agriculture has been followed regarding the characteristics of livestock in the analyzed areas and manure management (MAPAMA 2012). The process followed in this has consisted on the study of carbon footprint within the context of Life Cycle Analysis and incorporating the system's carbon sequestration.

Data collection

This study is based on the analysis of two different case studies. Data were obtained through the monitoring of two farms through field visits and interviews with farmers carried out between January and May of 2017. The following case studies were analysed, as they were considered to be the most representative of the extensive systems in the Mediterranean agroforestry systems: Extensive meat sheep farming and Extensive beef/veal cattle farming

Functional unit

In this paper, the functional unit (FU) is the reference unit with which all the produced emissions of the system will be associated. The FU varies according to the analyzed case and taking as a reference the main production of each system. The defined FU is the kg of live weight of product, i.e. the kg of live weight of lambs or calves. The functional unit is often based on the mass of the product under study. Therefore, mass allocation will be used as the method of assignment in this study.

Estimation of GHG emissions and calculation of CF in farms

Global Warming Potentials proposed by the IPCC have been used to convert the raw data of methane (CH_4) or nitrous oxide sources (N_2O) emissions. Each gas has a specific value, 1 for CO_2, 25 for CH_4 and 298 for N_2O. In this way, data from raw emissions of CH_4 and N_2O gases are multiplied by 25 and 298, respectively, to transform this data to kg CO_2 equivalent.

In order to estimate the emissions, the emission factors of the gases produced by the system have been used, in addition to the inputs shown in Table 1.

Table1: Emission factors used to quantify GHG emissions of the analysed farms in the baseline scenario.

Emission and source	Type of GHC	EF
Into de systems		
Enteric fermentation	CH_4	8.64 kg CH_4/Sheep head year[a] 57 kg CH_4/Cow head year
Manure management		
Manure management CH_4	CH_4	(0.19 e 0.37 in sheep)[b] kg CH_4/head year 2.70 in Bovine kg CH_4/head year
Manure management direct N_2O	N_2O	0.005 kg N_2O eN/kg N Solid storage system
Manure management indirect N_2O	N_2O	0.01 kg N_2O eN /volatilized
Soil management		
N from organic fertilizers (compost. manure)	N_2O	0.01 kg N_2O eN (kg N input)$^{-1}$
N from urine and dung inputs to grazed soils in Sheep	N_2O	0.01 kg N_2O eN (kg N input)$^{-1}$
N from urine and dung inputs to grazed soils in Cow	N_2O	0.02 kg N_2O eN (kg N input)$^{-1}$
Indirect emissions Management Soils	N_2O	0.01 kg N_2O eN (kg % N volatilised/leaching)$^{-1}$
Out of the systems		
Concentrates Meat Sheep	CO_2	0.512 kg CO_2eq/kg
Concentrates Meat Cow	CO_2	0.512 kg CO_2eq/kg
Forages	CO_2	0.100 kg CO_2eq/kg
Electricity	CO_2	0.308 kg CO_2eq/kWh
Diesel	CO_2	2.664 kg CO_2eq/litre - combustion 0.320 kg CO_2eq/litre - upstream

Most of the emission factors have been taken from IPCC Guidelines (2006). Vol 4. Chapter 10 and 11.
a Emission factor adapted to the area. MAPAMA (2012)
b With average temperature

Results

The studied farms correspond to the dehesa extensive systems that are devoted to the production of meat sheep and calves at weaning age. Table 2 shows the technical characteristics of these farms, together with estimated footprint, wich is 14.06 kg CO_2 / kg FU in the case of sheep and of 17.74 kg CO_2 / kg FU in beef.

Table 2: Technical indicators & Carbon footprint of the studied farms.

Indicators	Extensive meat sheep	Extensive Beef Cattle
Pasture surface (ha)	270	150
Kg DM pasture/ha	1100	1200
Nº of reproductive sheep or caw (average population)	900	50
Livestock Unit/ha	0.46	0.36
Born lambs/ sheep	1.12	-
Born calves / cow	-	0.81
Inputs of Farm		
Total Kg concentrate bought / reproductive sheep or cow	105	417
Fodder bought / reproductive sheep or cow	60.71	1221
Fuel (litres/year)	520	1168
Electricity (kwh/year)	4200	-
Outputs of Farm		
Sold lambs/ reproductive female	1	0.74
Kg lambs	25	220
TOTAL Footprint kg CO_2/FU	**14.06**	**17.74**
Total Kg CO_2	357321	159991
Total Kg CO_2 per ha	**1319.03**	**1066.61**

However when considering emissions in relation to the territory it can be seen that the emission levels are lower in the case of cattle with 1066.67 kg CO_2 / ha compared to 1319.03 kg CO_2 / ha of sheep. In this sense, the current system of linking the produced emissions to the product units is questioned, at least in dehesa agroforestry systems, characterized by extensification and low levels of production.

In Figure 1 we analyze the percentage contribution of the different greenhouse gases in the different processes, whether they are produced on the farm itself or due to inputs.

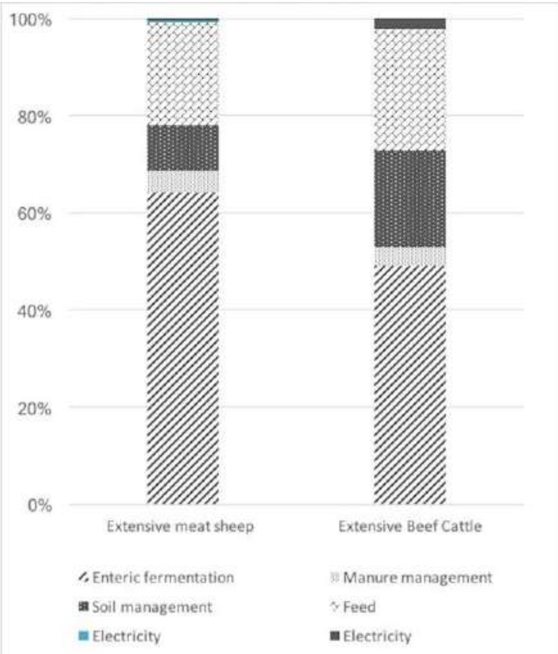


Figure 1: Percentage distribution of the carbon footprint according to processes in the analyzed farms.

The enteric fermentation varies in the case of sheep farms, as it reaches 64.10% compared to 48.99% for the production of calves. The emissions from manure management are similar in both farms; however in the soil management, the emissions are much higher in the case of beef farms reaching 20.02% of total emissions.

Discussion

Undoubtedly, feed is the highest input of the farm's emissions percentage, reaching up to 24.90% of the total in cattle farms and compared to 21.20% in sheep meat.

Enteric fermentation and feeding are the factors that produce the greatest range of emissions and their distribution will be largely conditioned on the operating based systems or not grazing systems. We can also observe its relation with the final carbon footprint, since the farms that have important feed inputs tend to have a smaller footprint because the number of product units increases.

In extensive systems, mitigation strategies should be aimed at increasing the digestibility of pastures that generally reduce GHG emissions from enteric fermentation and stored manure. In parallel, it should be noted that these systems cannot compete in product units with more intensive ones and therefore the carbon footprint in dehesa agroforestry systems should be referred to the territory. The compensation of their emissions due to carbon sequestration by carbon sinks also needs to be highlighted.

Conclusions

LCA is a useful tool for measuring the potential environmental performance of livestock production. LCA may be combined with other methods to assess economic sustainability of animal production in order to reveal on-farm efficiencies. It also could help reduce both environmental and monetary costs associated with animal rearing.

However, extensive farms usually have a territorial component (hectares of agricultural land, with pastures, trees…) which can help compensate for CO_2 emissions, due to carbon sequestration. Nevertheless, it is not common to take into account carbon sequestration in LCA studies, which creates a disadvantage for extensive systems, and can send confusing messages to the consumers and endanger the persistence of these valuable and complex systems.

References

IPCC (2006) IPCC guidelines for national greenhouse Gas inventories. In: Inter-governmental Panel of Climate Change (IPCC). National Greenhouse Gas Inventories Programme.

MAPAMA (2012) Inventarios Nacionales de Emisiones a la Atmósfera 1990-2012. Volumen 2: Análisis por Actividades SNAP. Capítulo 10: Agricultura.

Khasreen MM, Banfill PF, Menzies GF (2009) Life-cycle assessment and the environmental impact of buildings: a review. Sustainability 1: 674-701.

Ruviaro CF, da Costa JS, Florindo TJ, Rodrigues W, de Medeiros GIB, Vasconcelos PS (2016) Economic and environmental feasibility of beef production in different feed management systems in the Pampa biome. southern Brazil. Ecol Indic 60: 930-939.

Steinfeld H, Gerber P (2010) Livestock production and the global environment: consume less or produce better? PNAS 107: 18237–18238.

EFFECTIVE MANAGING, INITIATE AND MONITORING FOOD FORESTS

Fonk SG[1]*, Lenderink R[1], Sendar N[1]

(1) Ecovrede Nederland - ffrmnetwork - Arnhem, Park Lingezegen, van Hall Larenstein-students Velp, Wageningen University study group, Helicon Velp, The Netherlands

*Corresponding author: ffrmnetwork@gmail.com

Abstract

Biomonitoring as a baseline in the process of acceptance of food forests and insight into the ecological processes in a food forest, measurement methods and skills. With the positive influence to local food supply and structural help to the needy people with a lesson in learning how to produce their own fresh food and become more independent and healthy.

Keywords: biomonitoring; managing; poverty; local food supply; own food production

Food forest measurements

To speed up the transition in the direction of sustainable food and food forests, it's necessary that everyone get the possibility to participate. We need measurements and scientific results to make the basic acceptance of food forests possible and effective. We started in 2017 with a project in collaboration with students from Wageningen University (WUR 2018). With the main goal on how to make a system of easy, cheap and scientifically proven measurements to monitor the essential processes in a food forest, so we can compare measurements between food forest initiatives and learn from it. Society will better and more easily accept the newly shown possibilities. The second step is to stimulate the process of social interaction. The livestock population in the Netherlands must be drastically reduced in order to achieve the environmental goals and reducing the impact of climate change (Rli 2018), but also to reduce the suffering of animals that live in a bad condition. A food forest is an alternative for keeping livestock. Are the necessary data available to make this change practical and convincing? One of the reasons to start our monitoring initiative FFRMnetwork. A complete change in food consumption and production is necessary; “less meat and more vegetables and legumes”.

Worldwide and EcoVrede

Several national and international studies are motivated by and showed us the results of a needed fundamental change in the process of food production. To guarantee a basic food supply, anticipate on climate change, a better understanding of nature and new natural working processes, local food forests can give the tools. Food forests may have a essential function in these processes and beside that, they help people in poverty to get their needed fresh fruits and vegetables. This is a worldwide problem. They give the tools in the needed interaction with the process of climate change and its consequences. These are our goals and motivation.

Since 2010, EcoVrede (www.ecovrede.nl) distributes fruit, bread and vegetables in the area of Arnhem. The number of poor people without enough fresh food is still growing. This is in contrast to the recent economic growth and the expected effects for people with low incomes. Our food forest and distribution network provide the tools in practical help and a diving board to a better individual situation. We coach the people in this process and organise diverse other services like coaching, legal advice, advice in healthy living, learning trajectories, internships, household goods, repairs and clothes; everything needed to get free space to an effective individual transition. Food Forest EcoVredeGaard is an essential part in this process. We do this for free or small gifts and offer a workable, locally applicable initiative that we can implement at any place. In order to support needy people in our rich society, EcoVrede started a multifunctional food forest called EcoVredeGaard (EVG) in October 2016, between Arnhem and Nijmegen in the Netherlands. We are also working towards other locations and we participate in different initiatives. We like to be invited to more locations and possibilities (Mulder 2018).

How can we teach people to take responsibility of their own food production

A recent article (2018) of High School Larenstein Netherlands shows the need for food forests because of the badly organised food distribution in the Netherlands. People will be hungry in the city of Arnhem in five days if there would be an interruption in food deliveries. There is not enough local production of food, which is a really unwanted and unstable situation. A food forest adds to the production of fresh local fruit and vegetables. It’s an essential tool in the process to a more stable food supply (Lohman 2018). We show the local possibilities (WUR 2012).

Poverty and food forests

Beside this fact a lot of people are hungry, homeless, poor or without perspective. In the Netherlands there are between 1 and 2.5 million people (Achterbosch 2018). To support this group of people, a practical organization had to be developed (Margrite et al. 2017). At the same time, various tools were needed to enable volunteers, students and people in poverty to start. In addition, EcoVrede initiated and registered the effects and background of food forests in order to gain a more scientific substantiation to initiate and stimulate food forests initiatives.

Because of their often stressful, hopeless, uncertain situation, people with a low income get a lack of perspective and are sometimes far away from a healthy way of living (Kem and Ritzen 2015). They die at a younger age on average. Children also get their own problems because of poverty, also because of a lack of money to buy fresh fruits and vegetables. In addition, people can cooperate with existing natural projects, initiatives and learn to produce their own food. By offering people new knowledge and a practical, enjoyable workplace, EcoVrede gives this group a better perspective and a new, positive personal vision and scope. Building up a new fundament with more natural goals. In time, we hope people participate in different aspects of developing food forests in more places. Let's multiply!

In the following section, based on the practical situation, the preconditions and the results of these first developments are presented.

Practical situation and preconditions

Planning structure: The EcoVredeGaard has the disposal of various sub-areas to a great diversity of people and a organization structure in which everyone can carry out their duties properly.

Planning module: The work on the EcoVredeGaard is done on a voluntary basis. The volunteers live on relatively long distances, making it necessary to communicate by telephone or video calls which gives the possibility to several people to participate in the EcoVredeGaard on different levels.

Education program: Volunteers often have a limited background in the field of sustainable food production. An education program must be made so that people with a limited background understand the essence of sustainable food production and their personal profits. Education must be made as attractive as possible.

Biomonitoring program: Food forests provide diverse positive contributions and we promote these to policy makers. We developed a monitoring program to produce practical data in which people with a limited background are able to participate in the field of (scientific) research. This monitoring program is implemented with a (very) low budget (Slier et al. 2018)

Results

Planning structure

We have chosen to work with a 3-layer planning:

1. Layer 1: Main task - the responsibility lies with the managers of the EcoVredeGaard

Interaction with (local) government, participants and colleagues, media and (high) schools.

2. Layer 2: Project setup (everyone, but you need some experience)

An example for a project is making a sawah (rice field) with a construction for aquaponics (a symbiotic by growing plants and aquatic animals in a recirculating surrounding). When a project is successful, we scale it up. People in poverty and other people can participate and have their own experience and build up knowledge.

3. Layer 3: To develop initiatives, everyone is able to do with some help

An example for an initiative: the initiator can set up an exchange between the local restaurant and EcoVredeGaard. Old vegetables can be used as compost for the EcovredeGaard. This compost can be used for food production. We can offer this food to the local restaurant. People are coached in these individual processes.

The 3-layer planning gives a more effective way of working in general.

Planning module: We developed an effective planning module (based on Google sheet) which combinates planning with a data storage system with direct input on location. This tool can be used effectively with applications such as Whatsapp or Hangout. People from around the world with different skills are able to participate in their own field of interest in our food forest. This way we build up new opportunities and innovations with the actual possibilities there are on a daily basis.

Education program: To support people with a less educated background, we developed an education program. We use master posters with all the essential information. Based on these master posters, we explain the essential information. In this program we handle the following subjects: Definition (nature) ecosystem and sustainable food system, Four functions of each ecosystem (Supporting -, Provisioning -, Regulating - services), History of human food supply, implementation of traditional knowledge, New innovations like Food Forests; How to make the right choice on any location (Figure 1).

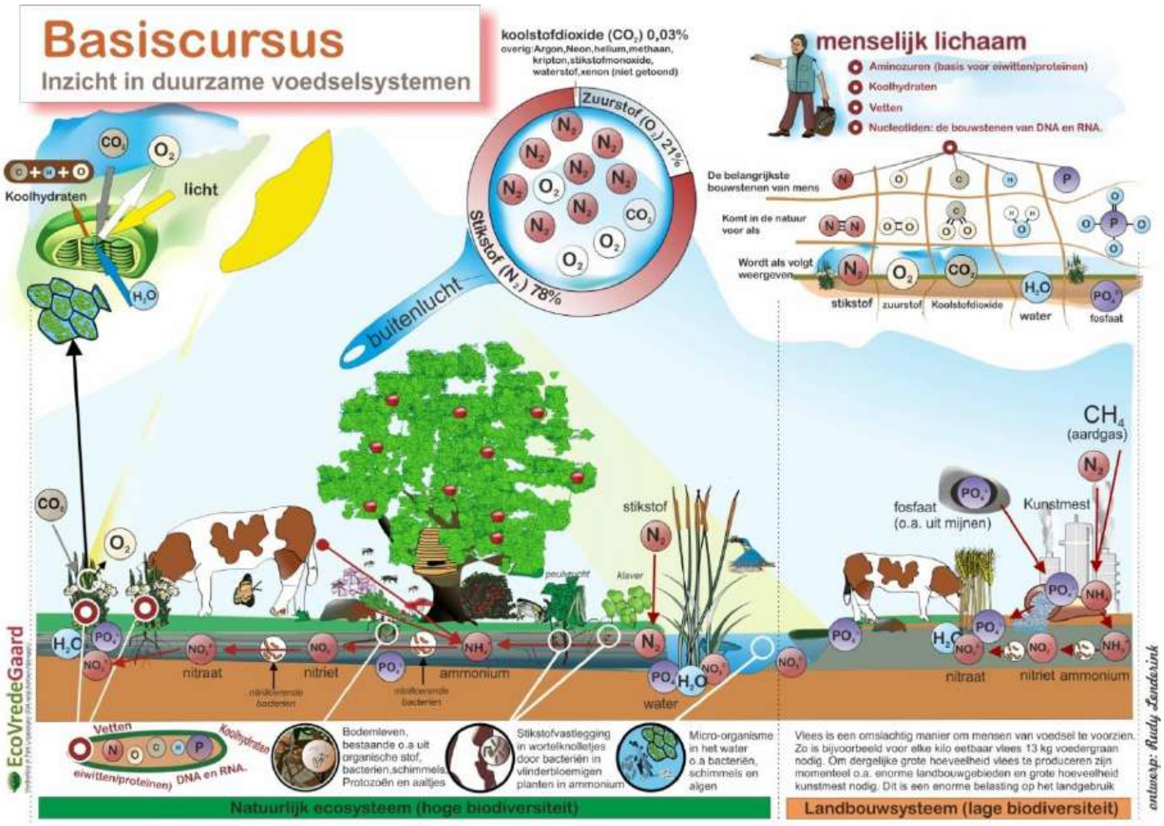


Figure 1: Master poster.

Development of a unique, low-budget biomonitoring program for food forests

EcoVrede has asked Wageningen University & Research to provide support in developing a biomonitoring program. The students have developed a unique, low-budget biomonitoring program consisting of a manual and a report. The manual explains how to carry out a proper biomonitoring research. Accepted by the scientific world and carried out at relatively low costs (Table 1).

Table 1: Result low-budget biomonitoring program for food forests.

	Original situation	**New monitoring program**
Is being done by	scientists	**almost for everyone**
Price	high	**very low**

Follow up

FFRM network gives support in monitoring of food forests. We collect and share the monitoring information and give backup in collecting the data. We support monitoring and background information about food forests and related items.

References

Achterbosch TJ (2018) “Voldoende voedzaam en betaalbaar voedsel voor iedereen” https://www.wur.nl/nl/artikel/Voldoende-voedzaam-en-betaalbaar-voedsel-voor-iedereen.htm (accesed 22/04/2018).

Kem A, Ritzen J (2005) “Dying for Change: ‘Poor people’s experience of health and ill-health” http://documents.worldbank.org/curated/en/123521468332446432/pdf/331250ENGLISH0Dying0for0change.pdf (accessed 22/04/2018).

Lohman J (2018) “Waar stad en land elkaar ontmoeten kunnen we de wereld voeden” https://www.volkskrant.nl/kijkverder/2018/voedselzaak/ideeen/daar-waar-stad-en-land-elkaar-ontmoeten-kunnen-we-de-wereld-voeden/ (accessed 22/04/2018).

Mulder K (2018) “Voedselbossen” https://eetbaarnijmegen.nl/voedselbossen/ (accessed 22/04/2018).

Margrite KK (2017) “Alle kinderen kansrijk” https://www.dekinderombudsman.nl/ul/cms/fck-uploaded/2017.12.05RapportAllekinderenkansrijk.pdf (accessed 22/04/2018).

Rli (2018) “Duurzaam en gezond - Samen naar een duurzaam voedselsysteem” http://www.rli.nl/sites/default/files/duurzaam_en_gezond_samen_naar_een_houdbaar_voedselsysteem_def.pdf (accessed 22/04/2018).

Slier T, Mahesh N, Aguinaga I, Harper S, Jin T, Ridwan M (2018) “Dutch Food Forest: A low-cost monitoring design”. Wageningen University & Research https://drive.google.com/file/d/0ByQOxkwH4h2Sc1ZuOFhoeDAtYnM4bEhWN2NabkhhUm5EbnpZ/view (accessed 22/04/2018).

WUR (2012) “Regionaal Voedsel in Arnhem” https://www.wur.nl/nl/artikel/Regionaal-Voedsel-in-Arnhem.htm (accessed 22/04/2018).

WUR (2018) “Fieldwork Manual for the Volunteers of EcoVredeGaard. URL: https://drive.google.com/file/d/0ByQOxkwH4h2SeXFQTnVDTDJDSWlURWJ2ZDh1TE5ZQURXMFpj/view (accessed 23/04/2018).

REMAINS OF CHESTNUT WOOD PASTURES AS PART OF AGROFORESTRY SYSTEMS IN SLOVAKIA

Pástor M[1]*, Jankovič J[1], Pažitný J[2]

(1) Department of Silviculture and Forest Production, National Forest Centre – Forest Research Institute, Zvolen, Slovakia (2) Department of Phytopathology and Mycology, Institute of Forest Ecology, Nitra, Slovakia

*Corresponding author: michalpastor65@gmail.com

Abstract

Slovakian agroforestry does not officially exist yet, although remnants of these traditional systems developed in the past, which have high environmental and cultural value, are still to be found. Slovakia due to its natural conditions also has great potential for establishment of modern agroforestry systems, which has been developed during the last decades by many research centres in Europe. The contribution is devoted to one of the remains of a previously applied agroforestry systems in Slovakia – chestnut *(Castanea sativa* Mill.) wood pastures. Unfortunately, today they are getting worse markedly due to insufficient management and spreading parasitic fungus *Cryphonectria parasitica*. Populations of this useful crop are small today, but they are important habitats that would deserve more scientific interest. The main objectives of the contribution are focus on the mapping of chestnut population in the south part of central Slovakia and chestnut biocultural value assessment in the given traditional landscape types.

Keywords: agroforestry systems; chestnut; bioculture value; old stables; traditional land use

Introduction

Current status and national initiatives related to agroforestry systems in Slovakia

In Slovakia, as in many other European countries, we have had a long period of time when our administrative and governance structures were considered to be legitimate to use only agriculture or forestry. This condition still persists and the term "agroforestry" does not even exist today in any Slovak legislation, despite the fact that such systems have been used in the past and their remains are present in Slovakia even today.

The professional discussion about agroforestry systems and possibilities of their utilization and establishment in the conditions of Slovakia started to be initiated after the participation at the 2nd European Agroforestry Conference in Cottbus (Germany) in 2014. Since 2015 we have published several agroforestry contributions in different journals and we are currently registering the increased interest of landowners regarding establishment of agroforestry systems. Our intention is to gradually connect and organize both scientific community and farmers related to agroforestry systems in Slovakia. At the same time we implement activities in creating expert background and preparing proposals to modify national legislation so that agroforestry systems can become a legal part of agricultural land management in the near future. In the field of research, since 2015 we have been working on the project supported by the Slovak Research and Development Agency (APVV) with title "Research possibilities of growing of common juniper (*Juniperus communis* L.) for the production of fruit“, where the most effective system is "juniper pastures". In 2017 we again submitted to the APVV a proposal for the project with name "Research possibilities of using of black walnut (*Juglans nigra* L.) and sweet chestnut (*Castanea sativa* Mill.) in agroforestry systems in Slovakia". We are currently preparing a proposal for the research program "Agroforestry systems for combination production and more efficient use of agricultural land" as a research intention for long-term strategic research.

Historical background and current state of chestnut occurrence and cultivation in Slovakia

Sweet chestnut (*Castanea sativa* Mill.) is one of the oldest non-native woody plant species in Slovakia. It is supposed that chestnut was brought for the first time to the area of current Slovakia by ancient Romans. Probably some old chestnut trees grown near the capitol Bratislava on slopes of Little Carpathians Mts. could be descendants of this introduction. However, the first historically proven chestnut introduction was done by count Forgach in the 13th century to the oak forest under the castle Gymesh near the village Jelenec. The original chestnut grove planted on an area of about 1 ha had turned during centuries to the naturally regenerated high forest, which covers at present about 15 ha. The last most important introduction of chestnut to the territory of the present Slovakia is dated back to 16th and 17th centuries to the period of Ottoman invasions. The primary centre of this introduction is considered the town Modrý Kameň, particularly the surroundings of the local castle. Nowadays, chestnuts grow at this location on several sites in the series of old orchards of seed origin. In each introduction centre the majority of chestnut trees are more than 100 years old and some trees reach the age of about 300 years. Old chestnut trees can be also found on other localities in old orchards established apparently from the chestnut seeds from the introduction centres.

At present, chestnut is widespread at more than 220 localities in Slovakia. It occurs in the southern part of the country, on steep slopes with altitudes ranging from about 200 to 400 m a.s.l. Distribution of chestnut is geographically limited to the latitude range 48˚– 49˚ N and longitude range 17˚– 49˚ E. On localities with chestnut occurrence, long term mean annual air temperature fluctuates from 9˚ C to 10˚ C and long term mean annual sum of precipitation between 600 and 700 mm. Chestnut grows here outside the recorded natural distribution range and therefore doesn´t have optimal climatic conditions. In Slovakia, chestnut occurs mostly in extensive old orchards, with a total area of about 130 ha, of which 95 ha represent the old, more than 100 years old trees of seed origin (Figure 1). Young trees between 30 – 35 years old are registered on the area around 35 ha. The area on which chestnut is considered as forest tree species is more precisely recorded. It corresponds to approximately 1405 ha, including mixed forest stands of chestnut with other tree species (*Tilia* spp., *Pinus sylvestris*, *Quercus* spp.).

Currently, the health condition as well as chestnut production have rapidly declined as a result of enormous dying out of chestnut individuals infected by fungus *Cryphonectria parasitica* (Murr.) Barr. (Bolvanský et al. 2008).

Figure 1: Active chestnut wood pasture in central Slovakia grazed by sheep.

Main objectives of the research

The submitted contribution is devoted to one of the remains of a previously applied agroforestry systems in Slovakia – chestnut wood pastures. The main objective of the research was to locate the current chestnut occurrence and its present state in the Modrý Kameň area (southeast Slovakia) based on detailed mapping and to assess the chestnut biocultural value in the traditional landscape types, which are present in the study area. Chestnut trees have been creating wood pastures here. Unfortunately, today they are getting worse markedly due to insufficient management.

Materials and methods

Modrý Kameň area is situated in the southern part of central Slovakia and its vicinity represents the largest area with the chestnut occurrence in Slovakia. The estimated number of trees growing in this area is 1500 – 2000. The natural values were represented by high nature value (HNV) farmlands (Keenleyside et al. 2014) and habitats of European importance (Galvánek and Lasák 2011). In the study area, the habitat of Lowland Hay meadows (no. 6510) was identified. The cultural values related to chestnuts were represented by historical farm buildings in the vicinity of chestnuts dispersed in the countryside. The residents of villages usually owned agricultural plots with fields, meadows, pastures and vineyards, where specific seasonal dwellings called “chišky” and “koňice” were built (Chovanová et al. 2006). The English equivalent of both the words for this type of buildings is a stable. The geospatial relationship between chestnuts and old stables was tested by the distance matrix using the Distance Matrix Analysis Tool in QGIS. The traditional landscape types were adapted from the Atlas of the Slovak Republic (Miklós and Hrčiarová 2002). Chestnut individuals and its area formations were identified and positioned in 6 cadastral districts (Dolné Príbelce, Horné Príbelce, Dolné Plachtince, Stredné Plachtince, Horné Plachtince, and Modrý Kameň). A touristic Global Navigation Satellite System (GNSS) Garmin (2010) was used for the positioning of chestnut trees and historical farm buildings.

Results and discussion

101 individuals and 123 groups (46 ha) of chestnut: 11 groups > 31 individuals, 10 groups of 16 – 30 individuals, 34 groups of 6 – 15 individuals, 68 groups of 2 – 5 individuals were identified and positioned in the field. Chestnut trees most frequently occurred in the extensively used Corine Land Cover (CLC) patches with pastures and with heterogeneous agricultural areas – “Land principally occupied by agriculture with significant areas of natural vegetation”, in parallel coinciding with HNV farmlands and Lowland hay meadows and with local occurrence of the protected bat species. The analysis of the geospatial relationship between chestnut individuals (49), centroids of its area formations (54) and old stables (26) showed that the most frequent distances of the nearest neighbour ranged from 82.79 m to 205.18 m. While the distance between buildings and chestnuts increased, the frequency of chestnuts and old stables decreased (Pástor et al. 2017).

Without a constant care (regular mowing and cattle grazing), chestnuts are heavily prone to damage and disease. They slowly decay and stop producing quality fruits (Michon 2011). They face an inadequate maintenance in Slovakia. Nowadays, chestnut preservation and protection according to the Act on Nature and Landscape Conservation is impossible as it is listed among the introduced tree species. A similar legal status of the chestnut preservation is documented in Italy by Agnoletti (2007). The absence of chestnut groves in the list of habitats meriting a protection is mostly due to its artificial origin, but also for the assumed low biodiversity value of these woods as compared with natural forests.

Suitable case of fruit agroforestry would be just chestnut planting in pastures and meadows. Chestnuts were frequently found in the vicinity of old stables. These findings partially confirmed the usage of chestnut products for cattle breading. Deeper social research would be expected to verify that chestnuts were an essential part of pastoral life of inhabitants in the study area (Pástor et al. 2017).

In Slovakia, chestnut belongs to the marginal nut tree species and minor fructiferous tree species. However, it contributes significantly to the preservation of traditional agricultural landscape and also it is a very suitable tree species for establishment of agroforestry systems. Populations of this useful crop are small today, but they are important habitats that would deserve more scientific interest.

References

Agnoletti M (2007) The degradation of traditional landscape in a mountain area of Tuscany during the 19th and 20th centuries: Implications for biodiversity and sustainable management. Forest Ecol Manag 249: 5-17.

Bolvanský M, Brindza J, Tóth D, Bacigálová K, Ferianc P, Karelová E, Harichová J, Kačániová M, Horčin V, Mendel Ľ, Užík M (2008) Gaštan jedlý (*Castanea sativa* Mill.) biológia, pestovanie a využívanie. Slovenská poľnohospodárska univerzita v Nitre.

Galvánek D, Lasák R (2011) Informačný Systém Lúk DAPHNE - Mapovanie travobylinnej vegetácie Slovenska. 6510 Lowland Hay Meadows. http://n2k.daphne.sk/mapy/6510.pdf. (accessed 16/09/2016).

Chovanová I, Paučová A, Damjanovová K, Botoš A, Šujanová S (2006) Urbanisticko-historický výskum a návrh zásad ochrany, obnovy a prezentácie hodnôt územia. Pamiatková zóna Horné Plachtince.https://www.pamiatky.sk/Content/PZ_ZASADY/Horne_Plachtince/011-zasady_horne_placht.pdf. (accessed 20/09/2016).

Keenleyside C, Beaufoy G, Tucker G, Jones G (2014) High Nature Value farming throughout EU-27 and its financial support under the CAP. Report Prepared for DG Environment. London: Institute for European Environmental Policy. (Contract No ENV B.1/ETU/2012/0035).

Michon G (2011) Revisiting the Resilience of Chestnut Forests in Corsica: from Social Ecological Systems Theory to Political Ecology. Ecol Soc 16(2): 5.

Miklós L, Hrnčiarová T [eds.] (2002) Landscape Atlas of the Slovak Republic. MŽP SR and Banská Bystrica: SAŽ, Bratislava.

Pástor M, Slámová M, Benčať T (2017) The Distribution and Biocultural Value Assessment of Sweet Chestnut (*Castanea sativa* Mill.) in the Cadastral Districts of Stredné Plachtince and Horné Plachtince (Slovakia). Ekológia 36:130–145.

DIFFERENCES WITHIN SIMILARITIES: TYPOLOGY OF FARMING STRATEGIES AND NATURAL RESOURCE MANAGEMENT IN TWO *EJIDOS* OF JALISCO, MEXICO

Monroy-Sais AS[1*], García-Frapolli E[1], Mora-Ardila F[1], Skutsch M[2], Gerritsen PRW[3], Casas A[1], Cohen D[1], Ugartechea-Salmerón O[1]

(1) Instituto de Investigaciones en Ecosistemas y Sustentabilidad, Universidad Nacional Autónoma de México, Morelia, Michoacán, México (2) Centro de Investigaciones en Geografía Ambiental, Universidad Nacional Autónoma de México, Morelia, Michoacán, México (3) Centro Universitario de la Costa Sur, Universidad de Guadalajara, Autlán, Jalisco, México

*Corresponding author: amonroy@cieco.unam.mx

Abstract

In the Mexican countryside, communally organised institutions called *ejidos* are a very important for the management of natural resources. This study develops a typology through social and ecological data to characterize farm management strategies and the agroforestry systems in two ecologically contrasting *ejidos* within a highly biodiverse region on the southern coast of Jalisco, Mexico. Taking the household as the unit of analysis, we conducted 55 structured interviews collecting data of 50 different socio-ecological variables. We found 4 consistently groups associated mainly with land tenure differences inside the ejido and the surrounding ecosystems in the farm. Also, diversification of strategies appears to be an inherent response of the social-ecological system to uncertainty and instability. These results have important public policy implications as they can boost specific strategies while diminish others with their environmental outcomes.

Keywords: household strategies; livelihoods; social-ecological systems; Mexico

Introduction

In the Mexican countryside, *ejidos* are a very important institutions in the management of natural resources (Alcorn and Toledo 1998). These peasant communities formally emerged as an outcome of the land redistribution policies which followed the Mexican Revolution. About 54% of all land in Mexico, and 60% of all forests, fall within these territories or similar land holding systems (Skutsch et al. 2015); *ejidos* represent around 90% of all these communally managed lands. The rural areas not communally organized are held by private landowners who may be large or small. An interesting feature is that sometimes these private owners may live in an *ejido*, although their property is external to it.

The analysis of management strategies in these institutions is relevant for conservation and sustainable use of biodiversity. This study develops a typology through social and ecological data to characterize farm management strategies and the agroforestry systems in two communities within a highly biodiverse region on the southern coast of Jalisco, Mexico. We hypothesize that the land tenure institution that is present (the *ejido* system), creates differential access to resources inside the communities, leading to different social groups adopting different strategies and, consequently causing different impacts on the surrounding ecosystems and environment.

Materials and methods

We choose two ecologically contrasting *ejidos* in the same region (Chamela-Cuixmala) (Figure 1), one with mainly tropical dry forest (*ejido* Ranchitos) (Schroeder and Castillo 2012) and one with temperate forests (*ejido* Pabelo) (Monroy et al. 2016) to observe differences in their land-management strategies. Taking the household as the unit of analysis, we conducted 55 structured interviews (29 in Ranchitos and 26 in Pabelo) relating to their productive activities and natural resource management. We collected information on 50 different socio-ecological variables on the: a) family unit, b) productive activities, c) natural resource management, and d) other financial activities, (Table 1). From this information, we performed first a cluster analysis of farm household types and then with the groups formed we displayed the ordination analysis to observe the most important variables in the ordination of the data. Both analyses were done using basic routines in the software R. In addition, field observations of plots were performed with some interviewees to identify specific characteristics of the agroforestry systems and management practices.

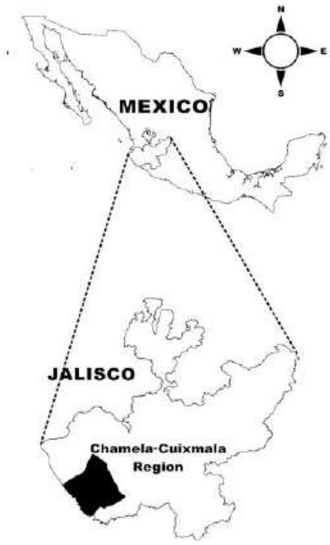


Figure 1: Chamela-Cuixmala región

Table 1: Social and ecological variables on which data was coded and the type of variable.

Family unit	Productive activities	Other capitals
Age of interviewee (d)	Farming (b)	Extra labor for ranching (b)
Figure within the *ejido* (c)	Cattle ranching (b)	Extra labor for crops (b)
Place of origin (b)	Agriculture (b)	Family labor (b)
Family in the U.S. (b)	Forest activities (b)	Daily wage labor (b)
Family members (d)	Business and services (b)	Reciprocal labor (b)
Adults (d)	Day laborer (b)	Receives government support (b)
Minors (d)	Reciprocal labor (b)	Amount of supports received (d)
Students (b)	Salaried work (b)	Communal areas benefit (b)
Housekeeping (b)	Total of activities (d)	Remittances (b)
Management of resources		
Hectares of plots (d)	Heads of cattle (d)	Farm crops (b)
Hectares of pasture (d)	Perform occasional sale (b)	Self-consumption crops (b)
Hectares of crops (d)	Perform specific season sale (b)	Market crops (b)
Hectares of forest (d)	Minimum annual sale of livestock (d)	Orchard cultivation (b)
Provision services (b)	Maximum annual sale of livestock (d)	Cultivation of useful plant (b)
Regulation services (b)	Produce milk and cheese (b)	Number of useful plants (d)
Cultural services (b)	Sale milk and cheese (b)	Backyard animals (b)
Perform clearcutting (b)		
Use firewood and poles (b)		

(b): binary variable, (c): categorical variable, (d) discrete variable

Results

Cluster analysis suggests the existence of four groups of household farming strategies (numbered 1 to 4 in Figure 2). From their characteristics we name them as: Group 1 ‘farmers with cattle specialization’; Group 2 ‘day laborers or off-farm workers’; Group 3 ‘private landowners’; Group 4 ‘diversified community farmers’. Of the 50 variables analyzed within the groups, 34 proved to be significantly different between at least two of the four groups. Ordination analysis shows these groups were also strongly associated with different land tenure characteristics or different status (Table 2). The first axis of the Principal Coordinate Analysis

(PCoA) shows a main differentiation between those households without cattle, without access to provision services, and commonly having small plots or no land at all (on the left in Figure 2, mostly from Group 2); and those who practice cattle ranching, use provisioning services, and have land and pasture (on the right in Figure 2, mostly from Groups 3 and 4). The second PCoA axis reveals a striking differentiation between the two *ejidos*. Other variables that are relevant, but that have less discriminating power, include: the presence of crops in the plots, crops designated for self-consumption, milk and cheese production and the payment of daily wages to laborers. The average amount of forest was greater in Group 3 (77.5 ha), followed by Group 1 and 4 that had similar amounts (17.3 to 15.2 ha), finally the group with the less forest was Group 2 (4. 8).

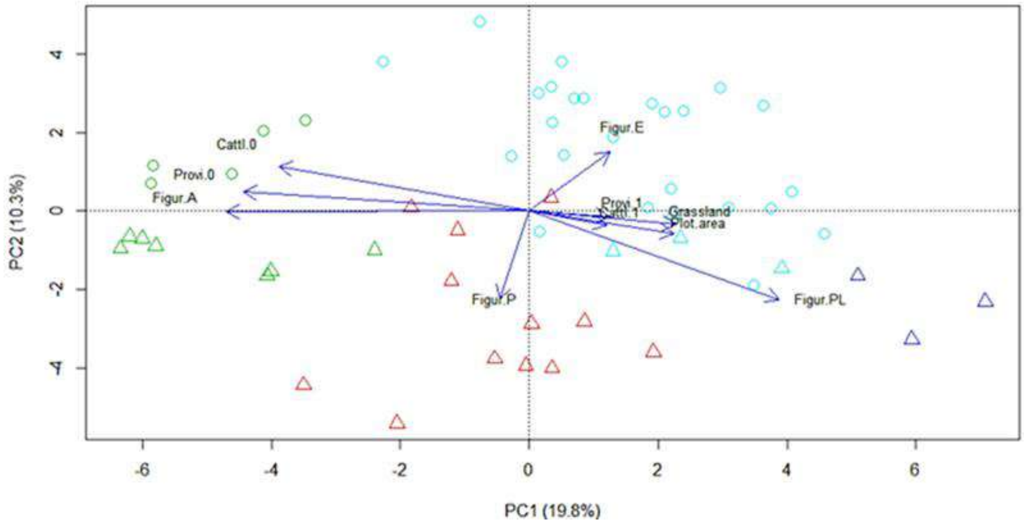


Figure 2: Ordination analysis, differentiating the groups from the cluster analysis. Group 1 in red, Group 2 in green, Group 3 in blue and Group 4 in turquoise. The triangles represent households in the ejido Pabelo and the circles in Ranchitos. The main variables are also observed on the two axes, these are: Figur.A: landless people (avecindados); Figur.E: people with community land rights (ejidatarios); Figur.PL: private landowners; Figur.P: partial land rights (posesionarios); Cattl.0: without cattle; Cattl.1: with cattle; Provi.0: provision services not used in plots; Provi.1: Provision services used in plots; Plot.area: total hectares of plot; Grassland: total hectares of grasslands in the plot.

Table 2: Different land tenure status among the four groups of strategies.

		Group1	Group2	Group3	Group4	Total
Ejido	Ranchitos	0	5	0	24	29
	Pabelo	12	7	3	4	26
Figure	*Avecindados* *	0	10	0	0	10
	Private landowners*	1	0	3	1	5
	Ejidatarios *	2	2	0	23	27
	Posesionarios *	9	0	0	4	13

*Variable different between groups with significance at p <0.05

According to the main characteristics occurring in landscapes and plots, we schematized the typical agroforestry systems in both *ejidos* (Figure 3). There are some elements shared, like: vegetation patches, sources of water, grasslands and forage and useful trees scattered. Also, plots are divided into paddocks that farmers use to keep the cattle for a certain time (between 15 days to 1 month) depending on the area available to them and the season. The typical agroforestry system in Pabelo (Figure 3a) has certain features like perennial rivers or streams and riparian forest alongside to protect river flow. Also, patches of oak forest are common, because oaks are very useful species for fences and firewood. Agroforestry systems in Ranchitos (Figure 3b) are differentiated by having bigger patches of tropical deciduous forest in various successional stages due to the rapid regrowth of this forest type. Also, by having hydraulic infrastructure, mainly watering holes, because of the low availability of natural water sources, in addition to maize cultivation to feed the cattle.

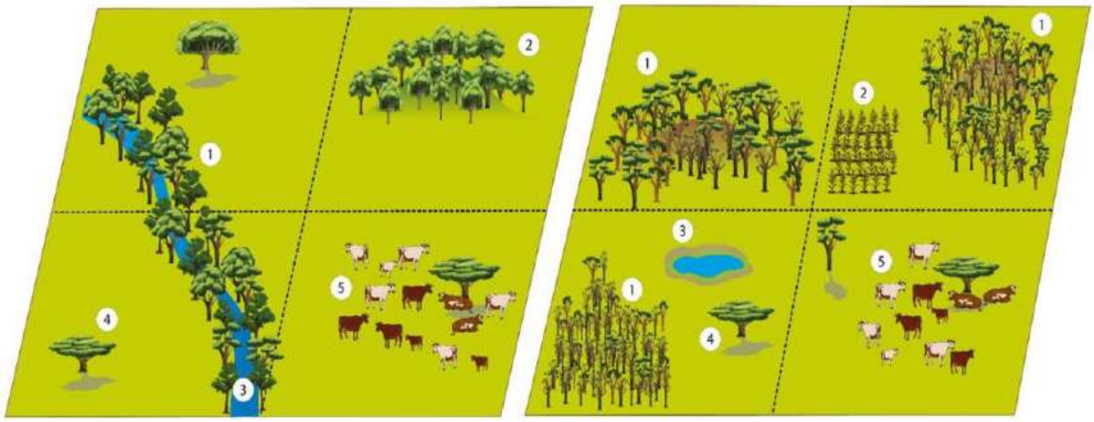


Figure 3a (left). The typical agroforestry system in Pabelo. 1: Riparian forest. 2: Oak forest remnants. 3: Permanent rivers or streams. 4: Useful trees. 5: Cattle. Figure 3b (right). The typical agroforestry system in Ranchitos. 1: Tropical deciduous forest in different successional stages. 2: Maize cultivation. 3: Watering hole. 4: Useful trees. 5: Cattle.

Discussion and conclusion

This study focused on understanding the land management strategies of two *ejidos* in a highly biodiverse region of Jalisco, Mexico. Based on the characterization of different socio-ecological attributes, we establish four different farming types. The recognition of these typologies has social, economic and ecological implications beyond the study region. According to our research, the farming typologies are directly related to access to land and the social position of the head of household as regards rights within the *ejido* institution, suggesting that this constitutes one of the main drivers of the farming strategy. Also, in our analysis diversification of strategies appears to be an inherent response of the social-ecological system to uncertainty and instability. Another result from the classification of strategies is the particular ecosystem in with each household is embedded. We suggest that differentiation of strategies is at least partially due to differences in the biophysical and ecological conditions between the two *ejidos*, which may condition the productive activities that can be implemented. This has been indicated by some authors as the 'system of strategies' or the 'farming style', which refers to the relationship between the human groups in a specific region and their surroundings, creating a spatial identity (Cochet 2015; Gerritsen 2004; van der Ploeg 1990).

The empirical evidence shows that the 'ideal' or theoretical paradigm of modern agriculture under which there is only one type of agrarian logic (i.e. productive specialization), does not materialize on our study site. In this sense, public policies can play a very important role in pushing farmers towards a more diversified strategy or towards a more specialized one.

References

Alcorn JB, Toledo VM (1998) Resilient resource management in Mexico's forest ecosystems: the contribution of property rights. In Berkes F, Folke C (eds) Linking social and ecological systems: management practices and social mechanisms for building resilience. Cambridge University Press, Cambridge, UK pp. 216–249.

Cochet H (2015) Comparative Agriculture. Springer, Francia.

Gerritsen PRW (2004) Estilos agrarios y la forestería comunitaria. Universidad de Guadalajara, Centro Universitario de la Costa Sur.

Monroy-Sais S, Castillo A, García-Frapolli E, Ibarra-Manríquez G (2016) Ecological variability and rule-making processes for forest management institutions: a social-ecological case study in the Jalisco coast, Mexico. I J Commons 10: 1144-1171.

Schroeder NM, Castillo A (2012) Collective action in the management of a tropical dry forest ecosystem: effects of Mexico's property rights regime. Environ Manage 51: 850–861.

Skutsch M, Borrego A, Morales-Barquero L, Paneque-Gálvez J, Salinas-Melgoza M, Ramírez M I, Gao Y (2015) Opportunities, constraints and perceptions of rural communities regarding their potential to contribute to forest landscape transitions under REDD + : case studies from Mexico. Int For Rev 17: 65–84.
van der Ploeg JD (1990) Labour, markets and agricultural production. Oxford: Westview Press, Boulder, San Francisco.

AGROFORESTRY IN THE NIJMEGEN-AREA; VISIONING, SHARING, DESIGNING

Van der Meulen SJ[1]*

(1) Regional Foodscapes in Urban Areas, Van Hall Larenstein University of Applied Sciences, Velp, the Netherlands

*Corresponding author: suzanne.vandermeulen@hvhl.nl

Abstract

In the area of Nijmegen, the Netherlands, a two-year project has started in 2018 to investigate the potential for agroforestry in the area, up to 1,000 ha. To assist policy makers and planners, the research will investigated opinions and visions of stakeholders in the area. The first step in this process is an investigation based on the RRA methodology. This will provide a starting for further research for and by design, which will be rooted in the principles of responsible innovation.

Keywords: agroforestry; RRA; responsible innovation; landscape design

Dreaming

In the area of Nijmegen, Van Hall Larenstein started a two-year project in January 2018 to investigate opportunities for a large area of agroforestry. As the project recently started, there are still many questions to answer, some deal with the technical aspects and some with the economic aspects. Other aspects that are very important in this project are the design of agroforestry and the vision on the landscape around Nijmegen. The projects intends to aid in the development of a vision for future development in the area between the cities of Arnhem-Nijmegen.

This provides a unique opportunity to design, to dream, to speculate about in all their appearances. This could mean a system of alleycropping with multiple woody crops, but it could also mean a variation of a so called foodforest, a multiple cropping system originating from the permaculture movement.

The starting point of the dream could be “what if…”.

What if we plan an area of 1,000 ha of agroforestry in the region? What if we made this into one big forested area or what if we split the 1,000 ha into smaller plots because many people will participate with a small plot of land? How can we make this economically viable? What if students would design this? What if, in the end there would be a vision welcomed by all who are living, working and recreating in the area?

Big dreams? Maybe. But, quoting Christopher Reeve “*At first, dreams seem impossible, then improbable, and eventually inevitable*”. However, at some point dreams have to turn into action, projects have to start and research has to be done. So, how to proceed the coming two years? The project intends to integrate landscape design with knowledge on agroforestry but also doesn’t want to overlook the socio-economical aspects. Therefore the landscape or landscapes which will be explored during the project, will be accompanied by an inventory of the potential of agroforestry in the area. This inventory will be rooted in the principles of responsible innovation. The four aspects these authors distinguish (anticipation, reflexivity, inclusion, responsiveness) provide a framework on which the research can be build (Stilgoe et al. 2013). It gives an opening for involving people living in a specific area but the framework also addresses the governance and even the role of the researchers themselves.

The project

As this project deals with the question whether there is a place for agroforestry/foodforest, and therefore with the land use, there is a connection with the body of literature on communication for rural development by authors such as Leeuwis and Aarts (2011) and Servaes and Lie (2014) These authors write about communication for sustainable development, communication and innovation processes and complex systems. Agroforestry in the area of Nijmegen, is, if only by its geographical size, a complex issue. It is an area which is, just as all other areas in the Netherlands, in use. It is owned, it is farmed, people live there, work, travel through and recreate in the area. Therefore, they have an opinion about the area. That leads to questions such as 'who are involved', 'who will benefit and who will lose something if the area will change', 'what will be the benefits and the losses' etc. etc.

But, what, then, is the link with landscape design? At this moment, the challenge for landscape design in the Netherlands, is not making the design itself. The challenge is the current focus on coalition-forming, working with participants and stakeholders in a certain area. (Van Dooren 2018). This makes the designer, with his or her knowledge of design but with less knowledge of the area, part of the discussion

So, what is the role of landscape design in questions of regional food production? This is firstly a philosophical question that has to be answered by landscapes designers individually. Secondly, it is a very practical question about methodology and organization (Figure 1). Van den Goorbergh (2014) makes an argument for the social-spatial analysis of how public spaces are used and Van der Linde (2014), who illustrates the use of Rapid Rural Appraisal as a strategy for landscape design. Including social aspects and using the RRA methodology which has its roots firmly in international rural development practices. This opens up the possibility for a landscape design, but also a research based on participative design. Using not only interviewing, but also other forms of recording, such as filmmaking, stakeholders are invited to express their voice differently and often more freely than during the large meetings that are often used in spatial planning processes (Cumming and Norwood 2012).

This will also allow for the answer to questions along the lines of who will use and maintain a food forest. If it is going to be a commercial forest, then the answer will be clearer than when social and recreational functions will be part of the final ideas. This is also a learning trajectory for all those involved. This will tough upon the terminology of socio-ecological learning and public learning. This in turn relates back to the questions of anticipation, inclusiveness, responsiveness and reflexivity (Stilgoe et al. 2013) and how to organize this process.

The role of the designer and the individual choices he or she has to make is also recognized in the model of Stilgoe et al. (2013): the emphasis they put on reflexivity is an important one, as they state that in responsible innovation, reflexivity on part of actors and institutions means not only thinking about their role and their responsibilities, but also acting upon it.

Figure 1: How to reconcile all wishes and needs when planning agroforestry in a region?

The work in progress

When you go back to the big dream again, and think of participative design, what if people involved are given the possibility to dream with us, are challenged to design with us? What if they are given a drawing pencil as well? And what if together we can draw a landscape in which agroforestry is firmly rooted?

The big question in this project is how the area could look if a substantial part of it would be agroforestry. The other question that will be answered is how organize research for design in the context of agroforestry.

The first steps of the research have been made already by doing desk research. This of course, does not bring the researchers any closer to the stakeholders in the area. That is why there will be a first start with a rapid rural appraisal (RRA). This form of social research has been used since the late 1970s and allows the researchers (master students in this specific case) to get into contact with people in the area and to have a conversation or interview about the topic. The quick and dirty approach doesn't allow for extended in-depth interviews, but has in the past provided a valuable methodology to extract information from an area or group of people (Chambers 1992). As Cumming & Norwood (2012) experienced, talking with people about the area they live and work in, an inclusive dialogue is vital to address land use issues. That is why we intend to expand on the knowledge from the RRA by organizing other activities in which we would like invite people to actually pick up a pencil and draw.

Results

The results from the RRA-project will fall into several categories: at first there are the actual results of the interviews and other methods that are used during the fieldwork. These will give us a first insight in the perceptions and interests of the stakeholders and provide the basis for more targeted and in-depth research and participatory activities. It will also help us to identify the correct stakeholders, not only as a group or organization but also the individuals who are important. The second category of results will be less tangible, but will hopefully serve a as second layer on which to continue the future work: here we are talking about the awareness of agroforestry and the options it may mean as a farming model for farmers and other land-owners or user as a viable business alternative.

References

Chambers R (1992) Rural Appraisal: Rapid, Relaxed and Participatory (IDS discussion paper No. 311). Brighton. https://www.ids.ac.uk/files/Dp311.pdf (accesses 22/04/2018).
Cumming G, Norwood C (2012) The Community Voice Method: Using participatory research and filmmaking to foster dialog about changing landscapes. Landscape Urban Plan 105: 434–444.
Leeuwis C, Aarts N (2011) The Journal of Agricultural Education and Extension Rethinking Communication in Innovation Processes: Creating Space for Change in Complex Systems Rethinking Communication in Innovation Processes: Creating Space for Change in Complex Systems. The Journal of Agricultural Education and Extension 17: 21–36.
Servaes J, Lie R (2014). New challenges for communication for sustainable development and social change: a review essay. Journal of Multicultural Discourses, 10: 124–148.
Stilgoe J, Owen R, Macnaghten P (2013). Developing a framework for responsible innovation. Res Policy 42: 1568–1580.
Van Dooren N (2018). Het platteland daar komt je eten vandaan. De Blauwe Kamer 1: 65–67.
Van den Goorbergh F (2014) Sociaal-ruimtelijke analyse: het gebruik van ruimte onderzocht. In: Simons W, en D van Dorp (eds) Praktijkgericht onderzoek in de ruimtelijke planvorming. Velp, The Netherlands.
Van der Linde (2014) Rapid Rural Appraisal: methode als begin van participatieve strategie. In: Simons W, en D. van Dorp (eds) Praktijkgericht onderzoek in de ruimtelijke planvorming. Velp, The Netherlands.

Session

Tree-Crop-Animal competition and facilitation

COMBINING SHORT ROTATION WILLOW COPPICE WITH FREE RANGE CHICKENS - EXPERIENCES FROM EXPERIMENTS ON FARM LEVEL IN THE NETHERLANDS

Boosten M[1*], Penninkhof J[1]

(1) Probos, Wageningen, the Netherlands

*Corresponding author: martijn.boosten@probos.nl

Abstract

Free-range areas are important for the welfare of laying hens. Chickens are forest animals that try to avoid large open areas. Providing shelter in the form of trees can improve the quality of the free-range area for the chicken. Also trees can provide extra income for the farmer. This paper discusses the results of an agroforestry pilot project in the Netherlands in which short rotation willow coppice plantations were established in four free range areas on chicken farms. Between 2013 and 2016 the farm-level experiences were studied, including planting and management of the willows, effects of chickens on the willows, biomass production, laws and regulations and effects on animal behavior. The project has shown that the combination of free range chickens and biomass production provides multi-benefits for both the environment and the chickens. Introducing short rotation willow coppice proved a cost-effective way to set up agroforestry on chicken farms.

Keywords: short rotation coppice; willow; free range chicken; agroforestry

Introduction

Free-range areas are important for the welfare of laying hens, because they reduce the degree of feather pecking. Chickens are forest animals that try to avoid large open areas. Therefore, providing shelter in the form of trees and shrubs can improve the quality of the free-range area and increase the proportion of laying hens using the area (Bestman and Wagenaar 2003). Planting trees in a free-range area can also provide extra income, because they can produce fruits, nuts, timber and biomass.

In the Netherlands there is an increased demand for woody biomass for the production of sustainable energy in e.g. wood fueled heating systems on farms, public swimming pools or district heating. However, biomass resources in the Netherlands are limited. The establishment of short rotation coppice plantations with fast growing tree species like willow could help to increase the domestic biomass availability. In the Netherlands there is a huge competition for land for agriculture, housing and nature. Therefore, possibilities for the establishment of short rotation coppice plantations are limited. One of the options is to combine biomass production with other forms of land-use. In 2012 we explored the opportunities for planting short rotation willow coppice in free range chicken areas as a possible win-win combination. This resulted in the agroforestry pilot and demonstration project 'Kiplekker onder de wilgen' (‘Happy healthy chickens under the willows’).

Materials and methods

In April 2013 a total of 2.75 ha of willow coppice was planted in the free range areas of four egg production farms (Figure 1). Between 2013 and 2016 the farm-level experiences were studied, including planting and management of the willows, effects of chickens on the willows, biomass production, laws and regulations and effects on animal behavior.

Figure 1: Locations of the free range chicken farms where short rotation willow coppice was plantend in 2013. 1: Schore (0.5 ha); 2: Overberg (1 ha); De Glind (1 ha); Welsum (0.25 ha).

Results

Per hectare 15,000 willow cuttings of 20-25 cm length were planted with planting machines (Figure 2). After planting it proved to be necessary to fence the willows for 2.5 to 3 months to avoid the hens digging out the cuttings or pecking the young willow leaves. After 3 months the willow shoots were approximately 50 cm high and the hens were let into the willow plantation. Monitoring showed that from this moment on the hens did not inflict any significant damage anymore to the plantation. Also planting large parcels instead of strips proved to reduce the damage by the hens.

The average establishment costs of the plantation including the weed control during the first year were € 4045.37 per ha. Measurements on one farm showed that the biomass production after 3 growing seasons is on average 33 tons DM per ha. The establishment costs and production figures are comparable to the figures of regular short rotation willow coppice plantations. The planned mechanized harvesting of the willows on two farms after 3 years proved to be a problem due to the low carrying capacity of the soils. On one of the farms the willows were manually harvested by an osier trader who uses the shoots to produce decorative woven garden fences (Boosten and Penninkhof 2016).

The willow plantations have proven to be effective in attracting the hens to the range area. Hens are seen on a distance up to 250 m from the stable. More than 75% of the hens are seen outside. The cover provided by the willows also contributes to a better distribution of hens across the free range area (Figure 3). This may reduce the manure load in the vicinity of the stable and the risk of parasitic contamination (Boosten and Penninkhof 2016; Bestman 2017). Research by Bestman et al. (2017) also shows that a higher degree of woody cover seems to be related to less avian influenza risk birds in the free range area.

All farmers in the project are satisfied with the willow plantations because they contribute to the welfare of the hens and improve the appearance of their farm. However, most of the farmers indicate that the amount of work to establish the plantation was higher than initially expected and the revenues during the first 3 growing seasons were lower. Nevertheless they would recommend the planting of willow short rotation coppice to other free range chicken farms.

Moreover, they state that after the first year of establishment the management of the willow plantations doesn't require much work (Boosten and Penninkhof 2016; Bestman 2017).

Figure 2: Site preparation for planting of the free range area on the farm in Overberg in 2013 (left picture) and short rotation willow coppice on the same location in 2017 (right picture).

Discussion

The pilot project 'Kiplekker onder de wilgen' has shown that the combination of free range chickens and biomass production provides multi-benefits for both the environment and the chickens. The latter result is confirmed by recent experiments in Flanders which demonstrated that free-range broiler chickens have a strong preference for short rotation coppice as a cover compared to open grassland or artificial shelter (Stadig 2017).

Moreover, this combination has proved to be a cost-effective way to set up agroforestry on chicken farms. However, it is advised to establish a minimum of 2 ha of short rotation coppice on a farm in order to have an economically viable biomass production.

In October 2016 the Forest and Timber Action Plan was launched to advocate an extension of the forest area in the Netherlands with 100,000 ha to make a substantial contribution to the Dutch climate goals. The ambition is to realize 25,000 ha of this forest expansion in the form of agroforestry. Approximately 2,700 ha of free-range area is present in the Netherlands on farms that have free-range or organic hens for the production of eggs. This means that agroforestry with e.g. biomass production on free-range chicken farms can provide a substantial contribution to the goals of the Dutch Forest and Timber Action Plan.

Figure 3: Free range chicken using the short rotation willow coppice on one of the farms.

References

Bestman MWP, Wagenaar JP (2003) Farm level factors associated with feather pecking damage in organic laying hens. Livest Prod Sci 80: 133–140.

Bestman M (2017) Lessons learnt – Agroforestry for organic and free-range egg production in the Netherlands. AGFORWARD Report Work-package 5: Agroforestry for Livestock Farmers.

Bestman M, De Jong W, Wagenaar J, Weerts T (2017) Presence of avian influenza risk birds in and around poultry free-range areas in relation to range vegetation and openness of surrounding landscape. Agrofor Syst https://doi.org/10.1007/s10457-017-0117-2.

Boosten M, Penninkhof J (2016) Happy healthy chickens under the willows. Experiences with biomass production in free range poultry areas (in Dutch). Report Probos. http://www.probos.nl/images/pdf/rapporten/Rap2016_Eindrapport_kiplekkeronderdewilgen.pdf (accessed 21/04/2018)

Stadig LM (2017) Gimme shelter. Combining free-range broiler chickens with production of short rotation coppice. Doctoral thesis, Ghent University.

IMPACT OF TREE ROOT PRUNING ON YIELD OF DURUM WHEAT AND BARLEY IN A MEDITERRANEAN ALLEY CROPPING SYSTEM

Inurreta-Aguirre HD[1]*, Lauri PÉ[1], Dupraz C[1], Gosme M[1]

(1) INRA, UMR 1230 SYSTEM F-34000

*Corresponding author: hector-daniel.inurreta-aguirre@supagro.fr

Abstract

Tree root pruning in agroforestry could reduce water competition and increase the crop yield. The aim of this study was to evaluate the impact of tree root pruning on the yield of winter cereals in a mature Mediterranean alley cropping system considering crop phenology and the position in the alley. An experiment was conducted in a walnut alley cropping. Two modalities were established: root pruning (RP+) and no root pruning (RP-). In each one four genotypes of winter cereals were sown. Microclimate, soil matric potential (SMP), crop phenology and yield components were measured. The SMP presented higher values in RP+, especially in the central part of the alley. The impact on crop phenology of the root pruning and the position in the alley varies according to the genotype. The barley yield was statistically higher in RP+, whereas wheat yield did not show significant differences between modalities.

Keywords: winter cereals; crop phenology; soil matric potential; position in the alley

Introduction

Agroforestry has been claimed as a way to increase total land productivity (Muschler 2015), however, it usually results in a decrease in crop yield compared to the pure crop because of the competition for resources between the crop and the tree (Jose et al. 2004). Belowground competition for water could reduce the productivity of the crop (Jose et al. 2000). On the other hand, agroforestry modifies the understory microclimate (Lin 2007) which could modify the evapotranspiration rate (Karki and Goodman 2013) and crop phenology (Inurreta-Aguirre et al. 2018). Due to the spatiotemporal complexity of the system (Talbot and Dupraz 2012), the net effect of agroforestry on crop productivity is uncertain (Ivezic and Van Der Werf 2016) and often depends on management practices (Gill et al. 2009).

Several authors have proven that tree root pruning in agroforestry could be a good management practice to increase crop yield (Wajja-Musukwe et al. 2008). The Mediterranean region presents particular climatic patterns, especially hot and dry summer, so it is important to know if root pruning can provide any advantage for the crop. The aim of this study was thus to evaluate the impact of tree root pruning on the yield of durum wheat and barley in a mature Mediterranean alley cropping system, considering the phenology of the crop.

Materials and methods

The experiment was carried out in 2017 in the “Restinclières Agroforestry Platform (RAP)” in Hérault department in the South of France (43° 42'N, 3° 51'E). The climate is sub-humid Mediterranean and the soil is deep calcareous silty clay. The experiment was conducted in an alley of 13m width, with an East-West orientation, planted with 23-year-old hybrid walnut trees (*Juglans nigra* X *regia* type NG23) at a density of 96 trees ha^{-1} with an irregular planting pattern, due to previous tree thinning in the plot (within-row distances between trees ranged from 4 to 12m). In order to minimize light competition and focus on the effect of the belowground competition, a branch pruning of 50% of the branches was applied to all the trees in the alley on November 8, 2016. Two modalities were established: root pruning (RP+) and no root pruning (RP-). The root pruning was done on October 21, 2016, using a tractor root pruner at a depth of one meter and at two meters from the centre of the tree line. Each modality was split into 24 plots (six across the alley and four along the alley) of 10.85 m² each (1.55 x 7m). In both modalities and each of the six positions relative to the tree row, an early (Claudio) and a late (Karur) variety of wheat and an early (Orpaille) and a late (Cassia) variety of barley were sown in a randomized pattern. Sowing was made on December 13, 2016. Two applications of mineral fertilizer, 50 kg of total nitrogen per hectare in each one, were carried out on February 21, 2017, and April 8, 2017, respectively. No pesticides were applied. In each modality, the air temperature and the global solar radiation in the centre and in the two borders of the alley were monitored, using humidity and temperature probes (HMP155, Campbell Scientific, USA) and pyranometers (SP1110, Campbell Scientific, USA), respectively. The soil matric potential (SMP) was measured with tensiometers placed at a depth of 1m, in the centre and in the southern border of the alley, i.e. just north of the tree row.

The yield was decomposed into measurable yield components. The yield components considered in the analysis were the number of plants per m², the number of tillers per plant, the percentage of fertile tillers, the number of grains per spike and the weight of grains. Due to time constraints, only 12 plots per modality (36 in total) were kept free of weeds with two manually weeding conducted on 25 March and May 9, respectively. These 36 weed-free plots were considered in the analysis of the yield components of the four genotypes in three different positions in the alley (southern border, centre, and northern border). Each yield component was analysed using a mixed effect model (‘lmer’ package of R statistical software), considering the root pruning as a fixed effect and the species (both varieties of a same species pooled) as a random effect. These components develop sequentially throughout the growing season and determine the final yield of the crop (Moragues et al. 2006). Therefore, studying yield components allows identifying the phenological stage when adverse conditions reduced yield (Gate 1995). To consider this in the study, the phenology was assessed twice a week using the Zadoks scale (Zadoks et al. 1974).

Results

The SMP was always almost the same in both modalities and in both positions until the tree leaf sprouting. From then on, RP+ presented higher values, especially when comparing the central areas of the alley. Comparing the distance from the tree line within a same modality, one can notice that in RP+, the SMP was lower in the border part, while in RP- the tendency was not so clear, the lowest value alternating between the two positions (Figure 1).

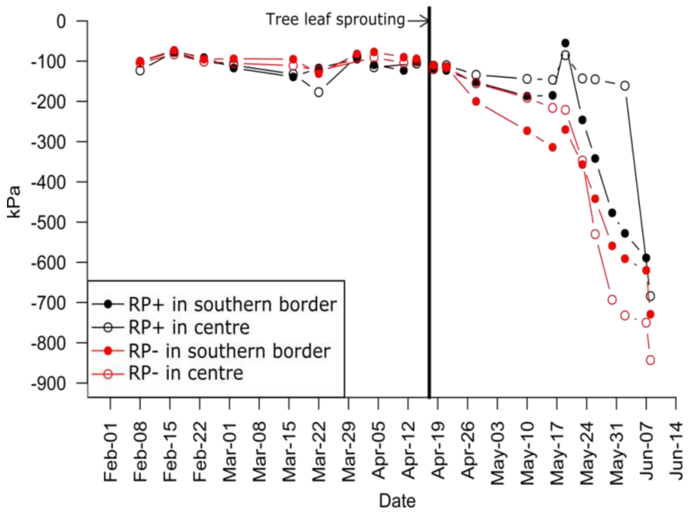


Figure 1: Soil matric potential (SMP) at 1m depth throughout the crop cycle in two different positions in the alley (southern border and centre) in the two modalities: root pruning (RP+) and no root pruning (RP-).

There was no difference in the global radiation between the modalities along the crop cycle (data not shown). The average air temperature presented small differences between systems (lesser than 0.4 °C). The RP+ modality was slightly warmer at the beginning of the cycle and slightly cooler at the end, the change in the trend occurred also around the tree leaf sprouting (data not shown).

The phenology of Claudio was the same regardless the modality or the position. For Karur, in both modalities, the border part of the alley showed a slight advance in the phenology in the spikes formation period. The phenology of Cassia was slightly faster in RP- from around tree leaf sprouting for the border part and after anthesis for the central part. RP+ also delayed the phenology of Orpaille, but in this case, the central part of the alley in RP+ was the one that was slower from around leaf sprouting and the border part of the alley was delayed from the end of anthesis (Zadoks stage 60) (Figure 2).

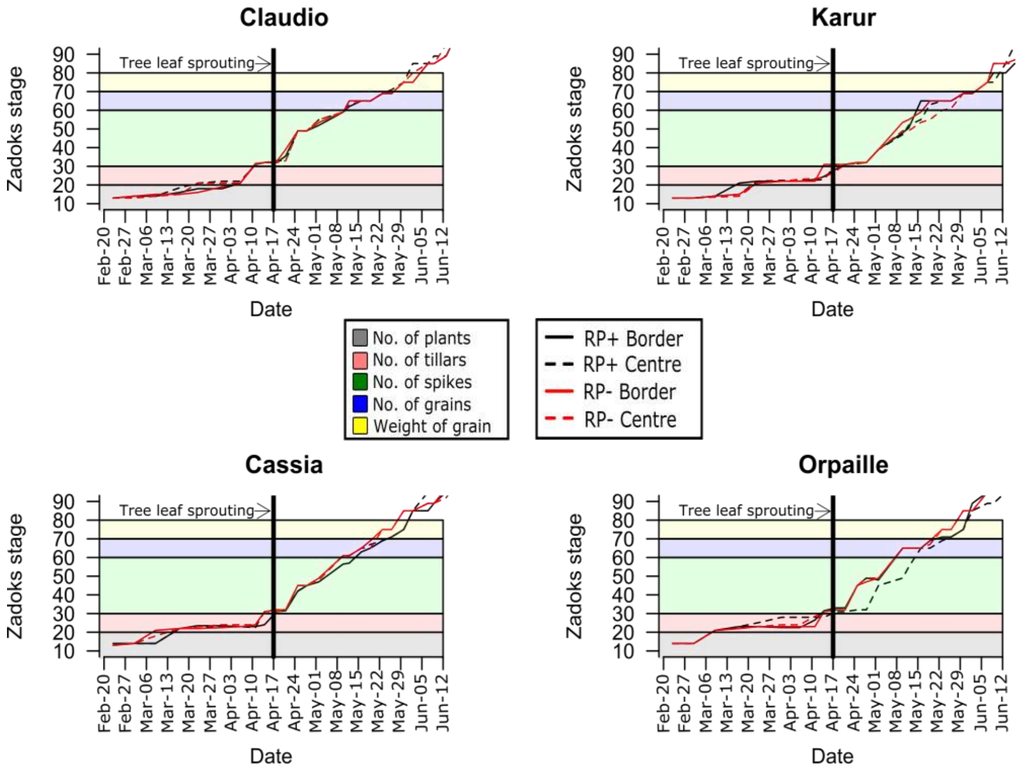


Figure 2: Phenology of the crops as a function of date. Background colours indicate the development period of the different yield components.

The grain yield of the wheat (combining both varieties) did not show significant differences between modalities. Nevertheless, two yield components were statistically higher in RP+, the number of plants per m² and the number of grains per spike. The grain yield of barley (combining both varieties) was statistically higher in RP+. All the yield components were higher in RP+, however, the only one statistically different from RP- was the weight of the grains (Table 1).

Table 1: Yield components (mean ±SD) and yield of the crop species [mean of both late and early varieties and the three positions (southern border, centre, and northern border)] in root pruning (RP+) and no root pruning (RP-)

	Modality	Pm^{-2}	TP^{-1}	%FT	GS^{-1}	TKW	GY
Wheat	RP+	142.25 (±33.53)*	3.38 (±0.48)	53 (±17)	16.45 (±1.45)*	44.08 (±3.13)	176.65 (±60.6)
	RP-	112 (±19.22)	3.88 (±1.18)	80 (±26)	14.87 (±1.94)	46.66 (±4.73)	246.87 (±140.7)
Barley	RP+	237.75 (±113.46)	5.38 (±2.43)	48 (±32)	13.57 (±2.74)	52.72 (±2.47)*	302.76 (±99.1)*
	RP-	202.50 (±59.75)	4.88 (±1.18)	36 (±13)	12.35 (±1.5)	48.43 (±2.87)	199.63 (±64.92)

Comparisons were made between modalities with the same crop. **Pm^{-2}:** number of plants per square meter, **TP^{-1}:** number of tillers per plant, **%FT**: percentage of fertile tillers, **GS^{-1}:** number of grains per spike, **TKW:** thousand kernel weight, **HI:** harvest index, **GY**: grain yield in $g.m^{-2}$. *: The means are significantly higher according to Tukey's HSD, ($p<0.05$).

Discussion

The SMP was lower in the RP+ modality after leaf sprouting, probably due to the transpiration of the unpruned trees, which produced a depletion of water. These results agree with what was obtained by Hou et al. (2003) in soybean with a windbreak (*Fraxinus pennsylvanica* L., *Pinus nigra* Arnold, and *Juniperus virginiana* L) in Mead, Nebraska. After the tree leaf flush, both varieties of barley had a slower phenology in RP+. This difference could be attributed to the lower temperature observed in the RP+ modality after leaf flush. This is surprising because the difference in temperature was very small. However, this acceleration in phenology could be due to water stress of the plants in the RP- modality. In accordance with this, Angus and Moncur (1977) reported an acceleration in the development of wheat plants sown in pots which had encountered a mild stress immediately and 20 days after of after floral initiation. Similarly, González et al. (2007) found that 12 different varieties of barley plants under stress in the terminal part of the growth cycle (Zadoks stage 41) reached maturity later than well-watered plants.

Wheat yield was lower (but not significantly) with root pruning, although two yield components (number of plants per m^2 and number of grains per spike) were significantly higher with root pruning. The number of grains per spike is known to be sensitive to water stress in wheat (Moghaddam et al. 2012), which could explain why it was higher with root pruning. For barley, there was a general trend of higher yield components in the RP+ system, but only grain weight was significantly higher with root pruning. This led to a significantly higher grain yield with root pruning. This reduction in grain weight of barley in RP- conditions could be due to the acceleration in the development caused by a mild water stress, which led to a shorter grain filling duration and therefore to a lower accumulation of dry matter in the growing grains (Samarah et al. 2009).

In conclusion, we found that root pruning could increase the productivity of barley in alley cropping systems in Mediterranean conditions, however, this effect was not observed in durum wheat. Before translating these results into recommendations for farmers, it would be necessary to study the impact of root pruning on tree growth, in order to check if the yield gain on the crop outweighs the potential growth decrease of the tree due to root pruning.

References

Angus JF, Moncur MW (1977) Water stress and phenology in wheat. Aust J Agric Res 28: 177–181.

Gate P (1995) Ecophysiologie du blé, 1st edn. Lavoisier Tec & Doc, Paris

Gill RIS, Singh B, Kaur N (2009) Productivity and nutrient uptake of newly released wheat varieties at different sowing times under poplar plantation in north-western India. Agrofort Syst 76: 579–590.

González A, Martín I, Ayerbe L (2007) Response of barley genotypes to terminal soil moisture stress: Phenology, growth, and yield. Aust J Agric Res 58: 29–37.

Hou Q, Brandle JR, Hubbard K, Schoeneberger M, Nieto C, Francis C (2003) Alteration of soil water content consequent to root- pruning at a windbreak/crop interface in Nebraska, USA. Agrofor Syst 57: 137–147.

Inurreta-Aguirre HD, Lauri P-E, Dupraz C, Gosme M (2018) Yield components and phenology of durum wheat in a Mediterranean alley-cropping system. Agrofor Syst https://doi.org/10.1007/s10457-018-0201-2.

Ivezic V, Van Der Werf W (2016) Relative crop yields of European silvoarable agroforestry systems. 3rd European Agroforestry Conference. Montpellier, France.

Jose S, Gillespie AR, Seifert JR, Biehle DJ (2000) Defining competition vectors in a temperate alley cropping system in the midwestern USA: 2. Competition for water. Agroforst Syst 48: 41–59.

Jose S, Gillespie AR, Pallardy SG (2004) Interspecific interactions in temperate agroforestry. Agroforst Syst 61: 237–255.

Karki U, Goodman MS (2013) Microclimatic differences between young longleaf-pine silvopasture and open-pasture. Agroforst Syst 87: 303–310.

Lin BB (2007) Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. Agric For Meteorol 144: 85–94.

Moghaddam HA, Galavi M, Soluki M, Siahsar BA, Nik SMM, Heidari M (2012) Effects of Deficit Irrigation on Yield, Yield Components and Some Morphological Traits of Wheat Cultivars under Field Conditins. Int J Agric: Research and Review 2: 825–833.

Moragues M, García Del Moral LF, Moralejo M, Royo C (2006) Yield formation strategies of durum wheat landraces with distinct pattern of dispersal within the Mediterranean basin I: Yield components. F Crop Res 95: 194–205

Muschler RG (2015) Agroforestry : essential for sustainable and climate-smart land use? In: Pancel L, Kohl M (eds) Tropical Forestry Handbook, 2nd edn. Springer-Verlag Berlin Heidelberg, Berlin, Germany, pp 2013–2116.

Samarah NH, Alqudah AM, Amayreh JA, McAndrews GM (2009) The effect of late-terminal drought stress on yield components of four barley cultivars. J Agron Crop Sci 195: 427–441.

Talbot G, Dupraz C (2012) Simple models for light competition within agroforestry discontinuous tree stands: are leaf clumpiness and light interception by woody parts relevant factors? Agroforst Syst 84: 101–116.

Wajja-Musukwe TN, Wilson J, Sprent JI, Ong CK, Deans JD, Okorio J (2008) Tree growth and management in Ugandan agroforestry systems: effects of root pruning on tree growth and crop yield. Tree Physiol 28: 233–242.

Zadoks JC, Chang TT, Konzak CF (1974) A decimal code for the growth stages of cereals. Weed Res 14: 415–421.

MODELLING SHADOW IN AGROFORESTRY SYSTEMS BASED ON 3D DATA

Morhart C[1]*, Rosskopf E[1], Nahm M[1]

(1) Chair of Forest Growth and Dendroecology, Albert-Ludwigs-University Freiburg, Freiburg, Germany

*Corresponding author: christopher.morhart@iww.uni-freiburg.de

Abstract

We describe an approach of a high-resolution model that allows for the quantification of tree shading on a daily, monthly, seasonal or annual time scale to generate realistic estimations of the shading dynamics in a given agroforestry system (AFS). We use 3D data of a tree derived from a terrestrial laser scanner and explain the steps undertaken to develop a vector-based model that quantifies and visualizes the shadow cast by single trees. It is able to compute the shadow of given tree models in time intervals of 10 min and above. The shadow model is flexible in its input of location (latitude, longitude), tree architecture and temporal resolution. The novel approach provides the possibility to feed this model with factual climate data such as cloud covers, enabling the user to retrospectively analyse the shadow regime below a given tree, and to quantify shadow-related developments in AFS.

Keywords: terrestrial laser scanning; light model; LiDAR; 3D tree model

Introduction

Plant growth depends on light interception. Hence, information about the availability of solar irradiance is of high importance for understanding and improving management practices of natural and agricultural ecosystems. Regarding the latter, estimations of solar irradiation availability are of particular interest for managing agroforestry systems (AFS). In these systems, woody perennials such as trees are deliberately grown together with agricultural crops and/or animals on the same land unit, resulting in a significant interaction of the AFS components with regard to the utilization of water, nutrients and light (Editors of Agroforestry systems 1982). On the one hand, a significant reduction of the light interception for the agricultural crops growing below trees can result in a drastic reduction of the crop productivity especially in case of light-demanding species, and on the other hand, more shade tolerant crop species may even react positively to shading.

Materials and methods

To develop the light model in question, we scanned a cherry tree (*Prunus avium* L.) growing on an experimental AFS site in SW-Germany close to the town of Breisach (48° 4’ 24’’ N; 7° 35’ 26’’ E, 182 m a.s.l.) with a terrestrial laser scanner (TLS). Scanning was performed in the dormant season to be able to generate a 3D tree model that comprises all branches without being occluded by leaves. The scans were performed with the phase shift scanner Z+F IMAGER 5010. At the time of scanning, the cherry tree was 19 years old, 11.0 m high and had a diameter at breast height of 16.8 cm. The field measurements were followed by a data processing step (Figure 1). The TLS data of the tree are first denoised and unnecessary surrounding was removed. The resulting point cloud was used as input for the open source Software SimpleTree (Hackenberg et al. 2015), which computes highly accurate cylinder models of trees.

Since we are not only interested in the shading effect of trees in Agroforestry systems in winter but also in summer, we had to model the leaves. For this purpose, we assumed that each twig with a diameter of 1 cm and less grows leaves. To simulate this situation, we adjoined computed ellipsoids around these twigs mimicking a set of leaves. The simulation process also included an increase of the minor axis radius of the ellipsoids of 1 cm per month from April to July, presuming a fully developed crown in July that stays at that level until September, and sheds its leaves in October. Subsequently, the position of the sun during the course of the day, month and year is calculated using the package insol in R (Corripio 2014). This information is merged with data about the solar irradiance that were obtained from the German Meteorological Service (Deutscher Wetterdienst, DWD). To quantify the loss of energy on the ground through shading, the information about solar irradiance in 10-minute intervals is calculated for a raster grid consisting of cells with a resolution of 10 cm x10 cm.

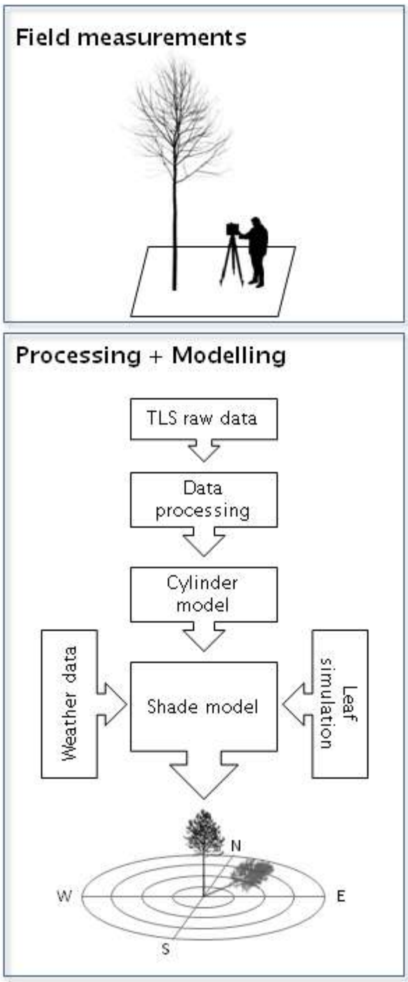


Figure 1: Data processing steps.

Results

Based on our approach, we modeled the monthly shadow for one entire year, covering the time from October 1, 2013, until September 31, 2014. The starting date was set to October since the tree was scanned at that time, and because October also represents the end of the vegetation period. Thus, the shadow projections of a full new growing season can be calculated. Figure 2 shows the shadow dynamics throughout this year in monthly sums.

From October to March, the shading effect of the leafless tree is comparably weak, but it reaches areas in a distance of more than 30 m northward from the tree's stem in a V-shape, especially in December. The shadow elongates until the time of the winter solstice, and widens after passing this time of the year. In spring, the shadow of the tree crown moves closer towards the tree due to the sun's shifting zenith positions, and it becomes increasingly intense due to the developing leaves. At the timings of the equinoxes, the shadow widens to a straight strip. In the period from June until September, the shadow is reaching the most intense and localized loss of solar energy on the ground, and spreads in a hyperbole shape around the tree. Figure 3a shows the annual solar radiation distribution below the model tree. The slightly asymmetrical shape of the cast shadow is due to the asymmetrical shape of the tree crown.

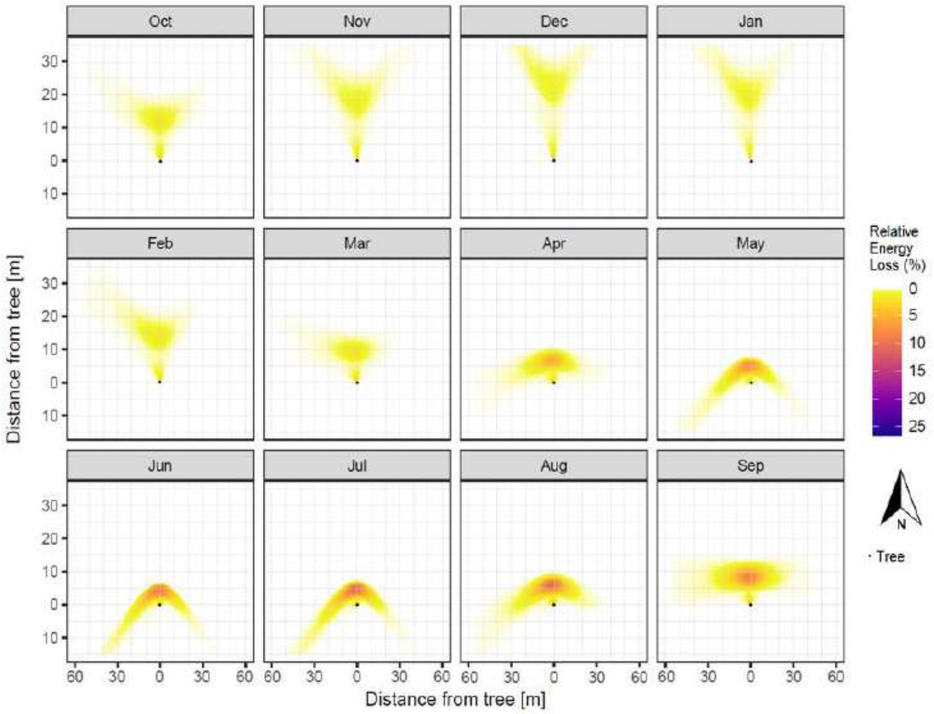
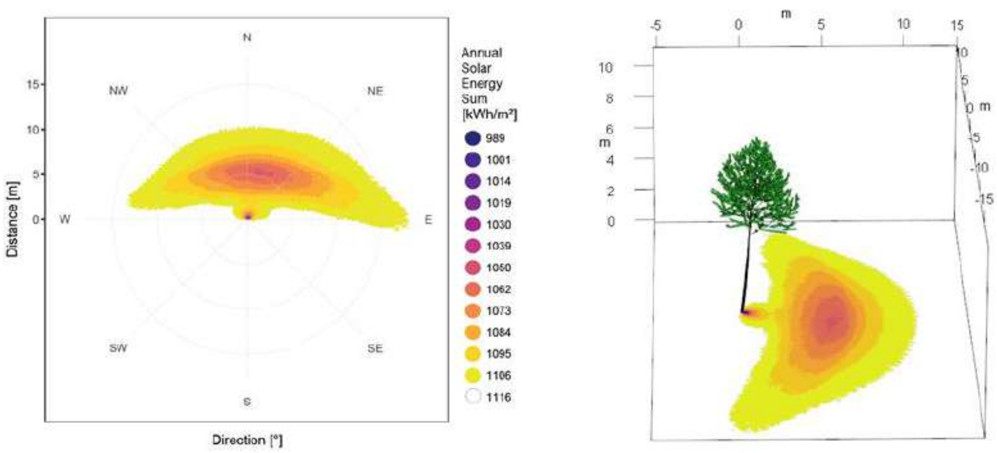


Figure 2: Monthly grids of solar energy losses from October 2013 until September 2014 in comparison to unshaded areas.

The maximum annual solar radiation without shadow amounts to 1116 kWh m-² (white area in Figure 3). The minimum annual solar radiation reaches 978 kWh m-² in the area under the tree crown (dark area in Figure 3). The tree crown shading is most intense in the area around five to seven meters northwards from the stem.



(**a**) (**b**)

Figure 3: (a) Annual solar radiation distribution below the model tree along the compass directions, the outer circle representing a radius of 15 m around the tree stem; (b) 3D visualization of the tree model with the annual solar radiation distribution.

Discussion and conclusion

Although the results displayed in former models from other research groups show similarities with our model outputs, (Dupraz and Liagre 2011; Talbot and Dupraz 2012; Artru et al. 2017), even the more advanced versions work with coarser resolutions of 1 m² grid cells (Talbot and Dupraz 2012; Artru et al. 2017) or 0.5 m x 0.5 m x 0.5 m voxels (Zhao et al. 2003; Sinoquet et al. 2005; Oshio and Asawa 2016; Grau et al. 2017). The high temporal resolution of 10-minute intervals and the options to compute hourly, daily, weekly, monthly, and seasonal dynamics of the light availability at any geographical location, but also the spatial resolution of a 10 cm x 10 cm grid on the ground surface provide new options for studying the interaction and the competition for light among trees and understorey crops with an unprecedented accuracy. The utilization of factual climate data enables a realistic retrospective modeling of the radiation regime of a given tree, and a quantification of future developments based on these data. The results can be adapted in management decisions in AFS or similar land use systems. With the obtained information, whole systems and their planting design can be planned and optimized to minimize light loss for light demanding crop species. Furthermore, our model can help to identify the best tree/crop combination, so that crops adjusted to the present or desired light regime can produce the maximal yield.

References

Artru S, Garré S, Dupraz C, Hiel M-P, Blitz-Frayret C, Lassois L (2017) Impact of spatio-temporal shade dynamics on wheat growth and yield, perspectives for temperate agroforestry. European Journal of Agronomy 82, Part A: 60–70.

Corripio JG (2014) insol: Solar Radiation. https://CRAN.R-project.org/package=insol (accesed 6/04/2018).

Dupraz C, Liagre F (2011) Agroforesterie: Des arbres et des cultures, 2nd edn. Éditions France agricole, Paris.

Editors of Agroforestry systems (1982) What is Agroforestry? Agrofor Syst 1:7–12.

Grau E, Durrieu S, Fournier R, Gastellu-Etchegorry J-P, Yin T (2017) Estimation of 3D vegetation density with Terrestrial Laser Scanning data using voxels. A sensitivity analysis of influencing parameters. Remote Sensing of Environment 191: 373–388.

Hackenberg J, Spiecker H, Calders K, Disney M, Raumonen P (2015) SimpleTree —An Efficient Open Source Tool to Build Tree Models from TLS Clouds 6:4245–4294.

Oshio H, Asawa T (2016) Estimating the Solar Transmittance of Urban Trees Using Airborne LiDAR and Radiative Transfer Simulation. IEEE Transactions on Geoscience and Remote Sensing 54: 5483–5492.

Sinoquet H, Sonohat G, Phattaralerphong J, Godin C (2005) Foliage randomness and light interception in 3D digitized trees: an analysis from multiscale discretization of the canopy. Plant, Cell & Environment 28: 1158–1170.

Talbot G, Dupraz C (2012) Simple models for light competition within agroforestry discontinuous tree stands: are leaf clumpiness and light interception by woody parts relevant factors? Agrofor Syst 84: 101–116.

Zhao W, Qualls RJ, Berliner PR (2003) Modeling of the short wave radiation distribution in an agroforestry system. Agricultural and Forest Meteorology 118: 185–206.

HORTICULTURAL AGROFORESTRY SYSTEMS: A MODELLING FRAMEWORK TO COMBINE DIVERSIFICATION AND ASSOCIATION EFFECTS

Paut R[1*], Sabatier R[1], Tchamitchian M[1]

(1) ECODEVELOPPEMENT, INRA, 84000, Avignon, France

*Corresponding author: raphael.paut@inra.fr

Abstract

While much research has been devoted to analyze the benefits of intercropping and agroforestry systems on yield, through the concept of Land Equivalent Ratio, little literature is available on the benefits of such systems for reducing yield variability. In the present study, we intend to introduce the notion of yield variability in the Land Equivalent Ratio and to combine both concepts in a new framework. Through an application of this new framework on cases selected from literature, we show how intercropping or agroforestry systems may result in both an increase in yield and a decrease in its variability. This exploratory work may nevertheless be completed with further studies to confirm and evaluate the situations under which such benefits can be expected.

Keywords: intercropping, fruits, vegetables, Land Equivalent Ratio, Modern Portfolio Theory

Introduction

In a context of increasing environmental awareness and evolving relationships between farmers and consumers, new farming organizations have emerged in the last decades thus creating innovative agro-ecological systems (Wezel et al. 2014). One of these systems, known as mixed horticultural system, which corresponds to the intercropping of fruit trees and vegetables is attracting a growing interest in Europe, especially among new entrants into farming (Warlop 2016).

From the agronomic perspective, this type of system presents two major advantages: (i) firstly, it reduces the overall risk on production through a **diversification effect** (Letourneau et al. 2011; Isbell et al. 2017) (ii) secondly, it benefits from positive interactions between crops through an **association effect** (Vandermeer 1989). The risk reduction arising from diversification which is a well-studied mechanism in the field of economy (Markowitz 1952) has been formalized in the Modern Portfolio Theory (MPT). Yet, this theory, primarily established to design a portfolio of assets in finance, does not take in account for assets that interact together such as crops in associations. On the other hand, the effect of crop association on production is covered in agricultural sciences by the concept of Land Equivalent Ratio (LER) that provides a standardized basis to assess intercropping system performance. However, this approach is still limited since it does not account for the effect of diversification on risk reduction. Our objective was therefore to combine these two theoretical approaches in a unified framework to formalize the effect of intercropping on both production and risk. After presenting the model linking diversification and association effects, we apply this unified framework on examples based on a literature review.

Materials and methods

Formalizing the effect of association: the Land Equivalent Ratio

When two crops are cultivated simultaneously on the same surface, interactions between the two crops may lead to an overall production different from the weighted sum of the production of each crop cultivated in sole crop. This association effect is classically assessed in the literature by the so-called Land Equivalent Ratio (Mead and Willey 1980; Vandermeer 1989). For a given proportion (k) of crop A in the association with crop B, the value of the LER_k corresponds to the area that would be needed to produce the same amount of crops in two separate sole crops. LER_k is formalized as follows:

$$LER_k = LER_k^A + LER_{1-k}^B = \frac{Y_k^A}{S_A} + \frac{Y_{1-k}^B}{S_B} \qquad (1)$$

where Y_{ki} is the yield of crop *i* cultivated in intercropping, and S_i represents the yield of a sole crop *i*.

An LER greater than 1 means that the intercropping system mixing crop A and crop B produces more than their respective sole crop for the same cultivated area.

Formalizing the effect of diversification: the Modern Portfolio Theory

The Modern Portfolio Theory (MPT) formalizes how risk can be reduced in a context of assets diversification (Markowitz 1952). The general idea behind this theory is that when assets are combined in a portfolio and when asset returns are not perfectly correlated, the portfolio risk is reduced compared to single assets portfolio. Applied to agriculture, a diversified portfolio becomes a combination of several crops within a farm.

According to this theory, the expected return of a portfolio P is the weighted sum of each individual assets in the portfolio:

$$E(R_P) = \sum_i w_i \, E(R_i) \qquad (2)$$

with *wi* the weight of crop *i* (that is, the proportion of crop *i* in the portfolio) and $E(R_i)$ the expected yield of crop i

On the other hand, the risk of a portfolio is measured by the standard deviation, σ_P:

$$\sigma_P{}^2 = \sum_i \sum_j w_i w_j \sigma_{ij} \qquad (3)$$

with σ_{ij} the yield standard deviation of crop *i* when *i=j*, and the covariance of crop *i* and *j* when *i≠j*

The MPT has already been used in agriculture (Knoke et al. 2015) but always considering farms as portfolios of non-interacting crops. When applying MPT to agroforestry systems, the challenge is to integrate the effects of interaction between associated crops on the yield of intercropped cultures.

Combining MPT and LER

Combining both Modern Portfolio Theory and Land Equivalent Ratio requires improving Eq. (2) so as to account for interactions between the two crops:

$$E_k(R_P) = E(R_A)LER_k^A + E(R_B)LER_k^B \qquad (4)$$

with $E(R_i)$ the expected yield of crop $i \in \{A;B\}$ and LER_{ki} the partial LER of crop *i* at the proportion of *k* in the portfolio.

Graphically, this new framework is represented in Figure 1. The **solid curve** displays the risk and yield of crops portfolio for different proportions of crop A and B in a situation where only the *diversification effect* is considered (Δσ formalized by MPT). The **dotted curve** represents the same combination of crops in a situation where both the *diversification effect* and the *association effects* are considered (ΔY formalized by our new framework combining MPT and LER). The **dashed line** represents the weighted average of risks and returns.

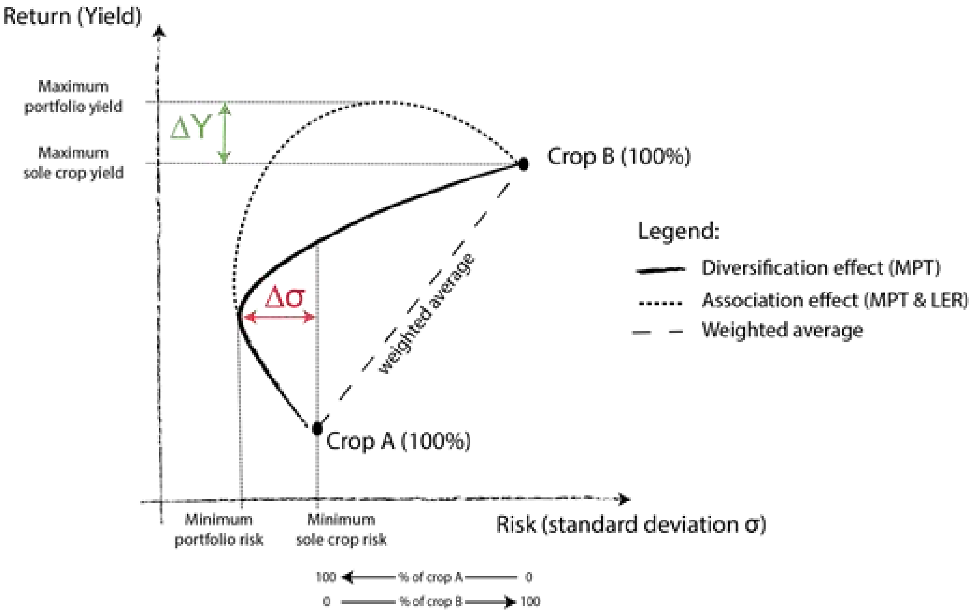


Figure 1: Possible return and risk combinations for a theoretical intercropping system for different proportions of crop A and crop B. Solid curve: *diversification effect* (Δσ formalized by MPT). Dotted curve: *association effect* (ΔY formalized by our new framework combining MPT & LER). The dashed line represents the weighted average of risks and returns.

Applying the new conceptual framework to cases selected from literature

A literature review was carried out for fruits and vegetables intercropping data in the Web of Science database, with the terms “agroforestry” OR “intercropping” OR “fruit” OR “orchard” OR “vegetable”. The search allowed to identify 24 studies containing LER data of fruits and/or vegetables intercropping systems. Furthermore, the search identified 12 studies which had data fitting our model requirements: crop yields, yield variability and LERs. For illustrative purpose, the model was run on three studies for which sufficient data was available: Guvenc and Yildirim 2006; Blazewicz-Wozniak and Wach 2011; van Asten et al. 2011.

Results

Characteristics of fruits and vegetables intercropping systems

The review of intercropping studies involving vegetables and/or resulted in 277 LER measures (often several experiments per study). On average, intercropping was more efficient than sole cropping, since 251 out of the 277 calculated LER values were larger than 1. The median LER was 1.28 and the mean 1.36. However, the standard deviation on LER was 0.36, suggesting a high variability in LERs depending on crop species, treatments and experimental designs (Figure 2).

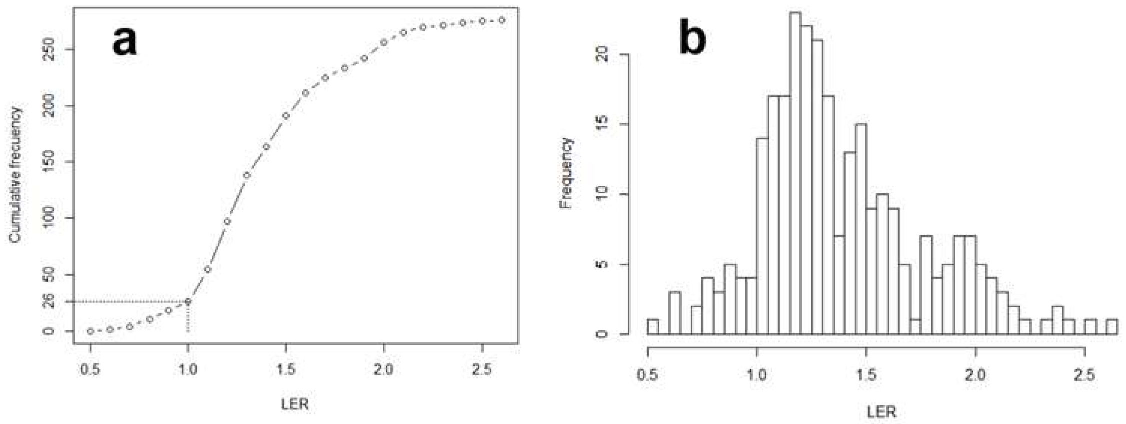


Figure 2: Cumulative frequencies (a) and frequency distribution (b) of land equivalent ratios (LER) for fruits and vegetables intercropping experiments.

Illustration with three cases from literature

Among the reviewed papers, the risk-return combination curves took two possible functional shapes. The first functional form appears when a low yield - low risk crop is combined with a high yield - high risk crop (Figure 3a; 15 of the 24 studies). In the example given here (cabbage-bean intercropping), diversification led to a strong reduction in risk and association made it possible to reach the lowest level of risk for a yield similar to the one obtained with cabbage only. The second functional form is obtained when a high yield - low risk crop is combined with a low yield - high risk crop (Figure 3b; 9 of the 24 studies). Interestingly, in this functional form, adding a high-risk / low-yield crop to a low-risk / high-yield monoculture is still beneficial in terms of risk reduction. In the example given here (carrot-parsley intercropping), risk reduction was moderate and yield improvement was particularly high. The only agroforestry systems for which we found sufficient data in the literature is the coffee-banana system (Figure 3c). It corresponds to the first functional form. In this particular example, risk reduction is marginal but yield improvement can be important. The main difference with the cabbage-bean association is that in the coffee-banana system, no combination of the two crops makes it possible to reach at the same time both a lower risk and a higher yield than the sole crops.

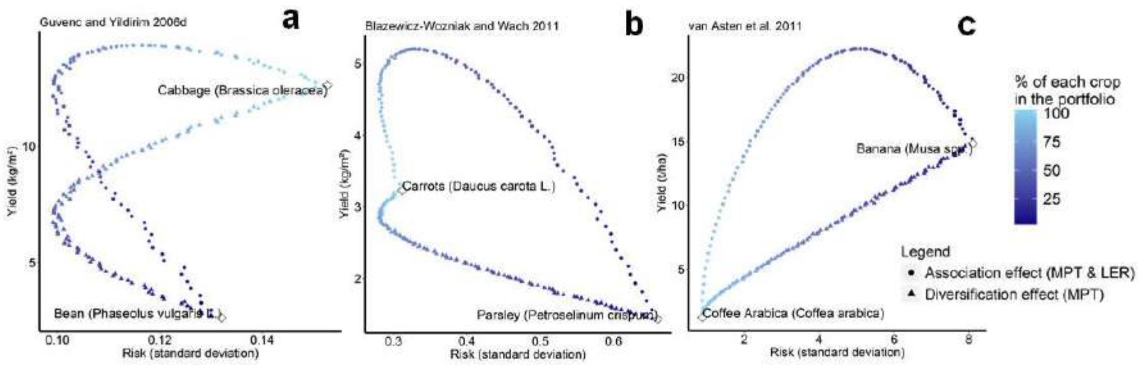


Figure 3: Risk-return combinations observed for different types of interactions. The interactions are detailed in the body of the text. Dots (●) represent the performances of intercropping systems for different proportions of crop A and B in the case where only the diversification effect is considered, triangles (▲) represent the performances of the same intercropping systems in the case where both the diversification effect and the association effect are considered.

Discussion

The two perspectives examined here were Modern Portfolio Theory, and Land Equivalent Ratio. The former quantifies the effect of diversification on risk, the latter measures the effect of association on production. This research has merged both approaches in a combined framework in order to assess horticultural-agroforestry system performances. The results show how some fruit and vegetable combinations can outperform monoculture in both the risk and production dimensions. In other words, that it is possible to reduce the overall risk related to production while maintaining or even increasing the global yield thanks to the association of fruits and vegetables. Even though application of this framework to real situations was limited in this study (due to the scarcity of literature data), our results indicate that a two dimensional analysis (risk and return) of agroforestry systems adds insight into the assessment of such systems. Further evaluations of yield and associated standard deviations in a wide variety of agroforestry systems are now needed to evaluate the conditions in which such benefits can be expected. It would be especially interesting to extend this approach to more diversified systems. From the theoretical point of view, extension of the framework to situations with more than two crops is straightforward and does not present any mathematical difficulty. The issue once again lies in the availability of data since (to our knowledge) no study have evaluated yield and standard deviations of more than 2 crops in associations compared to sole crops. Besides the issue of data availability on production, a further limitation of our study is that we limited our analysis to crop production. However, crop productivity does not directly reflect economic profitability. To further enhance and improve our model, more information on production costs and returns (especially in intercropping systems) would also be necessary (Betters 1988).

Finally, this study only accounts for the effect of association on production and does not consider the effect of crop association on risk. While many studies have focused on the effect of crop association on overall production, the particular issue of production variability in agroforestry systems remains unstudied (Mead and Willey 1980). A consensus seems to emerge on the fact that crop association can decrease the risk associated with each crop (Vandermeer 1989; Rao and Singh 1990) but this effect has rarely been quantified. Therefore, our hypothesis that the individual risk associated to each crop remains unchanged under intercropping can be considered as a conservative hypothesis; and integrating an effect of association on risk is likely to strengthen our conclusion that crop association benefits both production and risk reduction.

Acknowledgments

The present work was carried out with the support of the “Fondation de France”.

References

Betters DR (1988) Planning optimal economic strategies for agroforestry systems. Agrofor Syst 7: 17–31.

Blazewicz-Wozniak M, Wach D (2011) The effect of intercropping on yielding of root vegetables of Apiaceae family. Acta Sci Pol Hortorum Cultus 10: 233–243.

Guvenc I, Yildirim E (2006) Increasing Productivity with Intercropping Systems in Cabbage Production. J Sustain Agric 28:29–44.

Isbell F, Adler PR, Eisenhauer N, Fornara D, Kimmel K, Kremen C, Letourneau DK, Liebman M, Polley HW, Quijas S, Scherer-Lorenzen M (2017) Benefits of increasing plant diversity in sustainable agroecosystems. J Ecol 105:871–879.

Knoke T, Paul C, Härtl F, Castro ML, Calvas B, Hildebrandt P (2015) Optimizing agricultural land-use portfolios with scarce data-A non-stochastic model. Ecol Econ 120: 250–259.

Letourneau DK, Armbrecht I, Rivera BS, Montoya Lerma J, Jiménez Carmona E, Daza MC, Escobar S, Galindo V, Guitiérrez C, Duque López S, López Mejía J, Acosta Rangel AM, Herrera Rangel J, Rivera L, Saavedra CA, Torres AM, Trujillo AR (2011) Does plant diversity benefit agroecosystems? A synthetic review. Ecol Appl 21:9–21.

Markowitz H (1952) Portfolio Selection. J Finance 7: 77–91.

Mead R, Willey RW (1980) The Concept of a “Land Equivalent Ratio” and Advantages in Yields from Intercropping. Exp Agric 16: 217-228.

Rao MR, Singh M (1990) Productivity and risk evaluation in constrasting intercropping systems. F Crop Res 23: 279–293.

van Asten PJA, Wairegi LWI, Mukasa D, Uringi NO (2011) Agronomic and economic benefits of coffee-banana intercropping in Uganda’s smallholder farming systems. Agric Syst 104: 326–334.

Vandermeer J (1989) The Ecology of Intercropping. Cambridge University Press, Cambridge

Warlop F (2016) The smart project: a focus on fruit trees and vegetables agroforestry systems in France. 3rd European Agroforestry Conference. EURAF. Montpellier, France.

Wezel A, Casagrande M, Celette F, Vian JF, Ferrer A, Peigné J (2014) Agroecological practices for sustainable agriculture. A review. Agron Sustain Dev 34: 1–20.

IMPROVING CROP PRODUCTIVITY IN AGROFORESTRY SYSTEMS: LOW LEAF RESPIRATION IS A KEY TRAIT

Rosati A[1]*, Pang K[2], Van Sambeek J[3], Gold M[2], Jose S[2]

(1) Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, centro di ricerca Olivicoltura, Frutticoltura, Agrumicoltura (CREA – OFA), Spoleto (PG), Italy (2) School of Natural Resources, The Center for Agroforestry, University of Missouri, Columbia, MO, USA (3) USDA Forest Service Northern Research Station, Columbia, MO, USA

*Corresponding author: adolfo.rosati@crea.gov.it

Abstract

We studied the mechanisms of shade adaptation in gamagrass (*Tripsacum dactyloides*). We compared the photosynthetic response curves to light in leaves of plants grown in either full sun or shade, in a shade-tolerant and a control cultivar (total of 4 treatments). Plants grown in the shade had lower dark respiration rates and the shade-tolerant cultivar grown in the shade, had the lowest dark respiration rate. We also measured the actual light under the tree canopy in a variety of agroforestry situations. We then modeled the daily photosynthesis for each treatment in each agroforestry situation, using the measured light and the specific photosynthetic response curves to light. Lower leaf respiration rate in the shade-tolerant cultivar grown in the shade allowed maintaining a positive net photosynthesis at lower light conditions, than in the other cases. Low leaf respiration rate appears to be an important trait when breeding genotypes suitable for agroforestry conditions.

Keywords: shade-adaptation, photosynthesis, modeling, respiration, gamagrass

Introduction

The cultivation of crops and forages under tree plantations in agroforestry systems has been shown to be advantageous from both a productive and an environmental perspective (Jose et al. 2004). While the overall productivity of the land (trees + crop/forage) may be increased, tree shade generally decreases the crop/forage productivity. However, in most instances the crop/forage cultivars employed in agroforestry systems are the same as for open field situations, which have been selected to perform best in full sun. It has long been suggested that selecting shade-adapted genotypes could greatly improve the productivity of crops in agroforestry systems (Barro et al. 2012; Ehret et al. 2015), but few breeding programs have considered this aspect, and no shade-adapted cultivars are available for most forages and crops. Even for those genotypes/species that have been shown to be more suitable for cultivation under tree shade, there is little if any information on the mechanisms that make such adaptation possible. Understanding these mechanisms is key to select and breed genotypes specifically adapted to grow under the shade of trees, and thus to increase the productivity of agroforestry systems.

Eastern gamagrass (*Tripsacum dactyloides*) is a native grass that can be found in North America, as well as in Central America, and Brazil. A selection if this grass, named "Bumpers" has been released (USDA, NRCS, 2006). Bumpers' appears to be more suitable than other cultivars to grow in shade, but no mechanisms for this adaptation have been investigated.

The aim of this study was to investigate the mechanisms of shade adaptation in Bumpers, compared to a control cultivar (Verl) that is not shade-tolerant. To do this we measured the photosynthetic response curves to the photosynthetically active radiation (PAR) of these genotypes, both when grown under tree shade and in full sun. We then used the measured curves to model photosynthesis under the actual PAR available below trees in different scenarios.

Materials and methods

Bumpers plants, together with plants of a common (i.e. non-shade-tolerant) cultivar of the same species (i.e. Verl) used as a control, were established in the Alley-Cropping Shade Laboratory (ACSL) at the Horticulture and Agroforestry Research Center during the 2010 and 2011 growing seasons. Plants were established in a 6 m-wide alley under oak trees, as well as in an adjacent open field.

During summer 2017, net photosynthetic response curves to light (i.e. PAR) were measured (between 9.00 and 12.00 h) on representative top-canopy leaves, both in the full sun and in the alleys. Curves were measured using a portable gas exchange system (LI-6400; LI-COR Inc., Lincoln, NE, USA), equipped with a cool light source (6400±02 LED) mounted on the leaf chamber. Leaves were exposed to high PAR (2000 μmol m±2 s±1) until photosynthesis was constant: this was defined as photosynthesis at saturating PAR (Amax). Then, PAR was decreased in steps down to zero (2000, 1500, 1000, 750, 500, 250, 100, 50, 20, 0 μmol m^{-2} s^{-1}). The rate of CO_2 emission at zero PAR was assumed to be the dark respiration rate (Rd) of the leaf. From the data, the curvature factor and the apparent quantum yield were calculated for each treatment combination (i.e. each cultivar in each light treatment) using the best fit to a non-rectangular hyperbola (Thornley 1976).

Curve parameters were then used to estimate net photosynthesis of top canopy leaves, when exposed to the actual incident light as measured in different alley cropping systems. To do this, the PAR transmitted under the trees (thus available for the understory crop) was measured (using 24 GaAsP photosensors, Hamamatsu, Japan) at different positions in a grid under the trees, in different adjacent chestnut orchards of different ages and with different tree spacing. In each position, PAR was measured every minute, from dawn to dusk, during different days (i.e. cloudy or sunny) in the summer of 2016. This provided a large and widely variable sample of daily light patterns, actually occurring under the trees.

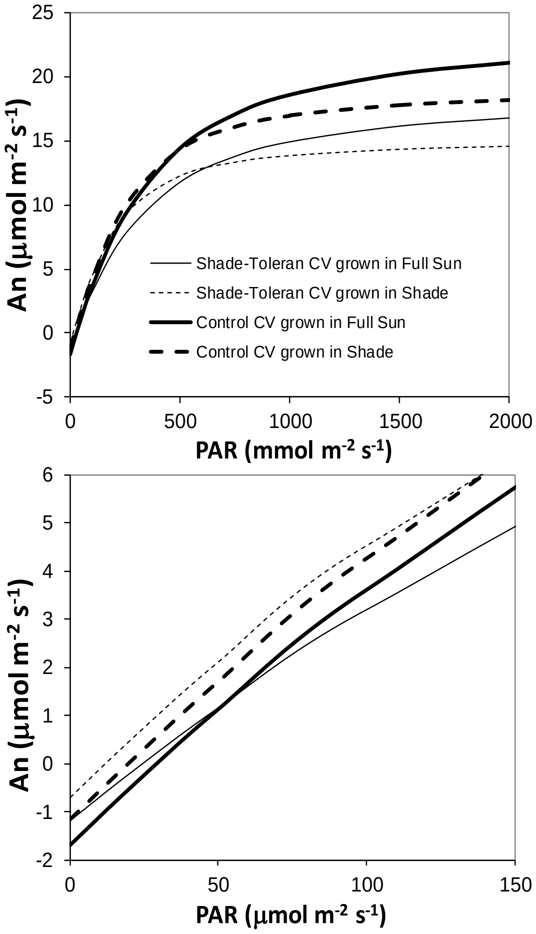
The minute-by-minute PAR data for each position, day and orchard, was then coupled with the photosynthetic response curve of each treatment combination (i.e. each cultivar grown in shade or in full sun), to model the respective minute by minute photosynthetic performance in that position, day and orchard, of each treatment combination. The minute by minute photosynthesis was then summed up for all minutes in the day (from dawn to dusk), to obtain the daily net photosynthesis of each treatment combination, for each position, day and orchard. Further details on this approach are provided in Rosati et al. (2003, 2004).

Results

The photosynthetic response curves to light differed between cultivars and growing conditions (i.e. full light vs. shade) (Figure 1). Within cultivars, plants grown in full sunlight had both greater light saturated net photosynthesis (Amax) (Figure 1 Top) and greater (i.e. more negative values) dark respiration rate (Rd) (Figure 1 Bottom) than the respective plants grown in the tree shade.

‘Bumpers’, the shade-adapted cultivar, had both lower Amax and lower Rd than the control cultivar, both when grown in the sun or in the shade.

The respective photosynthetic response curves to light were then used to model daily photosynthesis (Figure 2 Top). Daily net photosynthesis (Daily An) increased less than proportionally, with increasing daily PAR, as expected. At any value of daily incident PAR, the possible value of the daily An was very variable, even within each treatment. This was due to the fact that the same daily PAR value can be obtained with brighter/longer days in more shaded positions (i.e. more variable light), or with more overcast/short days in less shaded positions (i.e. more uniform light), and this changes the radiation use efficiency (RUE), as longer times at average PAR values results in higher RUE than alternating high and low incident PAR values (Hirose and Bazzaz 1998; Rosati et al. 2003, 2004). This broad range of response makes it difficult to appreciate differences across treatments. To better visualize the data, therefore, the difference in daily An between the control cultivar grown in the sun (i.e. the treatment with the highest Amax) and all the other treatments was plotted against the daily incident PAR (Figure 2 bottom). This figure clearly shows that the control cultivar grown in the sun had the highest daily photosynthesis at high irradiance, reflecting its highest Amax (Figure 1 Top). However, below about 17 mol m^{-2} d^{-1} of PAR, the control cultivar grown in the shade surpassed the same CV grown in the sun, thanks to its lower (i.e. less negative) leaf respiration (Rd) (Figure 1 Bottom). Similarly, the shade-tolerant cv, both grown in the shade and in the sun, also became more efficient than the control cv in the sun at daily PAR lower than, respectively, 10 and 5 mol m^{-2} d^{-1} of PAR. More interestingly, at daily PAR lower than 6 mol m^{-2} d^{-1} of PAR, the shade tolerant cv (i.e. Bumpers) grown in the shade had the highest photosynthesis, and this was again related to its lowest Rd (Figure 1 Bottom).



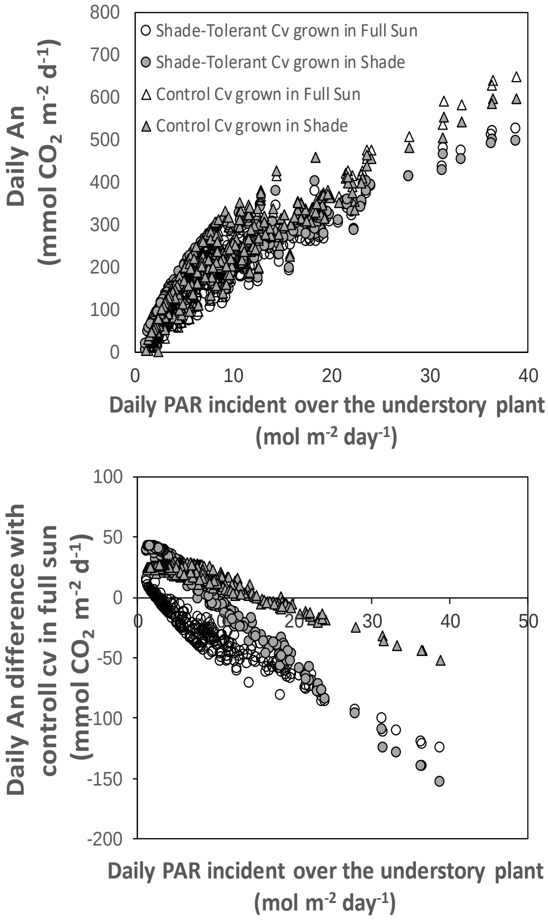


Figure 1: Photosynthetic response to light (i.e. photosynthetically active radiation: PAR) of a shade-tolerant cv (Bumpers) and a control cv (Verl) when grown in either full sun or in tree shade. Top panel: whole curves; bottom panel: details of the initial part of the curves.

Figure 2: Daily photosynthetic response to daily incident light (i.e. photosynthetically active radiation: PAR) of a shade-tolerant cv (Bumpers) and a control cv (Verl) when grown in either full sun or in tree shade. Top panel: actual values; bottom panel: difference in daily net photosynthesis between each treatment and the control cultivar (Verl) grown in full sun.

Discussion

The different treatment combinations had different photosynthetic response curves to light (Figure 1). Plants grown in full sunlight had greater light saturated photosynthesis (Amax) than plants grown in the tree shade, as well as greater (i.e. more negative values) dark respiration rate (Rd). This shows that also in gamagrass, as in many species, leaf metabolisms tend to be adjusted to the illumination conditions under which the leaf develops (Rosati at al. 1999). For the same growing light conditions (i.e. full light or shade), however, the shade-tolerant cultivar (Bumpers) appeared to have an intrinsically lower leaf respiration rate.

The different Rd rates proved to be the key physiological feature to improve photosynthesis at low incident light. In fact, the radiation use efficiency is typically highest at intermediate PAR values, and decreases both at increasing PAR, due to saturation, and at decreasing PAR, due to respiration (Hirose and Bazzaz 1998; Rosati et al. 2003, 2004). At low PAR, therefore, a condition which is typical in agroforestry crops, it is the Rd that determines the RUE, and thus the level of net photosynthesis that can be obtained at low incident radiation. The higher (i.e. more negative) the Rd, the faster the RUE and the net photosynthesis decline at decreasing incident PAR.

Conclusion

The present data suggests that differences in metabolic activity (i.e. in leaf respiration), across different genotypes exist, and can be exploited to increase crop performance in agroforestry systems. Breeding for lower leaf respiration rates might prove a viable tool to increase crop performance in agroforestry systems, particularly in those systems with greater shade levels.

Acknowledgements

This research was made possible thanks to a Fulbright research scholarship 2016, that was awarded to the first author, allowing him to visit the Center for Agroforestry at the University of Missouri, Columbia, MO, USA, and to collaborate with the other authors.

References

Barro RS, Varella AC, Lemaire G, Medeiros RBD, Saibro JCD, Nabinger C, Bangel FV, Carassai IJ (2012) Forage yield and nitrogen nutrition dynamics of warm season native forage genotypes under two shading levels and in full sunlight. Rev Bras Zootec 41:1589–1597.

Ehret M, Graß R, Wachendorf M (2015) The effect of shade and shade material on white clover/perennial ryegrass mixtures for temperate agroforestry systems. Agrofor Syst 89:557–570.

Hirose T, Bazzaz FA (1998) Trade off between light- and nitrogen-use efficiency in canopy photosynthesis. Ann Bot 82: 195-202.

Jose S, Gillespie AR, Pallardy SG (2004) Interspecific interactions in temperate agroforestry. Agrofor Syst 61:237–255

Rosati A, Esparza G, DeJong TM. and Pearcy RW (1999) Influence of canopy light environment and nitrogen availability on leaf photosynthetic characteristics and photosynthetic nitrogen-use efficiency of field-grown nectarine trees. Tree Physiol 19:173-180.

Rosati A, DeJong TM (2003) Estimating photosynthetic radiation use efficiency using incident light and photosynthesis of individual leaves. Ann Bot 91: 869-877.

Rosati A, Metcalf SG and Lampinen BD (2004) A simple method to estimate photosynthetic radiation use efficiency of canopies. Ann Bot 93: 567-574.

ThornleyJHM (1976) Mathematical models in plant physiology. Academic Press, London.

USDA, Natural Resources Conservation Service (2006) Notice of Release of “Bumpers” Eastern Gamagrass. http://www.plant-materials.nrcs.usda.gov/pubs/arpmcrn5878.pdf (accessed 21/04/2018).

LESS AVIAN INFLUENZA RISK BIRDS IN POULTRY FREE RANGE AREAS COVERED WITH TREES

Bestman M[1*], Wagenaar J[1], de Jong W[1], Weerts T[1], Luske B[1]

(1) Louis Bolk Institute, Bunnik, the Netherlands

*Corresponding author: m.bestman@louisbolk.nl

Abstract

This study investigated the relation between the presence of wild bird species that may infect domestic poultry with Avian Influenza, and woody vegetation within the range areas as well as in the landscape surrounding the range areas. During two seasons all wild birds were counted in the free-range areas of 11 poultry farms and their immediate surroundings. More high-risk birds were observed in free-range areas with less than 5 % woody cover, compared to free-range areas with more woody cover. Furthermore, more high-risk birds were observed in the surroundings of free-range areas in open landscapes, compared to half-open landscapes. For low-risk birds, no relation was found between woody cover or openness of the landscape and their presence in free-range areas or surroundings. These results merit further experimental research on the relation between the presence of AI risk birds and woody vegetation in and around poultry free-range areas.

Keywords: free-range poultry; organic poultry; animal welfare

Introduction

For several reasons poultry free-range areas are planted with trees. A reason from an animal welfare point of view is that a higher proportion of chickens from a flock will use the free-range area if there is cover by trees. If a higher proportion of the chickens is using the free-range area, significantly less feather pecking damage (a welfare problem) is seen (Bestman and Wagenaar 2003; Green et al. 2000). Another reason for planting the free-range area with trees is to combine two types of land use in order to improve the farming systems' Life Cycle Assessment (Paolotti et al. 2016). However, free-range chickens can have contact with wild birds and become infected with avian influenza (van der Goot et al. 2015). Water birds and waders are regarded as high risk birds (Veen et al. 2007). Since these birds are associated with open landscapes, we expected a negative relation between tree cover in the free-range area and presence of these risk birds. Our aim was to be able to advise free-range poultry farmers about the role of tree cover in relation to the presence of wild birds known for their risk to carry avian influenza. Wild birds have been counted in 11 poultry free-range areas with different proportions of tree cover.

Materials and methods

Eleven organic and conventional free-range egg production farms were selected based on their proportion of free-range area covered with trees (fruit trees, biomass willows or miscanthus). This varied from 0 to 90% cover. See Table 1 for farm characteristics.

Table 1: Characteristics of farms involved in this study.

Farm	No of hens, rounded to 1,000	Size of free-range area in hectares	Woody cover in % of free-range area	Type of vegetation in free-range area	Vegetation of surrounding landscape	Openness of surrounding landscape
1	24,000	12	0	Grass	Grassland	Open
2	18,000	8	35	Grass, fruit, Miscanthus	Agriculture*, woodland strips, forest	Half-open
3	30,000	17	8	Grass, trees, bushes	Agriculture, woodland strips	Half-open
4	15,000	6	75	Miscanthus, grass	Agriculture, woodland strips, forest	Half-open
5	12,000	5	90	Fruit, grass	Agriculture	Half-open
6	17,000	8	0	Grass	Grassland	Open
7	16,000	6	35	Grass, fruit	Agriculture, woodland strips	Half-open
8	15,000	8	50	Fruit, biomass willows, grass	Agriculture, woodland strips	Half-open
9	15,000	7	10	Grass, fruit	Agriculture, woodland strips, forest	Half-open
10	24,000	10	10	Grass, fruit	Agriculture, woodland strips, forest	Half-open
11	6,000	2	90	Fruit, diverse bushes	Grassland	Open

*'Agriculture': maize or wheat (= arable crops related to livestock farms)

The farm surface was divided in free-range area (accessible to the chickens) and farmyard (area with buildings and farm house; not accessible to chickens). For bird counts in the surroundings, we selected two plots bordering (or close to) the range area, which could be observed from a car from the public road. The farms were visited 4 times per season. The observations were done in 2 seasons: early spring and autumn/winter. All observations started at 10 am. All birds in and flying above the free-range area and in and flying above two selected neighboring plots were counted. Observations started from the car and were continued on foot walking all around the free-range area and the farm buildings. Based on large scale wild bird monitoring (Breed et al. 2011) and expert judgments (Veen et al. 2007; Slaterus personal information), wild birds were divided in 3 categories: high risk birds, low risk birds and no/unknown risk birds. High risk birds were all water birds and waders: geese, ducks, swans, storks, oystercatchers, et cetera. Low risk birds were birds that were not as vulnerable to influenza infection as the high risk birds, but who could carry the virus after they were in contact with infected birds. These were birds of prey and corvids, which are scavengers. The no/unknown risk birds were all other birds, mainly singing birds from sparrow tot woodpecker, that were rarely or not found with an avian influenza infection. Farms were divided into 4 categories depending on the proportion of tree cover in the free-range area (0–5%; 5–25%; 25–50%; >50%) and into 2 categories depending on the openness of the surrounding landscape (half closed or open) (Figure 1). Observations were divided in birds seen inside the free-range area (touching the ground or trees) and birds seen in the surroundings (flying above the free-range area or seen in or above the 2 selected neighboring plots). Bird counts were log transformed and data were analyzed by General Linear Models using Genstat.

Results

Totally 24,053 birds were counted during 21 observations: 268 high risk birds in the free-range area (see Table 2), 427 low risk birds in the free-range area, 3372 high risk birds in the surroundings, 1639 low risk birds in the surroundings and all other birds being no/unknown risk birds in either the free-range area or the surroundings.

Table 2: Avian Influenza high risk birds seen in 11 free-range areas in 2 seasons.

Farm	1	2	3	4	5	6	7	8	9	10	11	Total
% woody cover	0	35	8	75	90	0	35	50	10	10	90	
Openness landscape*	O	HC	HC	HC	HG	O	HC	HC	HC	HC	O	
Phalacrocorax carbo	1	-	-	-	-	8	-	-	-	-	-	9
Ardea cinera	3	1	-	-	1	8	1	-	-	-	-	14
Geese spec	26	-	-	-	-	-	-	-	-	-	-	26
Anser anser	25	-	-	-	-	49	-	-	-	-	-	74
Ardea alba	4	-	-	-	-	6	-	-	-	-	-	10
Vanellus vanellus	-	-	1	-	-	-	4	-	-	-	-	5
Cygnus olor	2	-	-	-	-	-	-	-	-	-	-	2
Anser albifrons	-	-	-	-	-	1	-	-	-	-	-	1
Anas strepera	-	-	-	-	-	5	-	-	-	-	-	5
Aythya fuligula	-	-	-	-	-	2	-	-	-	-	-	2
Fulica atra	-	1	-	-	-	4	-	-	-	1	-	6
Gull spec	9	-	60	-	-	-	-	-	-	-	-	69
Alopochen aegyptiaca	-	-	-	-	-	3	-	-	-	4	-	7
Haematopus ostalegus	2	-	-	2	-	-	4	-	-	-	-	8
Gallinula chloropus	-	-	-	1	-	-	-	-	-	-	-	1
Gallinago gallinago	-	-	-	2	1	-	-	-	-	-	-	3
Anas platyrhynchos	12	2	-	-	-	6	3	2	-	1	-	26
Total	84	4	61	5	2	92	12	2	0	6	0	268

*O=open landscape; HC=half closed landscape

Significantly more high risk birds were seen in free-range areas with less than 5 % tree cover (model: p=0.026; R²=35; se=15.8). However, all farms with low proportion of tree cover were located in an open landscape (see Table 1). Therefore it was not possible to conclude whether it was the low proportion of tree cover in the free-range area or the open landscape that was associated with higher numbers of high risk birds in the free-range area.

No relation was found between the number of low risk birds in free-range areas and the proportion of tree cover in the free-range area, nor in open, nor in half closed landscapes (model: p=0.613; se=2.5).

Significantly more high risk birds were seen in the surroundings of the free-range area if the landscape was more open (p=0.005; R²=39; se=1.3). However, 2 out of 3 farms in open landscape had 0 % cover with trees in their free-range area and 1 out of 3 had 90% cover. Therefore it was not possible to conclude whether it was the open landscape or the absence of tree cover in the free-range area that was associated with higher number of high risk birds in the surroundings.

No relation was found between the number of low risk birds in the surroundings of the free range area and the openness of the landscape, nor in case of range areas with higher or lower proportion of tree cover, nor in half closed or open landscapes (model: (p=0.58; se=1.3)).

Figure 1: Examples of free-range areas with <5% tree cover (left) and with 90% tree cover (right).

Discussion

The farm sample available makes it difficult to separate the effects of tree cover in the free-range area and the openness of the landscape around the farm.

Explanations for higher numbers of geese and ducks in free-range areas with a smaller proportion of tree cover could be that they prefer open areas in which they can see predators, they forage on the ground and eat mostly grass. Moreover, they prefer foraging in large groups, for which they need large open spaces. These traits may also explain why higher numbers of high risk birds are seen in the surroundings of free-range areas, if located in an open landscape.

The absence of a relation between low risk birds in the free-range area and proportion of tree cover might have to do with the low number of birds of prey seen anyway. Corvids were seen on all farms. The corvids were attracted by other aspects than those related to the proportion of tree cover in the free-range area. Moreover, corvids often live and roam in large groups, a reason why you see more of them, which is not the case in birds of prey. These traits may also explain why no relation was found between low risk birds and openness of surrounding landscape.

Conclusions

The results support to further investigate the role of trees as a measure to keep down avian influenza risk birds in and around poultry free-range areas. Especially experimental research, in which the presence of these species before and after the planting of trees is being investigated, may show whether planting of trees can be advised as a measure.

Acknowledements

This study was made possible by financial support from ‘Trees for chickens’ (funded by the European Agricultural Fund for Rural Development, the Dutch Ministry of Economic Affairs, and the Dutch ‘Fonds voor Pluimveebelangen’); ‘Low pathogenic AI on free-range farms’ (funded by the Dutch Ministry of Economic Affairs) and the AGFORWARD EU 7th Framework Programme of RTD (Grant Agreement N° 613520).

References

Bestman M, Wagenaar JP (2003) Farm level factors associated with feather pecking damage in organic laying hens. Livest Prod Sci 80: 133–140. doi

Breed C, Duncan D, Stroud D, Nicholson R, Edwards J (2011) Annual report on surveillance for avian influenza in wild birds in member states of the European Union in 2011. European Reference Laboratory for avian influenza, Weybridge, Addlestone, Surrey, UK.

Goot J van der, Elbers A, Bouwstra R, Fabri T, Wijhe-Kiezebrink M van, Niekerk T van (2015) Risicofactoren voor introductie van laag-pathogeen aviaire influenza virus op legpluimveebedrijven met vrije uitloop Nederland. CVI Rapport 15/CVI0078.

Green LE, Lewis K, Kimpton A, Nicol CJ (2000) A cross sectional study of the prevalence of feather pecking damage in laying hens in alternative systems and its association with management and disease. Vet Rec 147: 233–238.

Paolotti L, Boggia A, Castellini C, Rocchi L, Rosati A (2016). Combining livestock and tree crops to improve ustainability in agriculture: a case study using the Life Cycle Assessment (LCA) approach. J Clean Prod 131: 351-363.

Veen J, Brouwer J, Atkinson P, Bilgin C, Blew J, Eksioglu S, Hoffman M, Nardelli R, Spina F, Tendi C, Delany S (2007) Ornithological data relevant to the spread of Avian Influenza in Europe (phase 2): further identification and first field assessment of higher risk species. Wetlands International, Wageningen, The Netherlands.

POLYCULTURES IN AGROFORESTRY

Groeneweg D[1], Vischedijk F[1], Appelman J[2], van Buiten G[3], San Giorgi X[4], Hautier Y[1]*

(1) Ecology and Biodiversity Group, Department of Biology, Utrecht University, The Netherlands (2) Education Institute Biology, Utrecht University, The Netherlands (3) Botanical Gardens, Utrecht University, The Netherlands (4) Food Forestry Development, Utrecht, The Netherlands

*Corresponding author: y.hautier@uu.nl

Abstract

Food forestry could help feeding a growing population in a sustainable way. Growing perennial plant species in polycultures and combining different plant traits could allow complementarity between plant species and thus to produce more yield (overyield) as compared to when the species are grown in monocultures. Morevoer, by mimicking natural systems food forestry could enhance carbon storage and mitigate climate change. Whether food forestry can deliver both overyielding and sustainability is not clear. We set up 28 mesocosms containing either monocultures or polycultures of one tree, one bush and one ground cover species, to assess whether perennial polycultures can produce more biomass than their constituent counterparts while at same time store carbon. After four month of growth we found that biomass production and soil organic carbon increased with diversity. Our results suggest that food forestry could be a sustainable alternative for biomass production.

Keywords: monocultures; polycultures; selection effect; complementarity effect; carbon cycle

Introduction

Solutions must be found to keep feeding a growing population in a sustainable way (Gerland et al. 2014; Tilman 1999; Tilman et al. 2001). By mimicking the structure and relationships of natural forest ecosystems, food forestry could allow us to produce food while preserving the functioning of our ecosystems (Kandji et al. 2006). Additionally, the combination of plant species with different traits, for example a mixture of plants fixing atmospheric nitrogen with plants that do not, could allow complementarity between plant species to produce more yield (overyield) as compared to when the species are grown in monocultures (Loreau and Hector 2001). However, competition between plants for the use of available resources could lead to a reduction of yield (Grace 1993). The current state of research in agroforestry does not allow us to determine whether plant species in mixtures work together or against each other to affect the yield and the functioning of our ecosystems. In this study we investigate whether a polyculture of plants could produce more than its constituent counterparts while preserving ecosystem functioning (https://www.uu.nl/staff/YHautier/0).

In other systems such as grasslands, it has been showed that plant communities with higher diversity can overyield (Cardinale 2012; Hooper et al. 2012), that is, the biomass produced by a species in polyculture is higher when compared to the biomass of that species in a monoculture. Overyielding can come from two different mechanisms: the complementarity effect and the selection effect (Loreau and Hector 2001). Both effects operate in combination and have a different influence on productivity. Complementarity effect includes niche complementarity in which species differ in their resource requirements thus reducing potentail competition between them, and facilitation in which species can modify the environment in a way that benefits other species. Selection effect is the increase in the likelihood of including in the polyculture a species that is highly influencial for biomass production, either positively of negatively, with increasing number of species. Thus the dominance of species with particular traits that affect the ecosystem processes (Loreau and Hector 2001), can increase or counteract complementarity. Currently it is not well understood whether a food forest can overyield and how complementarity and selection effects function in this system. Theoretically it has the potential to produce overyielding, but not enough research has been done to support this theory.

This study is thus designed not only to investigate whether polycultures produce more biomass than monocultures in an agroforestry system, but also to understand the underlying mechanisms and potential impact on the carbon cycle.

Materials and methods

In April 2017, we established mesocosms of 1.2 x 1 x 1 m (l x w x h) in Intermediate Bulk Containers (IBC) in a greenhouse at Utrecht University's Botanical Garden (Figure 1 A). Each mesocosm is filled with two layers of bottom and top soil excavated from a nearby pig farm (Zwolle). Mesocosms contained one of three levels of plant diversity: monocultures of each of three selected species, polycultures of all combinations of two species, and polycultures of all three species (Figure 1 B). Each species composition was replicated four times for a total of 28 mesocosms. Species selection was based on potential complementarity between the three species in terms of acquisition of nutrients and use of canopy space. In particular, we chose the tree species *Toona sinensis*, the nitrogen fixer bush *Cytisus scoparius* and the mineral accumulator ground cover *Achillea millefolium*. We planted the same number of plants for the tree and bush species in each of the monocultures and polycutures. Per mesocosm, we planted three individuals of the tree *T. Sinensis*, eight individuals of the bush *C. Scoparius* and we sowed 1000 seeds *A. millefolium* (Figure 1 C). The experiment will run for a period of minimum five years.

We are measuring a suite of parameters including above and belowground biomass production, nutrient leaching, leaf carbon content, soil organic carbon (SOC), dissolved organic carbon (DOC), and soil respiration.

Aboveground biomass production (g) was assessed after 111 days of growth. *T. sinensis* was measured by harvesting the leaves and cutting the parts of the trees that were higher than 120 cm from the soil. The leaves of each individual were counted. *C. scoparius* was pruned back to the starting size (about 10 cm high). Above ground biomass production of *A. millefolium* was measured by clipping the entire plots at ground level. All the harvested biomass was oven dried at 70°C to constant mass and weighted.

Below ground biomass production (g) was measured by using root ingrowth cores, 74 cm long, with a diameter of 7.5 cm and mesh size of 50 mm. The root ingrowth cores were buried in every mesocosms at the onset of the experiment in March and collected after 116 days. The contents of the cores were sieved, washed, oven dried at 70°C to constant mass and weighted.

Soil samples of the upper 10 cm of the soil were collected every three weeks from the mesocosms between May 9th and July 20th for SOC analysis using an EA/1110 CHNS-O analyser (Interscience BV, Breda, The Netherlands). Water was collected from the taps of the mesocosms, between May 9th and July 20th, and filtrated to measure DOC using a continuous flow auto analyser (Skalar SA-40, Breda, The Netherlands).

Basal soil respiration after 99 days and 126 days of growth in the mesocosms was measured by using a respirometer equipped with carbon dioxide and oxygen sensors (Biometric Systems, Germany).

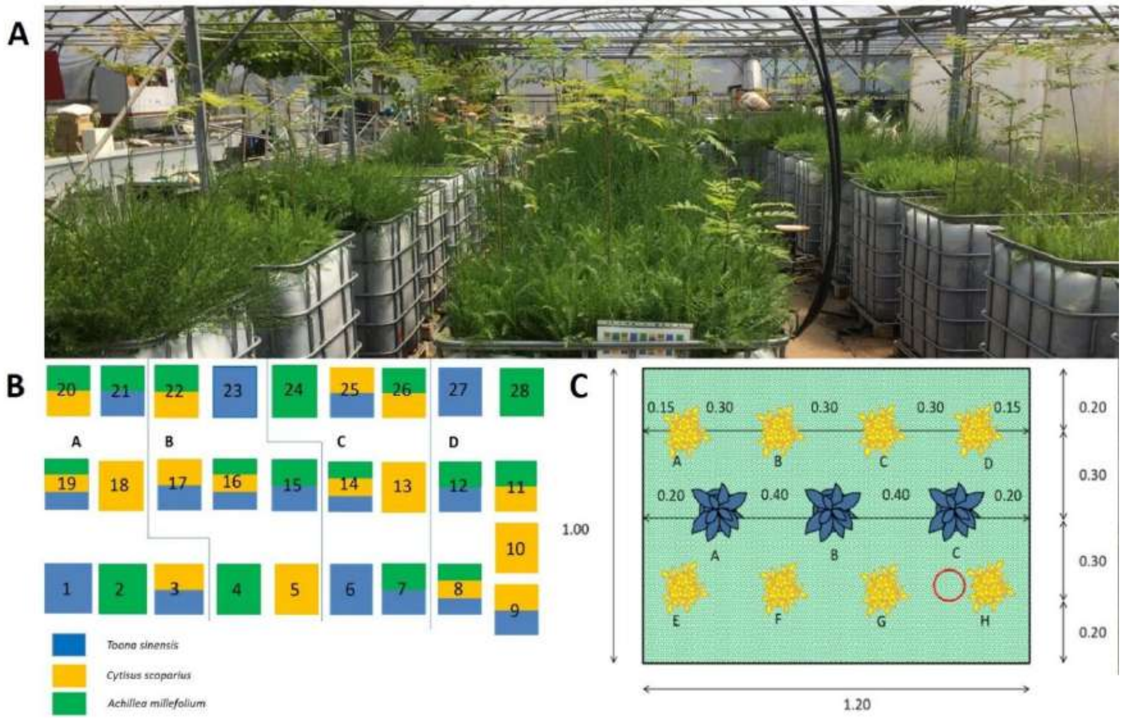


Figure 1: Experimental setup. A) Pictures showing the agroforestry experiment in a greenhouse at Utrecht University Botanical Gardens. B) Setup of the mesocosms, the content of the mesocosms and the distribution of the blocks. C) Setup of the plants in the mesocosm. Numbers indicate distances in metres. The three blue plants in the middle represent the tree *Toona sinensis*, the eight yellow plants represent the bush *Cytisus scoparius* and the green background represents the ground cover forb *Achilea millefolium*.

Results

After the first four months of the experiment, we found that the polycultures of two and three species produced more biomass compared to the monocultures (Figure 2). This overyielding was due to both a complementarity effect and a selection effect. The complementarity effects probably came from complementarity in space (filling up of the different layers in the canopy structure, thus intercepting more light). The selection effect emerged from the highly productive species in monoculture (*Cytisus scoparius*) which was a major determinant of productivity in the polycutures.

On the other hand, both the tree *Toona sinensis* and the bush *Cytisus scoparius* produced more biomass when grown in a monoculture while biomass production of the herb *Achillea millefolium was constant along the diversity gradient.* This result highlights the duality between overyielding at the community level (niche complementarity) and overyielding at the species level (facilitation). None of the species investigated produced more biomass in polycultures, while altogether, polycultures produced more than any of their constituent counterparts grown in monoculture.

Additionally, we found that polycultures contained more soil organic carbon, while monocultures and polycultures did not differ in terms of below ground biomass production, dissolved organic carbon or soil respiration (data not shown).

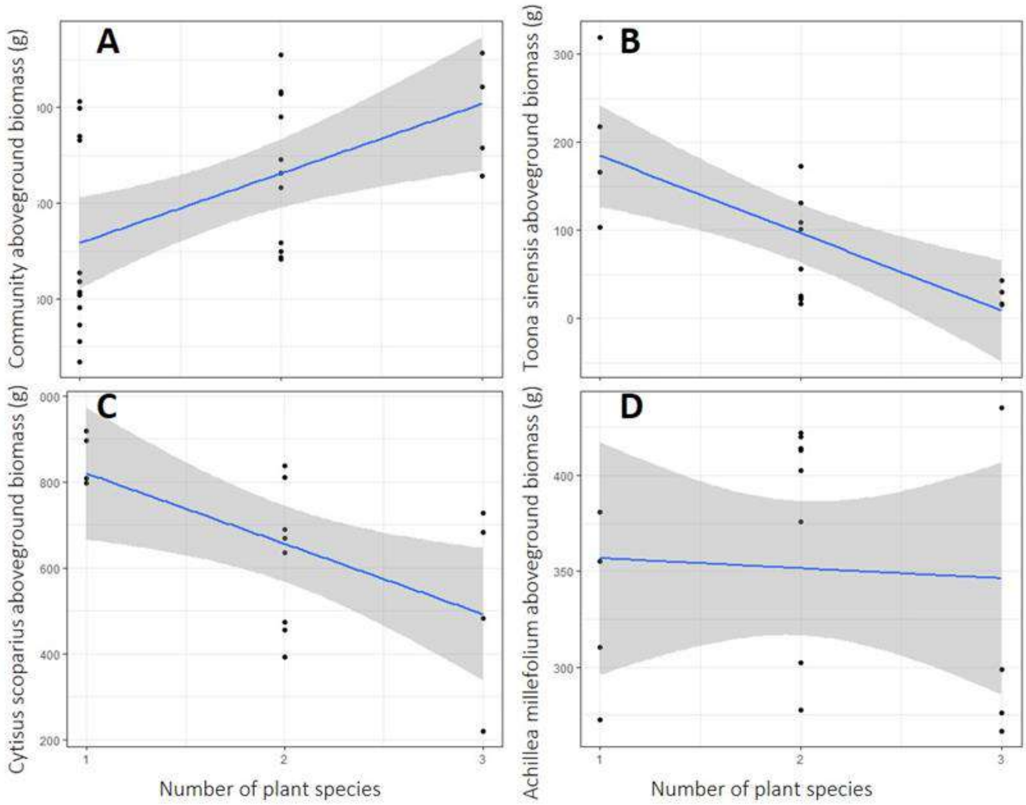


Figure 2: Aboveground biomass after four months of growth of A) all plant species, B) all *Toona sinensis*, C) all *Cytisus scoparius* and D) all *Achillea millefolium* in each mesocosm along the manipulated plant diversity gradient.

Discussion

Our results showed an increase in above ground biomass with an increase in species richness. This result is in line with studies conducted in grasslands (Cardinale 2012; Hooper et al. 2012). This was due to both a complementarity and selection effect. Despite the increase in above ground biomass production with higher species richness we did not find a difference of below ground biomass production with higher species richness.

Because we found more above ground biomass in which carbon can be stored with higher species richness, we can say that polycultures appear to have the potential to store more carbon in their above ground biomass compared to monocultures. This was also found by other studies in which large amounts of carbon were stored in plant biomass, especially in forests (Luyssaert et al. 2008). We found no significant relation of soil respiration or DOC leakage with an increase in species richness. A neutral effect of species richness on soil respiration was also found by De Boeck et al. (2007) who determined the impact of grassland plant diversity on respiration rates. We did find a slight but significant increase in SOC with an increase in species richness (data not shown). This agrees with previous evidence that polycultures have a higher potential to sequester carbon than monocultures (Nair et al. 2009; Richards et al. 2010). Since our results are from the very first stages of a food forest systems, we expect to have clearer results with more factors contributing to SOC in the next five years. Furthermore, the findings depend on the species (composition) and will probably be different with different species or different number of species. For example, tree plantation monocultures can become a carbon sink if the right species and managemental practices are chosen (Freibauer et al. 2004; Sharrow and Ismail 2004).

Conclusion

We found that polycultures produced more above ground biomass and contained more SOC. However, monocultures and polycultures did not differ in terms of below ground biomass production, DOC or respiration. Our results suggest that food forest systems have the potential to overyield and store more carbon compared to monocultures.

References

Cardinale BJ (2012) Biodiversity loss and its impact on humanity. Nature 489: 326-326.

De Boeck HJ, Lemmens C, Vicca S, Van den Berge J, Van Dongen S, Janssens IA, Ceulemans R, Nijs I (2007) How do climate warming and species richness affect CO_2 fluxes in experimental grasslands? New Phytologist 175: 512-522.

Freibauer A, Rounsevell MDA, Smith P, Verhagen J. (2004) Carbon sequestration in the agricultural soils of Europe. Geoderma 122: 1-23.

Gerland P, Raftery AE, Sevcikova H, Li N, Gu D, Spoorenberg T, Alkema L, Fosdick BK, Chunn J, Lalic N, Bay G, Buettner T, Heilig GK, Wilmoth J (2014) World population stabilization unlikely this century. Science 346: 234-237.

Grace JB (1993) The effects of habitat productivity on competition intensity. Tree 8: 229-230.

Hooper DU, Adair EC, Cardinale BJ, Byrnes JEK, Hungate BA, Matulich KL, Gonzalez A, Duffy JE, Gamfeldt L, O'Connor MI (2012) A global synthesis reveals biodiversity loss as a major driver of ecosystem change. Nature 486: 105-129.

Kandji ST, Verchot L, Mackensen J (2006) Climate change and variability in the Sahel region: Impacts and adaptation strategies in the agricultural sector. UNEP, ICRAF.

Loreau M, Hector A. (2001) Partitioning selection and complementarity in biodiversity experiments. Nature 412: 72-76.

Luyssaert S, Schulze ED, Borner A, Knohl A, Hessenmoller D, Law BE, Ciais P, Grace J (2008) Old-growth forests as global carbon sinks. Nature 455: 213-215.

Nair PKR, Kumar BM, Nair VD (2009) Agroforestry as a strategy for carbon sequestration. J Plan Nutr Soil Sci 172: 10-23.

Richards AE, Forrester DI, Bauhus J, Scherer-Lorenzen M. (2010) The influence of mixed tree plantations on the nutrition of individual species: a review. Tree Physiol 30: 1192-1208.

Sharrow SH, Ismail S. (2004) Carbon and nitrogen storage in agroforests, tree plantations, and pastures in western Oregon, USA. Agrofor Syst 60: 123-130.

Tilman D. (1999) Diversity and production in European Grasslands. Science 286: 1099 - 1100.

Tilman D, Fargione J, Wolff B, D'Antonio C, Dobson A, Howarth R, Schindler D, Schlesinger WH, Simberloff D, Swackhamer D (2001) Forecasting agriculturally driven global environmental change. Science 292: 281-284.

IMPROVE THE EFFICIENCY OF AFFORESTATION BY THE USE OF ALLEY CROPPING SYSTEM

Kovács K[1], Vityi A[1]*

(1) Institute of Forest Mechanisation and Environmental Techniques, University of Sopron, Sopron, Hungary

*Corresponding author: vityi.andrea@uni-sopron.hu

Abstract

"Vákáncsos" is a traditional Hungarian practice where agricultural or horticultural crops were grown in the alleyways between spaced rows of woody plants in early stage in the 19th century. This study aimed at analyzing the results of the use of this old practice – in a modern form - in forest management. Results show that during the early stages of forest plantation, intercropping of young trees with food crops is beneficial in terms of the improvement of microclimate, tree development and survival, and food crop production.

Keywords: intercrop; alley cropping; forest management; tree; crop production; microclimate

Introduction

Agroforestry is a traditional practice in the Carpathian Basin. For example, abandoned forest areas owned by the city, where agricultural or horticultural crops are grown in the alleyways between spaced rows of woody plants were mentioned in the 1820s administrative records of the Municipality of Debrecen. These areas were called as "*vákáncs" from the latin "vacans"* (in English "vacant") which means "vacant land" (Miklós 1974). We considered, that the old practice used in these areas can be applied in forest management of today as well, but in a modern form adapted to the current (technological) environment. In this way, afforestation is manageable as a sustainable and productive system. The aim of the present research is to investigate the effect of intercropping between alleys on the soil microclimate and the development of seedlings, compared with a control site.

Materials and methods

In the summer of 2015, an experimental agro-forestry system was established in the area of Hajdúhadház Forestry Office of Nyírerdő Forestry Co (Vityi et al. 2016). The main purposes were to maximise the utilisation of available space, protect seedlings and ensure the success of afforestation. By using maize as intercrop in the alleys of the area replanted with oak trees fodder production for animal stock of the forestry company was also feasible. This experimental system provided possibility for measuring the effects of alley cropping on the local microclimate and the development of trees and thus on the success rate of afforestation. For this purpose, areas close to each other and of similar site conditions were involved in the experiment. The same tree row orientation and management were applied in both plots (Table 1).

Table 1: Basic data of the experimental areas.

	Alley cropping system	Control
Area	0,66 ha	4,0 ha
Plant	Oak (Quercus robur) and corn	Oak (Quercus robur)
Row spacing (cm)	90-70-90	250
Orientation of row	North-south	North-south
Irrigation	No	No
Physical characteristics of soil	Sandy soil with humus	Sandy soil with humus
Corn production	30q/ha	-
Experimental period	3 years	

Measurements

Based on the monitoring results of the first year (2015), an initial research plan was developed for the following year, focusing on the measurement of soil temperature and soil conductivity as well as the development of the crop and the seedlings. (Table 2) Parameters of soil microclimate were measured for one month, in the statistically most dry and hot period of summer which is a critical and stressful period of the year for the plants. Based on soil conductivity, comparison of soil moisture in the two areas is feasible, due to a strong correlation between the soil's electrical conductivity and the soil moisture content (Nagy 2014). In 2016, soil parameters were tested in two sampling points per area.

Sampling points were designated to have the same site conditions, thus ensuring the comparability of the samples. Due to the sloping terrain of the control area, it has a tendency to soil erosion and leaching, thus sampling sites were selected lowland, in a more fertile part of area similar to the alley cropping area. Also the distance between two sampling points and thus covering of the sampled area was equal.

In order to increase the reliability of the results, the number of sampling points were raised to 17 in each plots (Table 2).

Table 2: Measured parameters of the experimental plots (August 2016, 2017).

Examined parameter	Soil temperature	Soil conductivity	Growth of trees
Period	01. Aug. - 02. Sept.	01. Aug. - 02. Sept.	02. Sept.
Sampling points	2 points/plot (2016) 17 points/plot (2017)	2 points/plot (2016) 17 points/plot (2017)	5x10 meters/plot
Test method and equipment	Soil temperature and conductivity meter (Hanna HI 98331)	Soil temperature and conductivity meter (Hanna HI 98331)	Height measurement with measuring tape

Results

The results show that the daily average soil temperature data in the agro-forestry area were below the soil temperature values of the control area, which indicated a moderated soil microclimate in the alley cropping system. (Figure 1 and Figure 2) In the average daily soil temperature there was a difference of 0.2-2.0 ° C between the two areas, which influenced the evaporation intensity and the growth of the plants. The reason for the curtail of the function is the precipitation on August 22 which did not allow the measurement to be carried out. Based on the results under the same soil conditions, we can infer that due to the presence of the intercrop, the soil moisture conditions of the two areas are different.

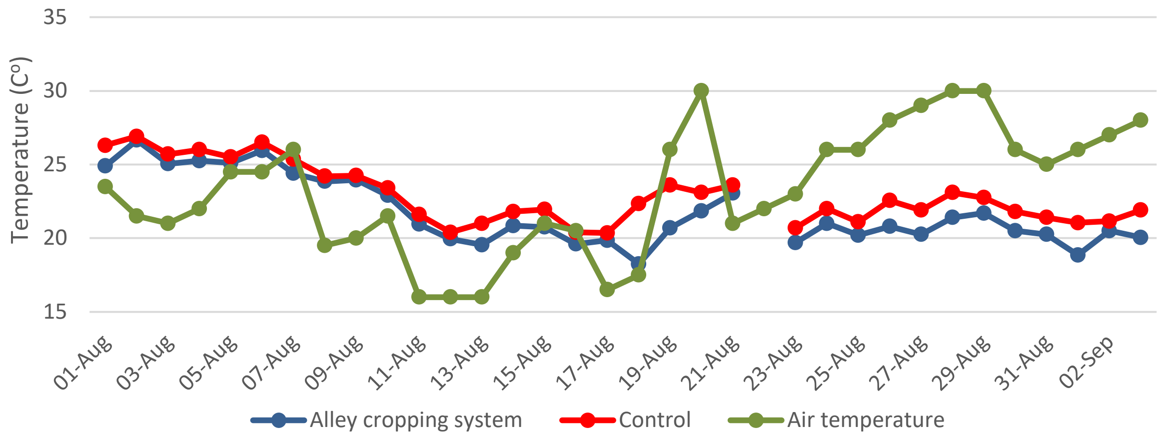


Figure 1: The change of daily average of soil temperature in August 2016.

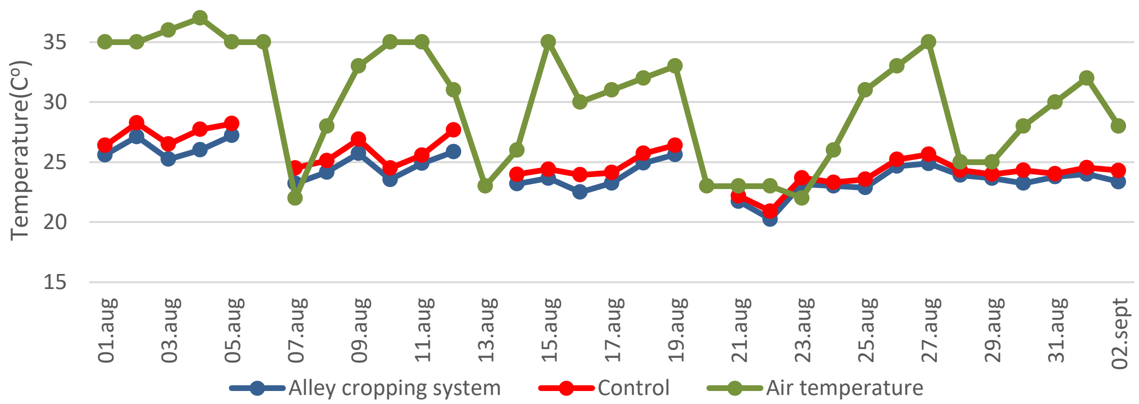


Figure 2: The change of daily average of soil temperature in August 2017.

The conductivity values of the soils follow well the distribution of precipitation, but in alley cropping system area the soil conductivity exceeded the values of the control area, in concluding that the agro-forest parcel had more favourable soil moisture values during drought period (Figure 3 and Figure 4).

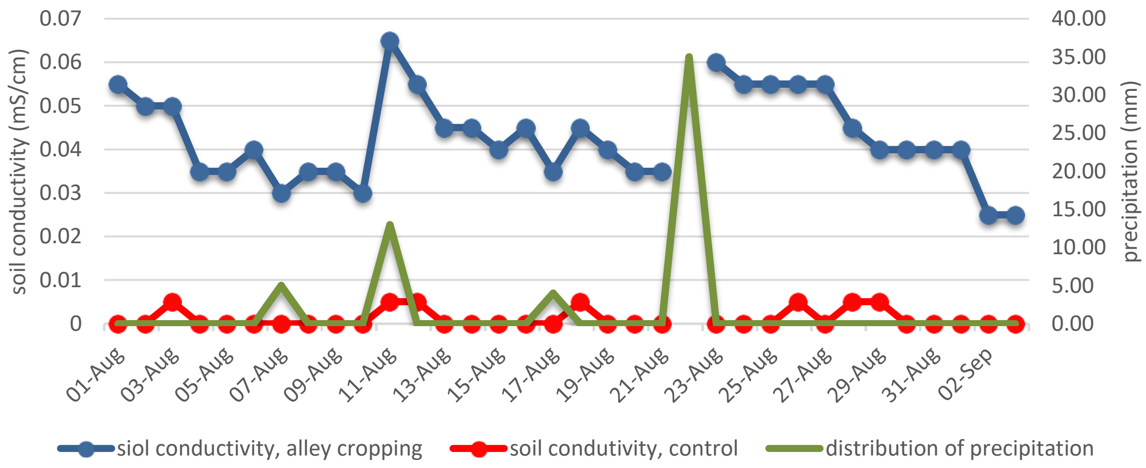


Figure 3: The change of daily average of soil conductivity (August 2016).

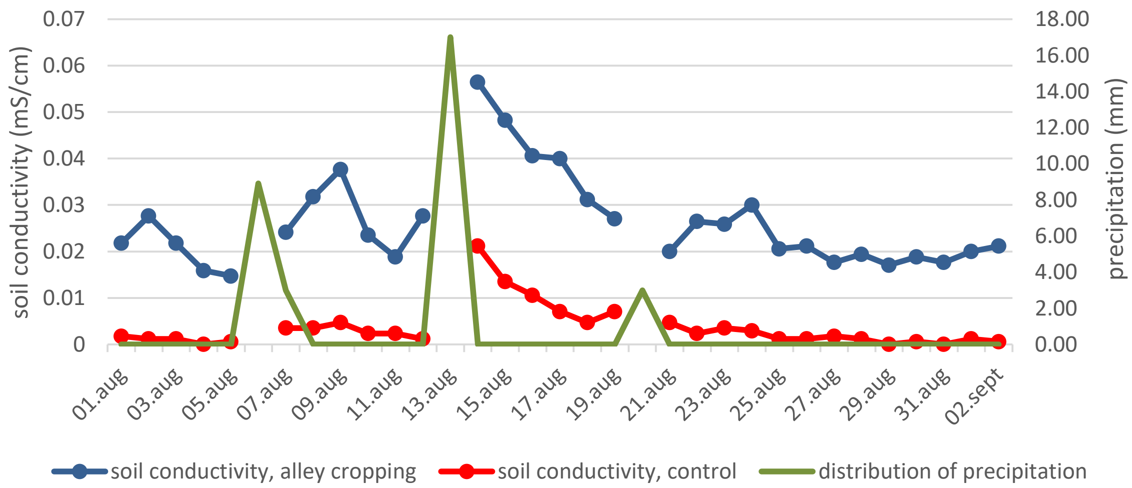


Figure 4: The change of daily average of soil conductivity (August 2017).

Results of tree development and rate of survival show that there is a significant difference between the agroforestry and the control systems. In 2015 the mortality rate was 50% in the control plot, requiring double plant replacement, on the contrary in the agroforestry parcel no drought damages were recorded (both systems are non-irrigated). Additionally, in the following years, the trees in the alley cropping plot showed significantly better growing, on average 18 cm (2016) and 21 cm (2017) ($t<0.05$; $p=0.0023$). The yield of the intermediate crop (60 q/ha) reached the average yield in monocultures under similar conditions.

Discussion and conclusion

Based on the results, the water balance of agroforestry system proved to be better than the control area in the examined drought periods. Significant difference was found between the data of the two afforested parcels in terms of soil microclimate. The daily mean temperatures of the alley cropping area in the arid period are significantly smaller than the values of the control area. The more favourable microclimate resulted in a significantly stronger growth of alley cropping area. There was no noticeable drought damage in the agro-forestry experimental field and the growth parameters of the plants were more favourable, so it can be established that in the cultivation system associated with maize the development of the stand was more prosperous in all respects.

Based on our experience and measurements, application of agroforestry (alley cropping) practice system can significantly increase the efficiency of (artificial) afforestation, reduce the drought damage, and improve the survival and growth parameters of seedlings. By maximising the utilisation of the available area to serve other purposes (production, ecosystem services), the afforestation may be coupled with resource efficiency and economic returns.

Acknowledgement

The authors would like to thank the forestry company participated in this transdisciplinary exercise. We acknowledge the support of the European Commission through the AGFORWARD FP7 research project (contract 613520).

References

Miklós Zs (1974) A Debreceni Vákáncsosok. In: A Déri Múzeum Évkönyve. *Debrecen*, Pp.260-264.

Nagy G (2014) A Talaj Nedvességtartalmának Meghatározása Az Elektromos Vezetőképesség Vizsgálatával. Nyugat-Magyarországi Egyetem Mezőgazdaság- És Élelmiszertudományi Kar, Mosonmagyaróvár. http://Www.Hidrologia.Hu/Ifjusaginapok/22/Dolgozatok/Word/29_Nagy.Pdf (accessed 18/04/2018).

Vityi A, Kovács K, Dufla F, Bácsmegi L, Nagy I (2016) Improve the efficiency of afforestation by the use of agroforestry practices. 3rd European Agroforestry Conference, Montpellier, France.

GRASSLAND MANAGEMENT EFFECTS ON ABOVE-GROUND MATTER FLUXES IN SILVOPASTORAL AGROFORESTRY SYSTEMS

Malec S[1*], Graß R[1], Wachendorf M[1]

(1) Faculty of Organic Agricultural Science, Section Grassland Science and Renewable Plant Resources, University of Kassel, Witzenhausen, Germany

*Corresponding author: sarah.malec@uni-kassel.de

Abstract

Agroforestry systems offer an alternative agro-ecological approach to a sustainable intensification of food/forage crop and wood production. Therefore, this study investigates the biomass yields of the growing season 2016 in a silvopastoral agroforestry system. The system combines two different grassland types (both with an intensive and extensive management) and short rotation coppice (SCR) with willows (*Salix* spp.) in an alley cropping design. The DM yields of all grassland treatments were lower in the agroforestry system compared to the usual grassland yields without influences of trees at this location. The grassland biomass yields decreased close to trees and also the composition of plant functional groups changed with decreasing distance to trees. The DM yield of woody biomass was estimated with 15.7 t DM ha^{-1} in the second year of the second tree rotation cycle. Results show that systems productivity was higher during the second rotation compared to the first rotation (2011-2015).

Keywords: silvopastoral agroforestry; short rotation coppice - willows; Grassland; biomass yield; functional groups

Introduction

The Organization for Economic Co-operation and Development (OECD) aims to halve the global emissions of CO_2 by 2050, compared to the level in 2000. In order to reach this target, the replacement of fossil fuels with renewable energy resources has to be envisioned, with a particular role of bioenergy. As a result, the demand for arable land for the cultivation of energy crops increases. Competition for land use with food and energy plants is also increasing as well as environmental hazards like soil erosion, nutrient leaching or decreased biodiversity. Modern agroforestry systems offer an alternative agro-ecological approach to a sustainable intensification of concomitant food/forage/energy crop and wood production.

Therefore, the combined effect of tree/grassland sward competition and different grassland management treatments in a silvopastoral agroforestry system on biomass yields has been investigated. The system combines grassland and short rotation coppice (SCR) in an alley cropping design. The grassland biomass is used for food or energy production and the willows (Salix spp.) are used as SRC for energy production. In the present paper the biomass yields of the agroforestry system obtained in 2016 are shown and further research aims are outlined.

Materials and methods

The agroforestry system has been established in March 2011 and is located in Lower Saxony, Germany (51°23´56´´N and 9°59´13´´E, 327 m a.s.l.). It covers an area of approximately 1.3 hectare (Ehret et al. 2015a). The climate is characterized as temperate with an average temperature of 9.2 °C and a mean annual precipitation of 642 mm over a 20-year period. The predominant soil type is classified as a stagnosol according to the FAO World Reference of Soil

Resources (2006) and consists of sedimentary deposits from sandstone, siltstone and claystone (Hartmann et al. 2014).

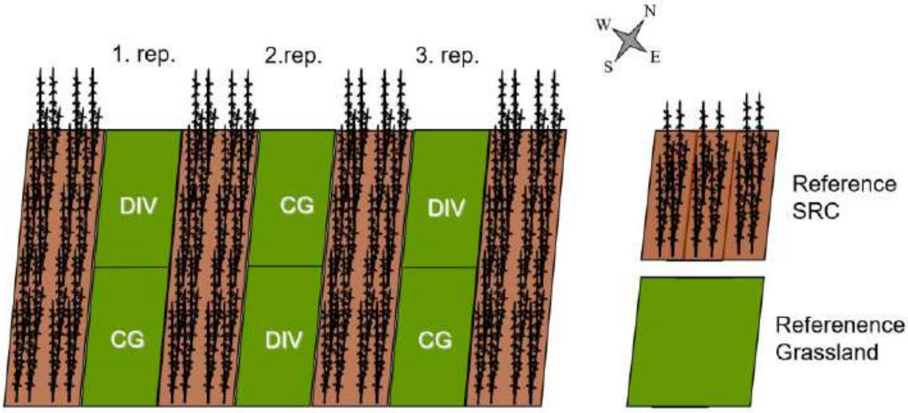


Figure 1: Alley cropping design with different grassland types (CG=clover-grass; Div=Diversity mixture) and willow stripes as short-rotation coppices (SRC), 3 replicates (rep.).

The system consists of alternating, 80-meter-long rows of willow and grassland strips each in a threefold repetition. Each tree strip consists of four double rows of willows (eight willow rows total). Alternating inter-row distances were 0.75 and 1.5 m, with a within-row spacing of 0.75 m, to yield a planting density of 12 000 trees per hectare (Ehret et al. 2015a). The grassland strips are 9-meter-wide and cultivated with two different seed mixtures, clover-grass (CG) and a biodiversity mixture containing 32 herbaceous species (DIV). Different management strategies include an extensive (2 cuts per year) and intensive (4 cuts per year) management of both grassland types. The grassland strips alternate with 7-meter-wide strips of willow hybrid ((*Salix viminalis x Salix Schwerinii*) x *Salix viminalis* = breeding Tora x Z. Ulv), which are characterized by their bushy growth making this willow variety particularly suitable for SRC (Figure 1). The trees have a rotation period of 3-4 years and the first willow harvest was in winter 2014/2015. Thus, in the growing period of 2016 the willows aged 2 years on 5-year-old stools.

The effects of different management strategies on grassland biomass yields, -quality and above ground matter fluxes are measured as a function of distance to trees along a transect. It comprises five transect points (TPs) in the grassland stripes among the willow alleys in each treatment. TP 1 and 5 are located in the edge regions of the grassland, 1 m distant from willow strips. The remaining TPs are equally distributed between them. All statistical analyses have been performed in R. For each treatment a two-sampled-t-test has been performed to investigate the difference in the means of annual biomass yields. The variance of biomass yields at each transectpoint was tested using a pairwise-t-test. As an additional parameter the composition of plant functional groups (grasses, herbs, legumes) is recorded.

The annual DM growth of willows is estimated by an allometric functions based on diameter increment at breast height (1.30 m) and their associated DM yield. A non-linear least squares model was used to fit both parameters for 25 sampled shoots. The model was used to predict the DM yield of 68 trees with 284 shoots in total. Subsequently the total annual DM yield per hectare was calculated based on the mean stool method after Hytönen et al. (1987). Pure willow and grassland stands of each treatment serve as location specific reference value.

Results

The biomass yields of grassland sampling for the growing season 2016 are shown in Figure 2a. The DM yields of all treatments were lower in the agroforestry system compared to the usual grassland yields without influences of trees at this location. The 3-cut-system in the agroforestry yielded 9 t DM ha^{-1} for CG and 6.9 t DM ha^{-1} for DIV. The DM yield of the 2-cut-system was with 6.3 t DM ha^{-1} for CG and 6 t DM ha^{-1} for DIV lower (Figure 2a). In comparison, the yield of pure grassland stands of each treatment (3-cut) measured at this location reached 12.7 t DM ha^{-1} for

CG and 9 t DM ha^{-1} for DIV. The 2-cut-system produced 8.9 t DM ha^{-1} for CG and 10.7 t DM ha^{-1} for DIV.

A detailed analysis of the biomass yields at the single TPs (Figure 2b) showed the lowest biomass values close to the trees (TP 1 and 5). Simultaneously, the composition of plant functional groups changed with decreasing distance to trees (Figure 2c), particularly in the 3-cut-system, where the fraction of legumes also decreased with decreasing distance to trees, while the share of grasses increased.

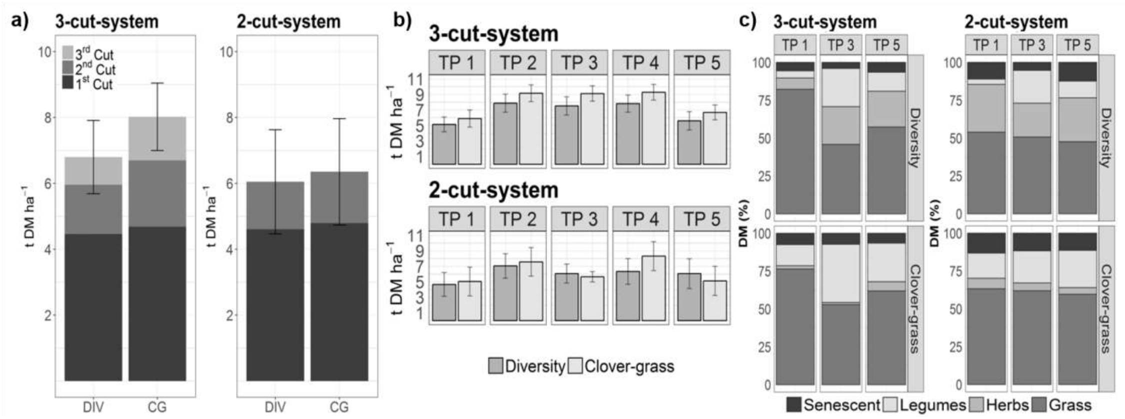


Figure 2: a) Annual biomass yield per cut for different grassland mixtures (DIV=diversity mixture; CG=clover-grass) and cutting regimes in the agroforestry system, b) annual biomass yield of treatments at TPs and c) fractions of plant functional groups at selected TPs.

The average tree height across all tree strips was 3.69 m with a mean Diameter at Breast Height (DBH) of 1.3 cm. The DM yield of woody willow biomass was estimated with 15.7 t DM ha^{-1} in 2016, the second year of the second rotation.

Discussion and outlook

The observed changes in the composition of plant functional groups along the transect can most likely be explained by shading of the grassland from trees. This assumption is consistent with findings of Ehret et al. (2015b), who showed that an increasing shading of grassland results in decreasing biomass production of herbs and legumes. The extensive managed grassland seems to benefit from this shading effect as the biomass yields are lower in areas where no shadow influenced the grassland (TP 3) then on the partially shaded areas (TP 2 and 4). The reason for that might be related to the relatively dry climatic conditions in 2016 with a strong drought period during early summer. Even though these assumptions cannot be validated statistically for 2016 the analyses will be extended by the integration of multitemporal yield data. Further analysis are planned to test the hypotheses of shading and water availability on grassland biomass yield based on illumination data derived from canopy models and soil moisture information at TP 1 and 3. During the first rotation period the agroforestry-system showed no significant economic benefits compared to conventional systems, which was expected due to the short-term establishment of the system (Ehret et al. 2016) and poor growth conditions with severe dryness during the establishment of the agroforestry-system. The productivity of the system seemed to be higher during the second rotation: the yield of the willow biomass was in 2016 higher compared to the woody biomass yield after the first rotation (2011-2015). Further research activities will use these parameters for the calculation of energy balances and the evaluation of further utilization paths. Once the data acquisition is concluded an agronomic assessment of the agroforestry system for a period of six years will be realised. Additionally, an agronomic assessment of woody biomass will be tested using a 3-D-data modelling approach based on terrestrial lidar scans.

Acknowledgement

This work is part of the research project “SIGNAL” (“Sustainable Intensification of Agriculture through Agroforestry”) funded by the Federal Ministry of Education and Research (BMBF).

References

Ehret M, Bühle L, Graß R, Lamersdorf N, Wachendorf M (2015a) Bioenergy provision by an alley cropping system of grassland and shrub willow hybrids: biomass, fuel characteristics and net energy yields. Agrofor Syst 89: 365–381.

Ehret M, Graß R, Wachendorf M (2015b) The effect of shade and shade material on white clover/perennial ryegrass mixtures for temperate agroforestry systems. Agrofor Syst 89: 557–570.

Ehret M, Graß R, Wachendorf M (2016) Productivity at the tree-crop interface of a young willow-grassland alley cropping system. Agrofor Syst 92: 71–83.

FAO World Reference of Soil Resources (2006) http://www.fao.org/3/a-a0510e.pdf (accessed 24/04/2018).

Hartmann L, Richter F, Busch G, Ehret M, Jansen M, Lamersdorf N (2014) Establishment of short rotation coppices in the South of Lower Saxony and in Central Thuringia in the context of the BEST-research framework—Site characteristics and initial biomass production. Forstarchiv 85: 134–150.

Hytönen J, Lumme I, Törmälä T (1987) Comparison of methods for estimating willow biomass. Biomass 14: 39–49.

DOES TREE DENSITY OR FERTILISATION IN SILVOPASTORAL SYSTEMS AFFECT TREE OR PASTURE PRODUCTION?

Mosquera-Losada MR[1*], Arias-Martínez D[1], Rigueiro-Rodríguez A[1], Ferreiro-Domínguez N[1, 2]

(1) Department of Crop Production and Engineering Projects, Escuela Politécnica Superior de Lugo, University of Santiago de Compostela, Campus Universitario s/n, 27002 Lugo, Spain (2) Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda s/n, 1349-017 Lisbon, Portugal

*Corresponding author: mrosa.mosquera.losada@usc.es

Abstract

Silvopastoral systems with high value timber trees are profitable due to the combination of long term high value timber tree production (over 4,000 € ha^{-1}) and the continuous meat production. Tree and pasture production depends on tree density and can be improved by the use of fertilisers, either organic or inorganic. Organic fertilisers, such as sewage sludge, can support agroforestry systems due to its high nutrient and organic matter contents if adequate doses are applied. This study aims at evaluating the effect of an initial sowing of pasture and plantation of two different tree densities fertilised with different types of organic fertilisers. Tree density did not affect tree growth probably due to the lack of competition at initial ages, being effective coppicing when frosts damaged the trees. Pasture production was improved by the different treatments depending on the limiting factor (fertility or water availability).

Keywords: sewage sludge, walnut, compost, pelletisation anaerobic digestion

Introduction

Sewage sludge (SS) has agronomic properties that make it suitable to use in agriculture as fertiliser as long as it is established before spreading and its heavy metal concentrations are below regulated limits (EU 1986). The main forms of stabilisation and processing the SS are aerobic digestion, anaerobic digestion and compost followed or not by pelletisation in the first two cases (Mosquera-Losada et al. 2010).

Silvopastoral practices and systems have great advantages as they increase biodiversity, enhance nutrient-use efficiency and increase carbon sequestration (Rigueiro-Rodríguez et al. 2009). Nevertheless, pasture production and tree growth may be affected, if adequate species are not used and if they are not planted in the right density for the farmer aims (Mosquera-Losada et al. 2011).We evaluated the tree growth and the productivity of a sown pasture in a *Junglans regia* L. silvopastoral system established in three treatments (open pasture (NT) and two tree densities 277 (LD) and 625 (HD) trees ha^{-1}) and fertilized with three differently stabilised SS (anaerobic, composted and pelletised) and two control treatments (no fertilisation and mineral fertilisation).

Materials and methods

This study was carried out in A Mota (Boimorto, A Coruña, Spain) on a plantation of *Juglans regia* L. managed by the Bosques Naturales company. In 2013, the plantation was established at low (LD: 277 trees ha^{-1}) and high tree density (HD: 625 trees ha^{-1}) and the plot was sown with *Dactylis glomerata* L., *Lolium perenne* L. and *Trifolium repens* L.

The experimental design was randomized blocks, with three replicates and five fertilisation treatments per each tree density which consisted of no fertilisation (NF), mineral fertilisation (MIN) with 500 kg of 8% N – 24% P_2O_5 – 16% K_2O ha^{-1} and fertilisation with anaerobic (ANA), composted (COM) and pelletised (PEL) SS (320 kg total N ha^{-1}) applied before tree planting. Mineral fertiliser was also applied in 2015, 2016 and 2017. The plots were grazed by sheep in a continuous stocking system.

Tree height was estimated with a measuring tape in April and December 2013, in January 2015 and in March 2016. Pasture production was determined by taking several samples of pasture per plot within an exclusion cage of 1 m^2 from 2014 to 2017. The samples were weighed in fresh in the field and a sub-sample was taken to the laboratory, weighed and dried (48 hours at 60ºC) and weighed again to determine the dry matter production. Pasture production was calculated without discounting the area occupied by the trees (NT) and taking into the area occupied by the trees established at high (HD) and low density (LD).

The data were analysed using ANOVA (proc glm procedure). Means were separated by using LSD test if ANOVA was significant (SAS 2001).

Results and discussion

Tree height was significantly affected by the year ($p<0.001$) and by the interaction year*tree density ($p<0.01$). Nevertheless, there were no significant differences between tree densities because the wide spacing used in these agroforestry systems allows trees to grow up without competition among them after plantation (Cabanettes et al. 1998).

Under each tree density, there were significant differences among years ($p<0.001$), mainly explained by the coppicing made in April 2014, but with a rapid recover of tree height in the following years (Figure 1) probably due to the already well developed root system in the soil after cutting. Walnut coppicing could be a good technique when frost damages trees after establishment.

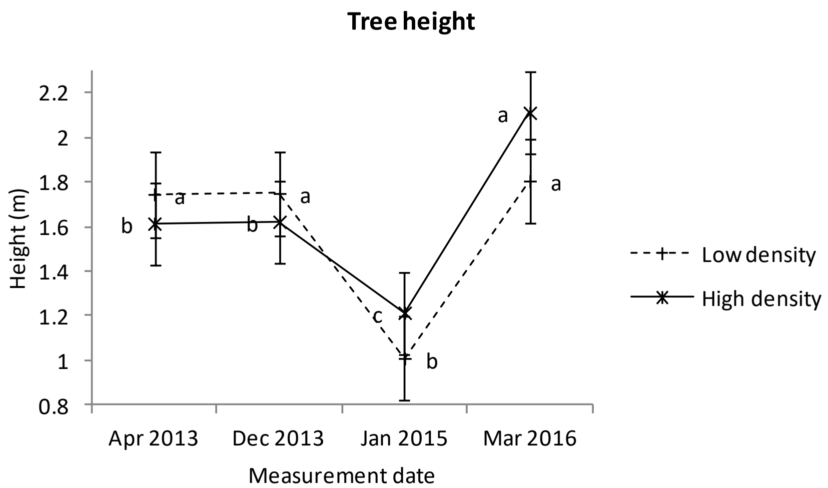


Figure 1: Tree height in each tree density during the study period. Different letters indicate significant differences between dates within each tree density.

Pasture production obtained under NT and LD treatments was similar in all evaluated harvests (Figure 2) with the exception of those happened at the beginning of the study, and when the meteorological conditions where improved (May 2015) ($p<0.05$). This could be explained by the initial better pasture establishment of those plots developed on open sites and with low tree density. Pasture production was always higher under NT compared with HD treatment, which could be explained because the reduction of pasture area was small (1 part for tree out of 6 parts of land use) and compensated by the heterogeneity of the land. .

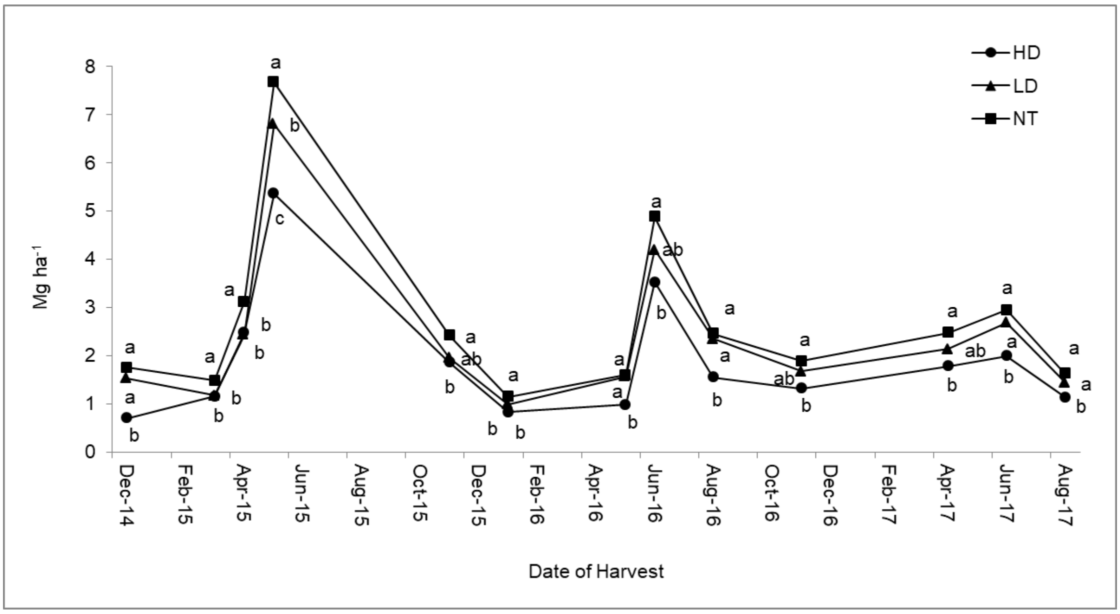


Figure 2: Pasture production (Mg dry matter ha^{-1}) in all treatments under open area (NT), low tree density (LD) and high tree density (HD). Different letters indicate significant differences between tree densities in each harvest.

Pasture production was modified by weather conditions, the long dry period in 2016 and the exceptional duration of the drought period happened during 2017 reduced significantly the production as the time came through. The reduction of the residual effect of fertilisation also explained the lower production of 2017 compared with 2016 and 2015. Pasture production of this study was similar to pasture production estimated by Mosquera-Losada et al. (2011) in a similar area.

When the mean pasture production in each treatment was considered, only April 2015, November 2015 and May 2016 had significant differences between treatments ($p<0.05$) (Figure 3). In April 2015, pasture production was higher in COM than in NF, ANA and PEL probably because COM implies higher inputs of organic matter that may reduce the negative effect of drought (Mosquera-Losada et al. 2010). However, in November 2015 NF plots had a higher production due to the higher pasture density and vascular plants biodiversity. Finally, in May 2016, pasture production was increased by PEL SS inputs compared with the other treatments, probably because PEL was applied every year and nitrogen was not leached (Mosquera-Losada et al. 2010).

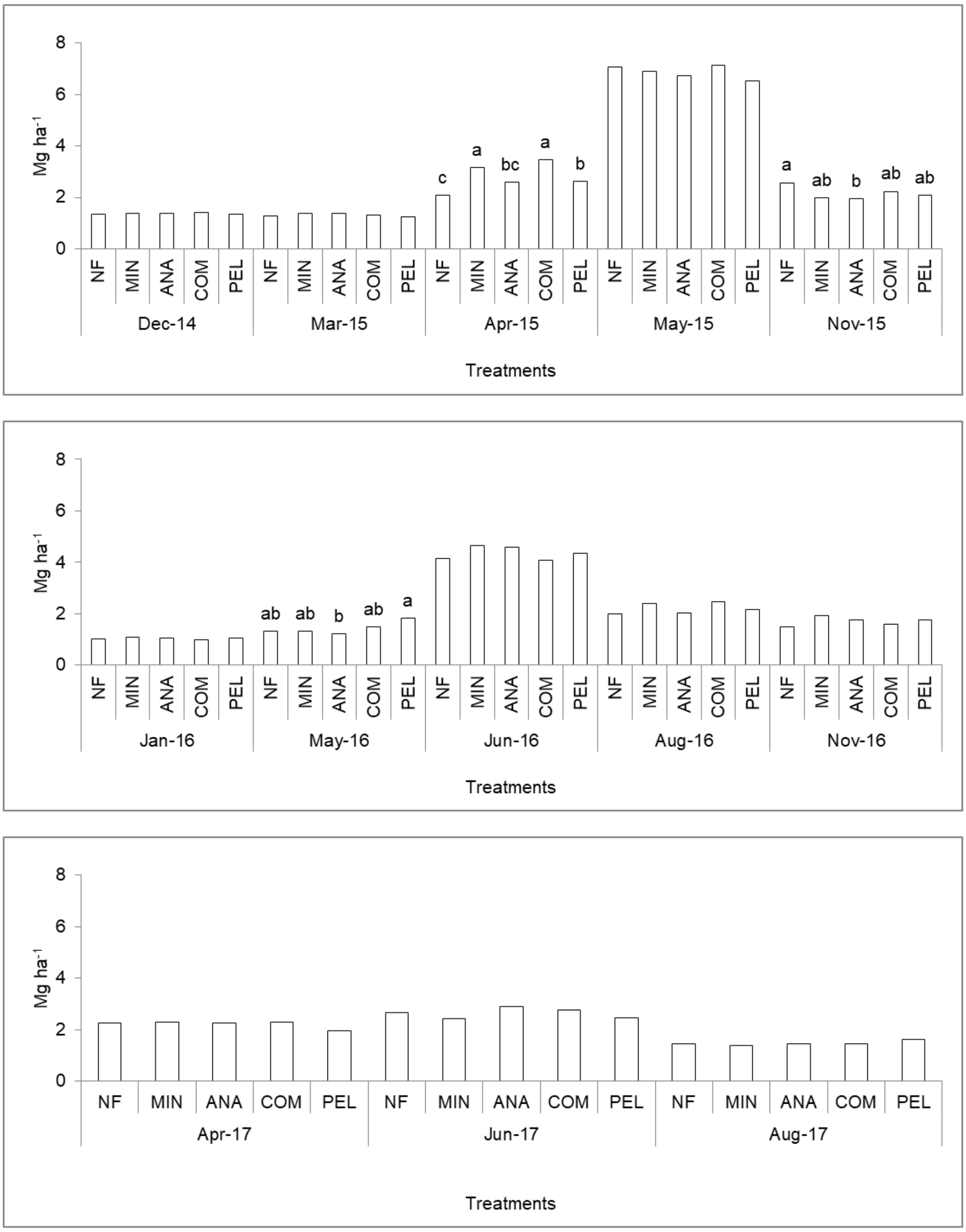


Figure 3: Mean pasture production (Mg dry matter ha^{-1}) in each treatment and in all harvests. NF: no fertilisation, MIN: mineral; ANA: anaerobic sludge; COM: composted sludge and PEL: pelletised sludge. Different letters indicate significant differences between fertiliser treatments in each harvest.

Conclusion

Walnut tree growth was not affected in young plantations, being effective coppicing when frosts damaged the trees. Pasture production was improved by the different treatments depending on the limiting factor (fertility or water availability). When the area occupied by the trees is discounted, pasture production was not affected by trees planted at low density at young ages, but the amount of land discounted with high density reduced pasture production.

The limitation of 100 trees per hectare in Regulation 640/2014 (EU 2014) should consider the age of the trees and be referred to mature trees, as no pasture production reduction was found when density is over 200 trees per hectare, in spite of discounting one out six parts of the territory to estimate production.

Acknowledgements

We are grateful to XUNTA DE GALICIA (Consolidation funds and Consellería de Cultura, Educación e Ordenación Universitaria ("Programa de axudas á etapa posdoutoral DOG nº122, 29/06/2016 p.27443, exp: ED481B 2016/0710")) and Bosques Naturales company (https://bosquesnaturales.com/).

References

Cabanettes A, Auclair D, Imam W (1998) Diameter and height growth curves for widely-spaced trees in European agroforestry. Agroforst Syst 43:169–181.

EU (1986) Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31986L0278 (accessed 13/05/2018).

EU (2014) Commission Delegated Regulation (EU) No 640/2014 of 11 March 2014 supplementing Regulation (EU) No 1306/2013 of the European Parliament and of the Council with regard to the integrated administration and control system and conditions for refusal or withdrawal of payments and administrative penalties applicable to direct payments, rural development support and cross compliance. https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32014R0640 (accessed 13/05/2018).

Mosquera-Losada MR, Muñoz-Ferreiro N, Rigueiro-Rodríguez A (2010) Agronomic characterisation of different types of sewage sludge: Policy implications. Waste Manag 30:492–503.

Mosquera-Losada MR, Morán-Zuloaga D, Rigueiro-Rodriguez A (2011) Effects of lime and sewage sludge on soil, pasture production, and tree growth in a six-year-old Populus canadensis Moench silvopastoral system. J Plant Nutr Soil Sci 174:145–153.

Rigueiro-Rodríguez A, Fernández-Núñez E, González-Hernández P, McAdam JH, Mosquera-Losada MR (2009) Agroforestry Systems in Europe: Productive, Ecological and Social Perspectives. In: Rigueiro-Rodríguez A, McAdam JH, Mosquera-Losada MR (eds) Agroforestry in Europe: Current Status and Future Prospects. Springer, pp 43–65.

SAS (2001) SAS/Stat User's Guide: Statistics. SAS Institute Inc., Cary, NC, USA.

TEMPERATE AGROFORESTRY: YIELD OF FIVE KEY ARABLE CROPS NEAR TREE ROWS OF *POPULUS x CANADENSIS*

Pardon P[1, 2, 3]*, Reubens B[3], Mertens J[1, 4], Verheyen K[1], De Frenne P[1, 2], Van Waes C[3], Reheul D[2]

(1) Department of Environment, Ghent University, Geraardsbergsesteenweg 267, 9090 Gontrode, Belgium (2) Department of Plants and Crops, Ghent University, Coupure Links 653, 9000 Ghent, Belgium (3) Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Burgemeester Van Gansberghelaan 109, 9820 Merelbeke, Belgium (4) Department of Applied Biosciences, Ghent University, Valentin Vaerwyckweg 1, 9000 Ghent, Belgium

*Corresponding author: paul.pardon@ugent.be

Abstract

Agroforestry systems (AFS) are considered to be a sustainable agricultural practice. However, at present, yield and quality data on arable crops in temperate AFS are scarce. Here we assessed the influence of tree rows of contrasting age on the yield and quality of key western European arable crops. Both tree age and crop type were key determinants of yield and quality of the arable crops. Substantial yield reductions were observed near mature trees, in particular for maize and potato. Effects on crop quality were limited, with substantial effects only arising near the oldest tree rows. To optimize the provisioning service of AFS, the cultivation of winter cereals may be advisable over maize and potato towards the end of the rotation of an AFS.

Keywords: alley cropping; maize; potato; winter cereals; poplar; mixed farming

Introduction

In temperate regions, interest in agroforestry has recently been growing (Borremans et al. 2016; Gillespie et al. 2000; Jose et al. 2004; Nair 2007) because it is considered as a sustainable agricultural practice that combines primary production with other ecosystem services (ES) (Torralba et al. 2016). However, in large parts of temperate Europe, implementation of agroforestry remains rather limited (Reisner et al. 2007; Rigueiro-Rodríguez et al. 2009). Besides uncertainties on the legislative and economic level (Borremans et al. 2016), this might result from a lack of actual quantification of the impact of the tree component on the yield and quality of the intercrop. The goal of the present research is to quantify these impacts for the agricultural crops most commonly cultivated in Western Europe, while focusing on arable alley cropping systems with poplar (*Populus x canadensis)* of different age classes.

Materials and methods

Two types of experimental fields (on-farm) were selected to investigate differences in crop performance for varying stages of tree maturity (Figure 1, Table 1). This set comprised six young alley cropping fields (age 2-7 yrs). Since older arable alley cropping systems in Flanders are scarce, a set of 11 common arable fields that are bordered by a tree row was selected as a proxy (age 48 yrs). The latter type of fields are further referred to as “boundary planted fields”. Following criteria were used for selection of these fields:

- Orientation of the tree row: (approximately) North-South
- Tree species: *Populus x canadensis*
- Tree rows are of homogenous age at field level but with varying age among the different fields

- Absence of headland next to the tree row
- Part of the field is not bordered by the tree row
- Soil type: loam or sandy loam

The differences in tree-size among the fields allowed to study the effect on crop yield for different stages in the rotation of an agroforestry system. The treeless parts of these fields hereby acts as a reference situation. On each field transects were laid out perpendicularly to both the tree row and the treeless border (# three and two transects respectively). In each transect, five measuring points were marked, located at distances 2 (“A”), 5 (“B”), 10 (“C”), 20 (“D”) and 30 (“E”) m away from the field edge. This allowed to study possible gradients as a function of distance to the tree row. On the alley cropping fields, three transects were laid out between and perpendicular to both selected tree rows (Figure 1). In each transect, six sampling plots were marked, the centre of which was located at distances 2 (“F”), 5 (“G”) and 12 (“H”) m from the closest tree row. In each plot, yield and quality measurements were conducted during three consecutive years (2015-2017). Sampled crops include winter wheat (*Triticum aestivum* L.), winter barley (*Hordeum vulgare* L.), forage maize (*Zea mays* L.), grain maize and potato (*Solanum tuberosum* L.). Linear mixed effects models were used to investigate differences in crop yield and quality.

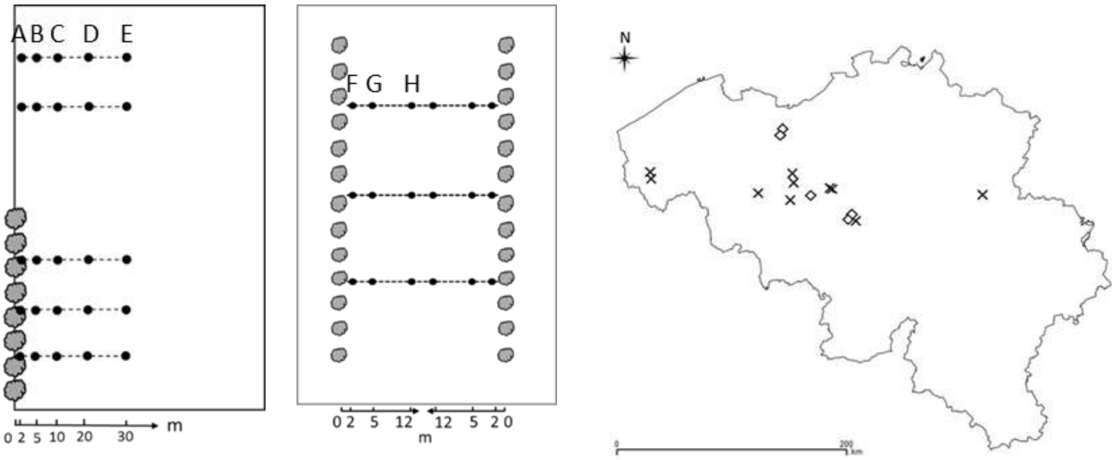


Figure 1: Experimental design. Left: boundary planted fields, middle: alley cropping fields, dots represent measuring locations. Right: Location of experimental fields in Belgium (x boundary planting, ◊ alley cropping).

Table 1: Characteristics of experimental fields. Year of plantation was estimated based on pers. comm. with farmer and/or tree coring. “Orientation”: orientation of tree alleys (EW: East-West, NS: North-South). “Exposition”: location of sampling field with regard to tree row. “NA”: no samples collected in this field.

ALLEY CROPPING					
Location	Year of plantation	Orientation	Crop 2015	Crop 2016	Crop 2017
Lochristi 1	2011	EW	Forage maize	Winter wheat	Forage maize
Lochristi 2	2011	EW	Forage maize	Forage maize	Potato
Lochristi 3	2012	EW	Winter wheat	Forage maize	Maize
Vollezele	2010	NS	Winter barley	Potato	Winter wheat
Haut-Ittre 1	2011	NS	Winter wheat	Winter wheat	Potato
Haut-Ittre 2	2011	NS	Grain maize	Winter wheat	Winter wheat
BOUNDARY PLANTING					
Location	Estimated year of plantation	Exposition	Crop 2015	Crop 2016	Crop 2017
St P. Leeuw 1	2001	West	Maize	NA	NA
St P. Leeuw 2	2001	West	Winter wheat	Forage maize	Winter wheat
Haut-Ittre 1	2000	East	Winter wheat	Cichory	Winter wheat
Haut-Ittre 2	2000	East	NA	Cichory	NA
Maarkedal	1998	West	Maize	Maize	Potato
Tongeren	1998	East	Winter wheat	Forage maize	Winter wheat
Ieper 1	1985	West	Maize	Maize	Pea
Geraardsbergen	1988	West	Winter barley	NA	NA
Herzele	1977	East	Forage maize	Winter wheat	Forage maize
Steenhuize	1985	East	Forage maize	Winter wheat	Forage maize
Ieper 2	1969	East	Winter barley	Maize	Potato

Results

Clear effects of tree row presence on yield of intercrops were observed as function of distance to the tree rows. The magnitude of these effects was however strongly dependent on both the size of the trees and the specific intercrop (Figure 2). The effects appeared to be most pronounced if (forage) maize was grown, in particular on fields with mature tree rows, whereas only limited effects were observed in case of winter barley. On the old boundary planted fields, the impact on crop yield appears to extent to ca. 30m into the field where yield-levels equal values observed in the control part of the fields.

Discussion

The substantial differences in crop response are assumed to be primarily related to the differences in growing season between the different types of crops and the consecutive differences in overlap with the growing season of the trees (Artru et al. 2017). Our results demonstrate that tree-impact on yield of winter cereals, maize and potato remains limited during the first six to seven years after tree establishment. However, if possible, a modified crop rotation may be recommended as trees mature to limit yield losses due to tree-crop competition. In practice, this implies a shift to a rotation dominated by winter cereals.

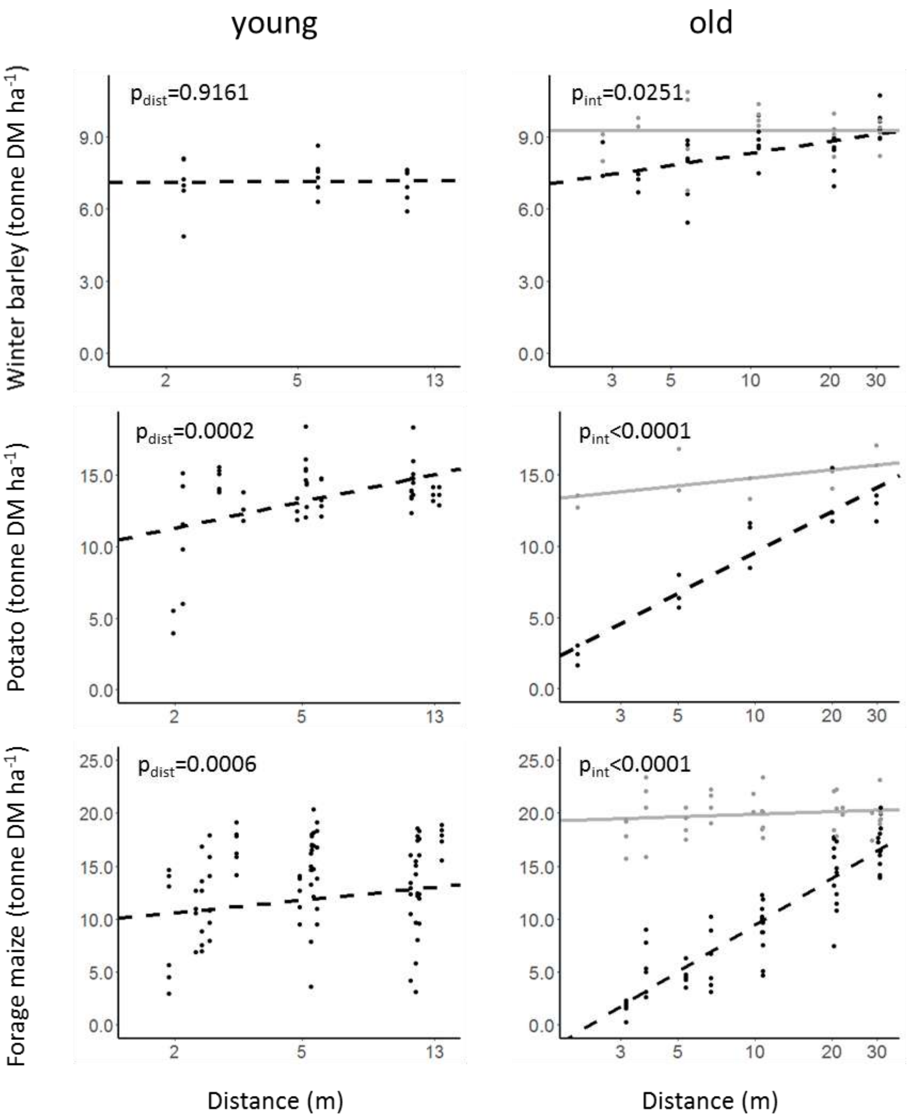


Figure 2: Effect of crop type and tree age on intercrop (tonne DM ha^{-1}) yield of winter barley, potato and forage maize. "$p_{dist.}$" indicates significance of distance to the tree row on young alley cropping fields (2-7 yrs). "$p_{int.}$" indicates significance of interaction between distance to the tree row and tree row presence on old boundary planted fields (27-48 yrs). Black (dashed): tree row, grey: treeless field edge.

Outlook

Future analysis will focus on further elaboration of crop yield results and associated quality parameters.

Acknowledgments

This research is executed within the framework of the project Agroforestry in Flanders, funded by Flanders Innovation & Entrepreneurship (VLAIO).

References

Artru S, Garré S, Dupraz C, Hiel MP, Blitz-Frayret C, Lassois L (2017) Impact of spatio-temporal shade dynamics on wheat growth and yield, perspectives for temperate agroforestry. Eur J Agron 82: 60–70.

Borremans L, Reubens B, Van Gils B, Baeyens D, Vandevelde C, Wauters E (2016) A Sociopsychological Analysis of Agroforestry Adoption in Flanders: Understanding the Discrepancy between Conceptual Opportunities and Actual Implementation. Agroecol. Sustain. Food Syst 40: 1008–1036.

Gillespie AR, Jose S, Mengel DB, Hoover WL, Pope PE, Seifert RJ, Biehle DJ, Stall T, Benjamin TJ (2000) Defining competition vectors in a temperate alley cropping system in the midwestern USA; 1. Production physiology. Agroforst Syst 48: 25–40.

Jose S, Gillespie AR, Pallardy SG (2004) Interspecific interactions in temperate agroforestry. Agroforst. Syst 61: 237–255.

Nair PKR (2007) The coming of age of agroforestry. J Sci Food Agric 87: 1613–1619.

Reisner Y, de Filippi R, Herzog F, Palma J (2007) Target regions for silvoarable agroforestry in Europe. Ecol Eng 29: 401–418.

Rigueiro-Rodríguez A, McAdam J, Mosquera-Losada MR (2009) Agroforestry in Europe Current Status and Future Prospects, 6th ed. Springer.

Torralba M, Fagerholm N, Burgess PJ, Moreno G, Plieninger T (2016) Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. Agric Ecosyst Environ 230: 150–161.

MEDITERRANEAN SILVOARABLE SYSTEMS FOR FEED AND FUEL: THE AGROFORCES PROJECT (AGROFORESTRY FOR CARBON SEQUESTRATION AND ECOSYSTEM SERVICES)

Pecchioni G[1*], Mantino A[1], Bosco S[1], Volpi I[1], Giannini V[1], Dragoni F[1], Tozzini C[1], Coli A[3], Mele M[2, 3], Ragaglini G[1]

(1) Institute of Life Sciences, Sant'Anna School of Advanced Studies, Pisa, Italy (2) Department of Agriculture, Food and Environment (DAFE), University of Pisa, Pisa, Italy (3) Centro di Ricerche Agro-Ambientali Enrico Avanzi (CIRAA), University of Pisa, San Piero a Grado, Pisa, Italy

*Corresponding author: g.pecchioni@santannapisa.it

Abstract

In a silvoarable systems designed for Mediterranean lowlands with water availability, poplar SRF (Short Rotation Forestry) for biomass production has been intercropped with forage species. In this study, we want to investigate poplar and forage crops suitability to alley-cropping, to assess soil carbon balance, to assess the tree-presence effect in competing for light, to set-up remote sensing techniques with UAVs (Unmanned Aerial Vehicles). Starting from 2018, we will collect data on forage and SRF poplar biomass production. The carbon balance will be calculated by the difference between carbon inputs (aboveground and belowground biomass) and carbon outputs (soil CO_2 efflux measurements). Competition for light will be studied taking hemispherical photographs according to a regular grid, to design maps of transmittance. Starting from emergency stage, we will perform flights with a drone in order to get multispectral images to study the canopies development, selecting the better performing vegetation indexes.

Keywords: silvoarable systems; forage crops; short-rotation forestry; poplar; shade tolerance; carbon balance

Introduction

In the last sixty years, trees have been progressively removed from arable lands because they were seen as an obstacle to productivity, even if they provide ecosystem services which can ensure soil fertility and soil carbon storage in the long term, coping with the goal of sustainable intensification (Quinkenstein et al. 2009). Silvoarable systems bring back trees into croplands, being low-input strategies which can improve nutrients and water cycles, reduce soil erosion and fertility loss, contributing to carbon sequestration. In the case of alley-cropping, herbaceous crops are grown within tree rows (Gruenewald et al. 2007). Innovative alley-cropping systems could be attractive to farmers if designed for bioenergy feedstock production together with forage production, thus providing a diversified income. In Mediterranean lowlands, where water is not a limitant factor, poplar SRF (Short Rotation Forestry) for biomass production could be intercropped with perennial forage species under rainfed conditions. The candidate herbaceous species should be shade-tolerant and overcome competition with trees by taking advantage of the inter-cropping facilitations such as evapotranspiration decrease (Pang et al. 2017).

Alternative land uses such as alley-cropping systems are considered as management practices that conserve and potentially increase soil carbon stocks (Shrestha et al. 2016). Thus, pushing on finding evidences that agroforestry could ensure not only a diversified income but also an economical return for farmers in terms of land value in the long term. Based on this, studying the C cycle dynamics in silvoarable systems as well as soil quality and agricultural GHG emissions should become a priority for researchers in present days.

General objectives

In this research, we want to assess the productivity and the carbon storage potential of several tree-crop combinations suited for agroforestry systems.

Specific objectives

In particular, we want: (i) to investigate poplar and forage crops suitability to alley-cropping, measuring yield and biomass quality for both; (ii) to assess soil carbon balance on different tree-crop combinations; (iii) to assess the tree-presence effect in terms of competition for resources such as light and nutrients. In addition, we want to set-up remote sensing techniques with UAVs (Unmanned Aerial Vehicles), aiming to collect data (e.g. vegetation cover indexes) for implementing GIS-based assessment of the whole agroforestry system.

Materials and methods

In a former poplar SRF plantation, four rows out of five were destroyed in order to have 13,5 m wide per 30 m long plots in the alleys (Figure 1). Plots were sown with two perennial grasses (*Panicum virgatum* L. and *Dactylis glomerata* L.), two perennial legumes (*Medicago sativa* L. and *Hedysarum coronarium* L.) and the two mixtures *P. virgatum* and *H. coronarium*, *D. glomerata* and *M. sativa*. Each forage system was replicated three times in a randomized blocks design. The open field controls were established in 2.5 x 6 m plots outside the alleys, in which the six forage systems were replicated three times. Moreover, five former poplar SRF rows were left with the previous layout, with a density of 7400 plants per hectare.

Starting from the 2018, we will collect data on forage biomass production at each harvest time and we will measure biometric parameters. Poplar SRF will be managed according to a two-year cutting cycle both in the alley system and in the control stand (Nassi o Di Nasso 2010).

The carbon balance will be calculated by the difference between carbon inputs and carbon outputs (Heinemeyer et al. 2012). Carbon inputs will be assessed measuring poplar litter, biomass residuals after mowing and belowground biomass (roots and rhizomes). Carbon outputs will be measured via soil CO_2 efflux measurements. We will apply the chamber method, in which an infra-red gas analyzer (IRGA) with a closed chamber will be placed on a PVC collar fixed in the soil. A PVC collar alone will measure total soil respiration, while the former PVC collar inserted in a PVC cylinder for excluding roots will measure heterotrophic respiration. The chamber method will be applied on three forage systems for three positions, varying according to the distance from the poplar row. Together with flux measurements, soil temperature and soil water content will be recorded (Lai et al. 2017).

Competition for light will be studied on three alfalfa varieties, taking hemispherical photographs in the understory according to a regular grid, to design maps of transmittance (Chianucci et al. 2013).

Monthly, starting from emergency stage, we will perform a flight with a drone in order to get multispectral images to study the canopies development, selecting the better performing vegetation indexes.

Figure 1: Plots within poplar SRF rows at the end of summer, after rotary harrowing and before sowing. Poplar stems are 6 months old, while the whole poplar stand is 8 years old. Stumps distance is 0.5 m within the row.

Expected results

We want to assess the productivity of forage systems in agroforestry, studying their adaptability to shading and competition for water and nutrient.

From this field experiment we expect to obtain a series of evidences about sustainability of alley cropping systems especially in terms of soil carbon storage. We expect to build datasets on crops' growth with remote sensing and to prove the economical feasibility and convenience of agroforestry systems.

References

Chianucci F Cutini A (2013) Estimation of canopy properties in deciduous forests with digital hemispherical and cover photography. Agr Forest Meteorol 168: 130-139.

Gruenewald H Brandt BKV Schneider U Bensa O Kendziab G Huttl RF (2007) Agroforestry systems for the production of woody biomass for energy transformation purposes. Ecol Eng 29: 319-328.

Heinemeyer A Tortorella D Petrovicova B Gelsomino A (2012) Partitioning of soil CO2 flux components in a temperate grassland ecosystem. Eur J Soil Sci 63: 249-260.

Lai R Arca P Lagomarsino A Cappai C Seddaiu G Demurtas CE Roggero PP (2017) Ecological benefits of the alley cropping agroforestry system in sensitive regions of Europe. Catena 151: 202-212.

Nassi o di Nasso N Guidi W Ragaglini G Tozzini C Bonari E (2010) Biomass production and energy balance of a 12-year-old short-rotation coppice poplar stand under different cutting cycles. Gcb Bioenergy 2: 89–97.

Pang K Van Sambeek JW Navarrete-Tindall NE Lin CH Jose S Garrett HE (2017) Responses of legumes and grasses to non-, moderate, and dense shade in Missouri, USA. I. Forage yield and its species-level plasticity. Agrofororest Syst DOI 10.1007/s10457-017-0067-8.

Quinkenstein A Wollecke J Bohm C Gruenewald H Freese D Schneider BU Huttl RF (2009) Ecological benefits of the alley cropping agroforestry system in sensitive regions of Europe. Environ Sci Pol 12: 1112-1121.

Shrestha P Seiler JR Strahm BD Sucre EB Leggett ZH (2016) Soil CO2 Efflux and Root Productivity in a Switchgrass and Loblolly Pine Intercropping System. Forests 7: 221 DOI 10.3390/f7100221.

INTERACTIONS BETWEEN TREES, CROPS AND ANIMALS: EXPERIENCES IN A NOVEL BIOENERGY-LIVESTOCK SYSTEM IN THE UK

Smith J[1*], Deremetz V[1, 2], Gerrard C[1], Costanzo A[1]

(1) Organic Research Centre, Newbury, UK. (2) IUT Amiens, France

*Corresponding author: jo.s@organicresearchcentre.com

Abstract

Managing the interactions between trees, crops and animals is an on-going challenge for agroforestry farmers. This paper reports on interactions between trees, crops and both wild animals and livestock in the establishment years of a novel UK agroforestry system combining short rotation coppice for energy production with livestock production. Our trials suggest that in the first six years there is no significant impact of trees on the alley crops (pasture and whole crop oat silage) in this system. Protecting the trees from livestock damage is essential in the early years; with cattle, our results show that it this is possible using a single stranded electric fence. Patterns of biodiversity varied between taxa; earthworm abundances were higher in the tree rows, which represent an undisturbed stable habitat, while the more active ground beetles were in greater abundances in the crop alleys which may reflect higher levels of prey within the crop.

Keywords: silvopastoral systems; biodiversity; competition; tree protection; earthworms; Carabidae

Introduction

A central hypothesis in agroforestry is that productivity is higher in agroforestry systems compared to monocropping systems due to complementarity in resource-capture i.e. trees acquire resources that the crops alone would not (Cannell et al. 1996). Interactions between the tree and crop/livestock components can be positive or synergistic, leading to complementarity between the systems components; negative or antagonistic, resulting in competition; or neutral, with no direct interactions (Jose et al. 2004). As agroforestry systems are dynamic, these interactions are likely to change over time, so that there may be complementarity between the components in the early stages which then shifts into competition for resources as the tree component reaches maturity (Jose et al. 2004). This paper reports on interactions between trees, crops and both wild animals and livestock in the establishment years of a novel organic bioenergy agroforestry system in the UK.

System description

An agroforestry system combining bioenergy and livestock production was established on Elm Farm in Berkshire in the UK in 2011 (51°23’14.19”N; 1°24’08.34”W), with the aim of assessing the potential impacts of utilising agroforestry for low-input and organic dairy systems. A replicated plot trial incorporating short rotation coppice (SRC) and pasture was planted in April 2011 using an alley-cropping design with tree rows running north/south (Figure 1). Willow was chosen as a SRC species as it has a dual value as both a bioenergy source and a livestock fodder; a mixture of five bioenergy varieties of *Salix viminalis* was planted. Common alder (*Alnus glutinosa*) was chosen as a second species to test; its value as a fodder crop was unknown, and while it coppices well, it is not a common species for SRC bioenergy production. However, it is one of only a few temperate tree species that fixes nitrogen, and so is of interest in an organic system. Trees were planted in twin rows, 0.7 m between twin rows and 1.0 m between trees within rows. Tree rows are roughly 3 m wide, with 24 m between tree row centres (i.e. about 21 m of pasture alley). A silage cut was taken once or twice a year for the first four years, and cattle were introduced in August 2015 for two months. A break crop of oats for whole crop silage was sown on 10 October 2016 (at a rate of 185 kg seed per hectare) ahead of re-seeding of pasture in Spring 2018.

Figure 1: Alder short rotation coppice with oats in the 21 m wide alley (May 2017).

Tree: animal interactions

In the summer of 2015 cattle were given access to the agroforestry system for the first time. To investigate measures which farmers could take to restrict browsing in such a system two types of electric fencing were investigated (single strand and two strands of electric wire) along with a no-fence control. The cattle were 14 dairy/beef cattle: 12 cows and two bulls. The two bulls were Friesian x short horns, born March 2014; the cows were Friesian x Jersey heifers, born March 2013, in calf with dairy replacements. At the start of the three week observation period the browsing that was observed was either of the mature boundary hedge or of the willow within the agroforestry system. However, later on in the three week observation period cattle were also observed browsing on alder. Post-grazing, assessments were made of all trees for signs of browsing by cattle. Analysis of variance identified a statistically significant difference in the proportion of trees browsed by cattle in the different levels of fencing (alder: F-value = 2594, df = 2, $p < 0.0001$; willow: F-value = 529, df = 2, $p < 0.0001$). Unsurprisingly, the highest level of browsing occurred in the no-fence control (willow 92.2% browsed; alder 98.7%). However there were no differences in levels of browsing between the single and double strand fencing treatments, indicating that a single strand of electric fencing is sufficient to protect the trees from cattle (single strand: willow 0.3% and alder 1.5%; double strand: willow 0% and alder 1.1%).

Tree: crop interactions

Pasture productivity

Productivity of the pasture was assessed annually before the first silage cut was taken from 2011 to 2015. To standardise timings between years, sampling was timed to occur during peak seed head production of cocksfoot (*Dactylis glomerata*). Sampling took place on transects running across the alleys from tree row to tree row, and in pasture-only controls. The herbage within each 1 m^2 quadrat was cut to 5 cm above ground in June each year and oven dried at 100°C. Biomass production averaged 233 g m^{-2} over the five years with the lowest production in 2011 (162 g m^{-2}) and highest in 2014 (321 g m^{-2}). Linear mixed model analyses of biomass from 2011-2015 found no statistically significant effects of tree planting on pasture productivity, indicating that the impact of tree planting on pasture production within the first five years was minimal.

Growth and cover of oats

Due to the tree harvesting rotation, it was possible to study the effects of tree height on the oat crop in the alley. Three tree rows were coppiced in February 2016, and three more in January 2017, leaving the three remaining rows un-harvested. The impact of tree growth on the oats in the adjacent alleys was investigated by assessing growth stage, percentage cover and height of oats from April to June. Assessments were carried out at 4 m, 8 m and 12 m from the centre of the tree row, on two transects in each of the willow and alder plots (1st year regrowth; 2nd year regrowth; un-harvested). Full details are given in Deremetz (2017). A more detailed study of crop height was carried out in the alley with the oldest trees to identify any impact of the tallest trees on the crop. The height of a main stem was recorded at eight points spaced 4 m apart on transects parallel to the tree rows, at distances 2.5, 4, 8 and 12 m from the tree rows both east and west of the tree row.

There were significant differences in terms of some growth stages, in response to age of the tree re-growth, and the interaction between tree re-growth age and distance from the tree row: timing of second nodes (Tree age: $X^2 = 10.671$, $p=0.005$ and interactions: $X^2 = 19.174$, $p = 0.014$) and timing of ear emergence (Age: $X^2 = 7.360$, $p = 0.025$). The timing of these growth stages was later in the second year of regrowth, compared to both the first year regrowth and the unharvested tree plots, so the delay can't be directly attributed to the effects of shading by the trees. It may be that the trees are too small, even the oldest, to significantly influence the timing of growth stages.

There were significant differences in percentage cover of the oats in response to the age of tree regrowth (21 April: $F = 4.285$, $p = 0.020$; 5 May: $F = 6.404$, $p = 0.004$; 12 May: $F = 4.565$, $p = 0.017$). However, similar to the effects on growth stages, percentage cover of oats in the second year regrowth plots were significantly lower from the first year regrowth and unharvested plots (38% compared to 51% and 47% respectively), suggesting that shading from the trees alone was not the driving factor. There were no significant influences of the distance from the tree row and the interaction of distance and age of the trees on the cover of oats.

Focusing in more detail on the tree row alleys with the unharvested trees, there were significant differences between the distance ($F = 64.521$, $p < 0.001$) and orientation of the alley (West and East of the tree row; $F = 21.251$, $p < 0.001$) and their interaction ($F = 3.300$, $p = 0.022$) (Figure 2). Crops were tallest adjacent to the tree rows with a decrease with increasing distance from the tree row; this effect was more noticeable on the east side of the tree rows. This may reflect the shading effect causing greater stem elongation in those plants closes to the tree rows. The impact of trees on the microclimate, enrichment of nitrogen by the fine tree roots, leaf litter and biological nitrogen fixation by the alders may also contribute to this effect.

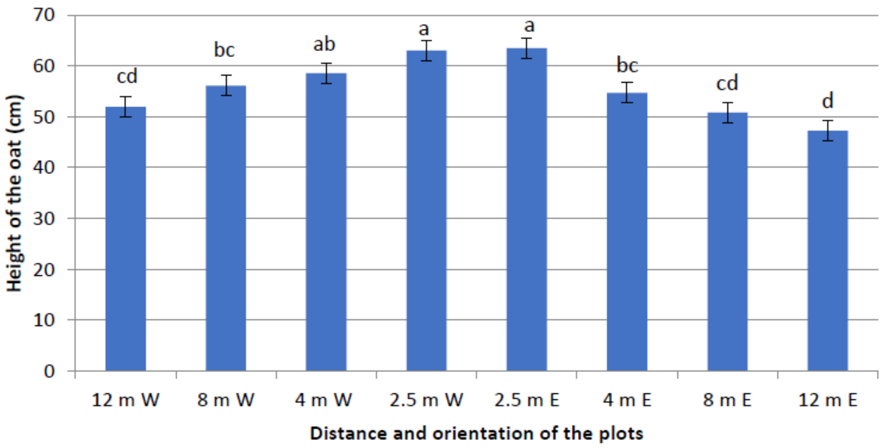


Figure 2: Crop height at 2.5 m, 4 m, 8 m and 12 m east (E) and west (W) from the tree rows (different letters signify significant differences).

Tree: crop: animal interactions

In 2017, the biodiversity of earthworms and ground beetles (Carabidae) were investigated in the tree rows and oat crop. Full details are available in Deremetz (2017). These two taxa support two important ecosystem services; earthworms are important drivers of organic matter decomposition and maintenance of soil structure, while ground beetles contribute to pest control. They showed different patterns of biodiversity in the agroforestry system, reflecting their different habitat and resource requirements. Earthworm abundances were higher in the tree rows (Figure 3a), which represent an undisturbed stable habitat, buffered from extremes of temperature. The more active ground beetles were in greater abundances in the crop alleys (Figure 3b); this may reflect higher levels of prey within the crop, or a preferable microclimate in the crop than in the tree rows. However, many species of carabids commonly associated with crops require undisturbed or extensively managed vegetation for overwintering or reproduction sites (Pfiffner and Luka 2000). The role of the tree rows in providing a refuge for ground beetles throughout the winter or during periods of cultivation in the alleys should be investigated further.

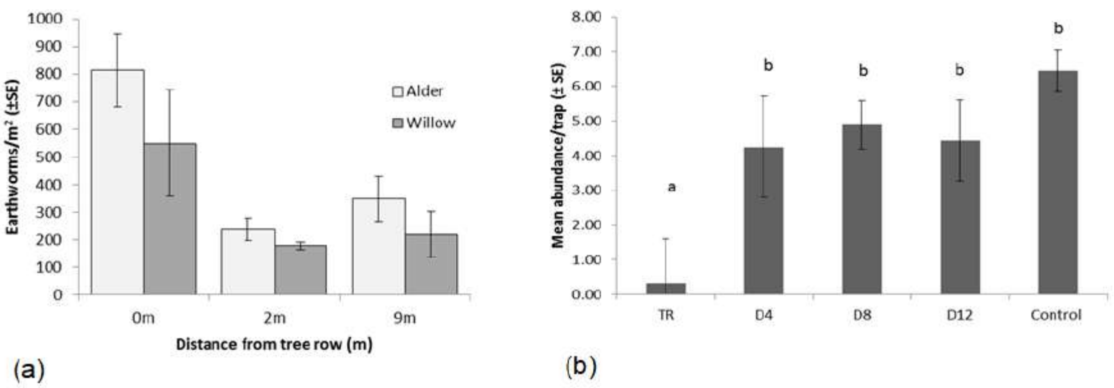


Figure 3: (a) Earthworm abundance at different distances from the tree row in alder and willow agroforestry plots. (b) Ground beetle abundance at different distances from the tree row in non-harvested alder agroforestry plots and a control plot. TR = Tree row; D4 = 4 m from tree row; D8 = 8 m from tree row; D12 = 12 m from tree row. Letters indicate significant differences (X^2 = 24.897, p< 0.001).

Conclusion

Managing the interactions between trees, crops and animals is an on-going challenge for agroforestry farmers. Our experiences suggest that in the first six years there is no significant impact of trees on the alley crops in this system. As the system will be coppiced on a 3-5 year rotation, it is expected that this will help manage the competition for light by keeping the level of shading lower than in a standard tree system. It may be possible, also, to time the harvesting of the trees to coincide with re-seeding of the pasture in the alleys, to ensure highest levels of establishment of the sward. Protecting the trees from livestock damage is essential in the early years; with cattle, our results show that it this is possible using a single stranded electric fence.

Acknowledgements

The AGFORWARD project (Grant Agreement N° 613520) is co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD, Theme 2 - Biotechnologies, Agriculture & Food. The views and opinions expressed in this report are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

References

Cannell MGR, Van Noordwijk M, Ong CK (1996) The central agroforestry hypothesis: the trees must acquire resources that the crop would not otherwise acquire. Agrofor Syst 34: 27-31.

Deremetz V (2017) Effects of Agroforestry on the agro-ecosystem: a study of the crops-soil-climate-biodiversity system in Short Rotation Coppice temperate agro-silvopastoral system. Internship report. Organic Research Centre and IUT D'Amiens,

Jose S, Gillespie AR, Pallardy SG (2004) Interspecific interactions in temperate agroforestry. Agrofor Syst 61: 237-255.

Pfiffner L, Luka H (2000) Overwintering of arthropods in soils of arable fields and adjacent semi-natural habitats. Agr Ecosyst Environ 78: 215-222.

COMPARING LONG-TERM CROP YIELDS OF A SHORT ROTATION ALLEY CROPPING AGROFORESTRY SYSTEM AND OF A STANDARD AGRICULTURAL FIELD IN NORTHERN GERMANY

Swieter A[1]*, Langhof M[1], Lamerre J[2], Greef JM[1]

(1) Julius Kühn-Institut (JKI), Federal Research Center for Cultivated Plants, Braunschweig, Germany (2) Agro-TransfertRessources et Territoires, Estrées Mons, France

*Corresponding author: anita.swieter@julius-kuehn.de

Abstract

Alley cropping agroforestry systems (ACS) provide various ecologically positive effects. However, trees and crop plants are competing for essential resources, especially in the transition zone. This study investigated the spatial distribution of oilseed rape and winter wheat yield in the tree-crop competition zone of an ACS with fast-growing poplars and narrow (48 m) and wide (96 m) crop alleys in northern Germany. Furthermore, multi-year crop yield data were compared with those of a corresponding non-agroforestry control field. Crop yields adjacent to the tree strips were significantly lower than at greater distances, mainly due to tree shading and leaf litter coverage. However, the average long-term crop yields of the narrow crop alley, the wide crop alley and the control field did not differ significantly among each other. In conclusion, yield reduction close to the tree strips had no negative influence on the average long-term crop yields of the ACS.

Keywords: agroforestry; alley cropping; crop yield; winter wheat; oilseed rape

Introduction

In short rotation alley cropping agroforestry systems (ACS) crop alleys or grassland and tree strips for energy wood production are arranged in parallel. Tree strips in ACS provide many ecologically positive effects, such as protection from wind erosion (Brandle et al. 2004), reduction of nutrient leaching (Böhm et al. 2013) and contribution to the habitat connectivity (Tsonkova et al. 2012). Litter fall provides an additional source of soil organic matter and can improve the soil properties (Pinho et al. 2012). However, in the transition zone between tree strip and crop/grass alley, trees and cultivated plants are competing for resources such as water, nutrients and light (Jose et al. 2004). In this study, we analyzed the effect of the tree strips on the spatial distribution of oilseed rape and winter wheat yield in a 9-year old ACS in northern Germany. Furthermore, we compared multi-year crop yields of oilseed rape and winter wheat in the ACS with those of a standard agricultural (i.e. non agroforestry) field.

Materials and methods

Our studies were conducted on a short rotation ACS, established in 2008 in northern Germany near the city of Braunschweig at 85 m above sea level. The climate is temperate with an average annual temperature of 9.8°C and an average annual precipitation sum of 616 mm. Local soil properties are rather heterogeneous, the soil in the ACS is mainly characterized by a silty clay texture, whereas the soil in the conventionally cultivated fields is characterized by a clayey loam texture. Yield potential at our study site has been classified as medium to low. The ACS includes 9 tree strips (12 x 225 meters) planted with fast growing poplars for energy wood production, 5 narrow (48 x 225 meters) and 3 wide (96 x 225 meters) crop alleys, each with a crop rotation of winter oilseed rape, winter wheat and winter barley. The same crop rotation was applied to 3 treeless control fields of about 3 hectares each that are located next to the ACS. Both, ACS-crop alleys and control fields were cultivated site-specific, fertilizer and crop protection products were applied according to regional recommendations and taking soil tests into account. In order to analyze spatial differences in crop yield in dependence on the distance to the tree strips, oilseed rape and winter wheat were harvested at 1, 4, 7 and 24 meters distance from the tree strips using a plot combine. This analysis was conducted in the narrow crop alleys of the ACS in 2016 and 2017. After the harvest, dry matter yields of oilseed rape and winter wheat were determined. From 2009 to 2016, annual crop yield and grain moisture estimation was done with a GPS-equipped harvester on all crop alleys of the ACS as well as on the control fields. The statistical analysis of the yield data was performed with generalized least squares models and linear mixed effects models, using the statistics program RStudio (RStudio Team 2015) and packages nlme (Pinheiro et al. 2017), lme4 (Bates et al. 2015), multcomp (Hothorn et al. 2008), multcompView (Graves et al. 2015), lsmeans (Lenth 2016), effects (Fox 2003), ggplot2 (Wickham 2009) and plyr (Wickham 2011). Firstly, we analyzed the effect of the distance from the tree strip (i.e. 1, 4, 7 and 24 m) in interaction with the orientation of the crop alley towards the tree strip (i.e. windward or leeward) on the oilseed rape (2016) and winter wheat (2017) yield, respectively. Secondly, we analyzed the effect of the cropping system (i.e. narrow ACS, wide ACS, control field) on the long-term crop yield (i.e. yield data from 2009 to 2016). The model selection was carried out using the Akaike information criterion (AIC) (Akaike 1978). Yield data, analyzed in both experiments, only refer to the cropland (crop alleys) area, excluding the area occupied by tree strips.

Results and discussion

Based on AIC, the model with the best fit for the oilseed rape yield took into account the interaction between the distance from the tree strip and the orientation of the crop alley towards the tree strip (windward or leeward). At the leeward side of the tree strip, the oilseed rape yield continuously increased with increasing distance from the tree strip (Figure 1A). The yield at 1 m was significantly lower than the yield at 7 and 24 m from the tree strip. At the windward side of the tree strip, the oilseed rape yield at 1 m from the tree strip was significantly lower than the yield at 4, 7 and 24 m from the tree strip (Figure 1B). Both, at the leeward and at the windward side of the tree strips, oilseed rape yield at 4, 7 and 24 m distance from the tree strips did not differ significantly among each other. The best model for the winter wheat yield took into account the distance from the tree strips. In contrast to the oilseed rape yield, the windward or leeward side of the tree strips had no influence on the winter wheat yield. Similar to the oilseed rape, winter wheat yield increased from 1 m distance to the middle of the crop alley (Figure 2). Yield at 1 m distance from the tree strips was significantly lower than the yield at 4, 7 and 24 m, respectively. The latter did not differ significantly among each other (Figure 2).

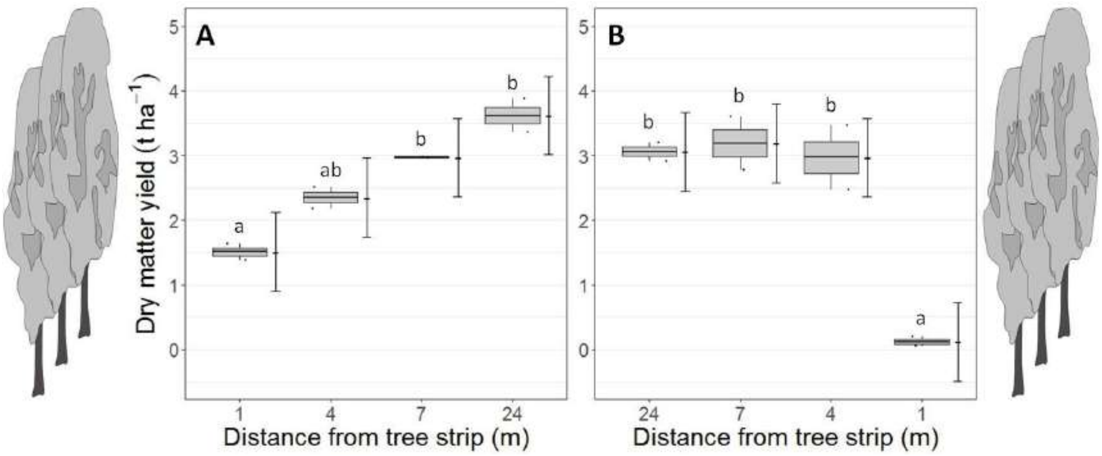


Figure 1: Boxplots with overlaid scatterplots showing oilseed rape yields at different distances from the tree strips at the leeward (A) and at the windward (B) sides of the crop alley, respectively. Error bars are the confidence intervals of the selected model. Different small letters indicate significantly different yields (p ≤ 0.05).

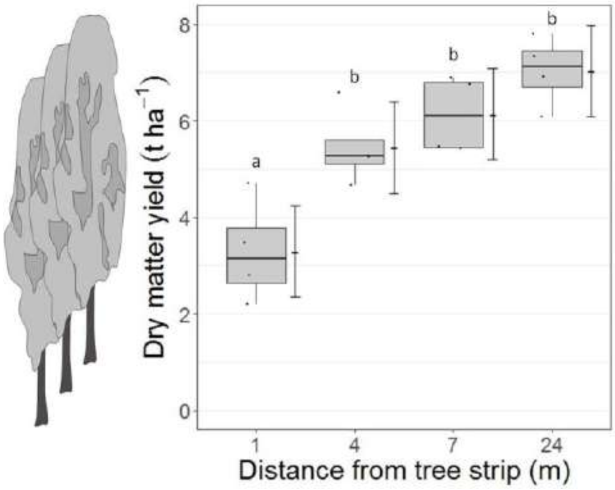


Figure 2: Boxplots with overlaid scatterplots showing winter wheat yields at different distances from the tree strips. Error bars are the confidence intervals of the selected model. Different small letters indicate significantly different yields ($p \leq 0.05$).

In general, yields at 1 meter from the tree strips were significantly lower than at 4, 7 and 24 meters from the tree strips. This might result from negative effects of the trees on the crop plants, such as competition for light, water and nutrients or leaf litter coverage of the seedlings in autumn. The extremely low oilseed rape yield at 1 meter windward from the tree strip, results from a very low plant density. It is supposed that sowing of oilseed rape seeds at 1 m from the tree strips in previous autumn was hampered by the trees.

The average long-term crop yields for oilseed rape and winter wheat for the narrow ACS, the wide ACS and the control field did not differ significantly among each other, i.e. there was no significant difference between the three cropping systems (Figure 3). By trend, crop yields of the narrow ACS were slightly lower than those of the wide ACS as well as the control field. This might be explained by a higher percentage of competition zone area (i.e. crop area close to the tree strip with reduced yields) in the narrow ACS compared with the wide ACS (Figure 1 and Figure 2). Especially in years with low precipitation, when competition for water between trees and crop plants was strongest, crop yield in the narrow ACS tended to be lower than in the wide ACS and the control, respectively. Statistical analysis of long-term crop yield data of oilseed rape and winter wheat revealed a great amount of unexplained variability, suggesting the influence of further factors on crop yield, such as distance from field edge, soil properties, tree height, weather conditions and microclimate. However, when comparing the productivity of the ACS and the control field, not only the area-specific crop yields should be taken into account but also the productivity of the tree strips. On the one hand, the area of the tree strips in the ACS reduces available land for crop production, but on the other hand, the tree strips produce up to 16 t ha^{-1} biomass (Lamerre et al. 2015) for bioenergy generation per year. Thus, in the long term, there is an economic gain from the tree strips.

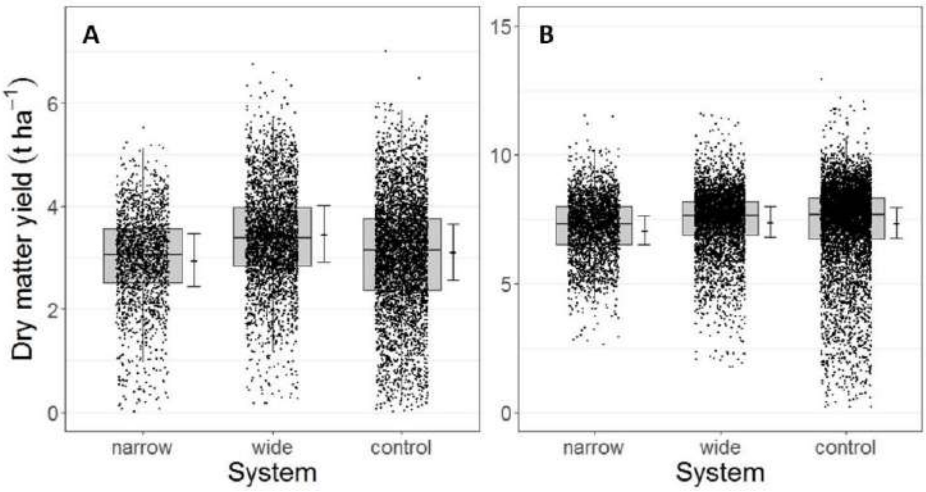


Figure 3: Boxplots with overlaid scatterplots showing winter oilseed rape (A) and winter wheat (B) yields of the years 2009-2016 for the crop alleys in the narrow alley cropping agroforestry system (ACS), the wide ACS and the control field. Error bars are the confidence intervals of the selected model.

References

Akaike H (1978) A Bayesian analysis of the minimum AIC procedure. AISM 30: 9–14.

Bates D, Maechler M, Bolker B, Walker S (2015) Fitting Linear Mixed-Effects Models Using lme4. J Stat Softw 67: 1–48.

Böhm C, Kanzler M, Freese D (2013) Agroforstsysteme in Südbrandenburg –Effekte aufMikroklima und Wasserqualität. Mitteilungen der Gesellschaft fürPflanzenbauwissenschaften 25: 180-181.

Brandle JR, Hodges L, Zhou XH (2004) Windbreaks in North American agricultural systems. Agrofor Syst 61: 65–78.

Fox J (2003) Effect Displays in R for Generalised Linear Models. J Stat Softw 8: 1–27.

Graves S, Piepho H-P, Selzer L (2015) MultcompView: Visualizations of Paired Comparisons. R package version 0.1-7, https://CRAN.R-project.org/package=multcompView (accessed 17/04/2018).

Hothorn T, Bretz F, Westfall P (2008) Simultaneous Inference in General Parametric Models. Biometrical J 50: 346–363.

Jose S, Gillespie AR, Pallardy SG (2004) Interspecific interactions in temperate agroforestry. Agrofor Syst 61: 237–255.

Lamerre J, Schwarz K-U, Langhof M, Wühlisch G, Greef J M (2015) Productivity of poplar short rotation coppice in an alley-cropping agroforestry system. Agrofor Syst 89: 933-942.

Lenth RV (2016) Least-Squares Means: The R Package lsmeans. J Stat Softw 69: 1-33.

Pinheiro J, Bates D, DebRoy S, Sarkar D, R Core Team (2017) nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-131, https://CRAN.R-project.org/package=nlme (accessed 17/04/2018).

Pinho RC, Miller RP, Alfaia SS (2012) Agroforestry and the Improvement of Soil Fertility: AView from Amazonia. Appl Environ Soil Sci, https://www.hindawi.com/journals/aess/2012/616383/ (accessed 17/04/2018).

RStudio Team (2015). RStudio: Integrated Development for R. RStudio, Inc., Boston. http://www.rstudio.com/ (accessed 17/04/2018).

Tsonkova P, Böhm C, Quinkenstein A, Freese D (2012) Ecological benefits provided by alleycropping systems for production of woody biomass in the temperate region: Areview. Agrofor Syst 85: 133–152.

Wickham H (2009) ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag, New York.

Wickham H (2011) The Split-Apply-Combine Strategy for Data Analysis. J Stat Softw 40: 1–29.

SIMULATION OF ANNUAL LEAF CARBON FLUXES AND ANALYSIS OF STAND STRUCTURE OF POPLARS AND BLACK LOCUSTS IN AN ALLEY-CROPPING SYSTEM, BRANDENBURG, GERMANY

Veste M[1, 2], Malaga Linares RA[3], Seserman DM[3*], Freese D[3], Schmitt D[2], Wachendorf M[2], Küppers M[2]

(1) CEBra-Centre for Energy Technology Brandenburg e.V., Cottbus, Germany (2) Institute of Botany, University of Hohenheim, Stuttgart-Hohenheim, Germany (3) Soil protection and Recultivation, Brandenburg University of Technology Cottbus-Senftenberg, Cottbus, Germany

*Corresponding author: seserman@b-tu.de

Abstract

Carbon gain by photosynthesis is significant for plant growth and biomass allocation estimations at a tree, stand, and landscape level. Our objective was to develop a leaf carbon model driven by daily light fluctuations and modulated by temperature and air humidity for poplar and black locust trees in a temperate agroforestry system. Different light regimes and the leaf area index (LAI) were considered for further up-scaling of the CO_2 fluxes. We obtained differences in the light intercepted by both tree species, which lead to drastic implications for the photosynthesis, leaf development, and stand structure. The LAI followed the declining pattern of the tree heights from leeward to windward strips and with respect to the sun-exposed crown. Our results highlight the importance of light competition and stand structure for the growth performance of agroforestry systems and can contribute to optimizing stand densities for either maximum single tree or stand biomass production.

Keywords: agroforestry; alley cropping; leaf carbon flux; leaf area index

Introduction

Planting of trees and shrubs into agricultural systems have ecological and economic benefits as they provide timber, fuel-wood and other products, and have positive effects on the ecosystem functioning (Kanzler et al. 2016; Veste and Böhm 2018). Site-specific species selection and their management are most crucial for a successful biomass production in agroforestry systems. Currently, the selection and planting of tree species are more economically oriented towards optimizing biomass production and poplars (*Populus* spec.) and willows (*Salix* spec.) are mainly cropped due to their high potential of biomass production. Under drier climatic conditions in East-Central Europe, black locust (*Robinia pseudoacacia* L.) is recommended for short-rotation forestry due its high ecophysiological plasticity and biological nitrogen-fixation (Mantovani et al. 2015a, b; Veste and Halke 2017). For a better understanding of growth performance of fast-growing trees in agroforestry systems, more detailed information about carbon fluxes is required. Photosynthesis is a predominant factor for plant growth and is largely influenced by microclimatic factors (light, temperature). Carbon gain by photosynthesis is a predominant factor for plant growth and essential in estimating biomass allocation at a tree, stand and landscape level (Küppers 1988). Our main objective was to develop a leaf carbon model driven by daily fluctuations in light and modulated by temperature and air humidity. The seasonal variation of CO_2 uptake and release can then be modelled to estimate annual carbon fluxes of sun, half-shade and shade leaves of black locust and poplars in a temperate agroforestry system. Furthermore, we investigated the importance of different light regimes on the growth of poplar and the differences of the leaf area index as a basis for further up-scaling of the CO_2 fluxes.

Materials and methods

The study site (51°47´ 24´´ N, 14°37´ 57´´ E) is situated in Lower Lusatia, in the South of the Federal State Brandenburg, Germany, with an average annual precipitation of 581 mm and a mean annual temperature of 9.3 °C (1981-2010, DWD Cottbus). It is part of an agricultural landscape stocking on naturally formed soils (Fluvisols) close to the Lusatian River Neiße.

Figure 1: Alley-cropping systems near Neu Sacro (Brandenburg, Germany).

Hedgerows are comprised of black locust trees (*Robinia pseudoacacia* L., planted in spring 2010) and hybrid poplar trees, clone "Max" (*Populus nigra* L. x *P. maximowiczii* Henry, planted in spring 2011). They were planted in around 170 m long alternating rows (Figure 1) as one-year-old, bare-rooted saplings and cuttings, respectively. Including buffer zones of 1 m between trees and crops, these hedgerows have a width about 10 m at a planting density of about 8,700 trees per hectare woodland. The Hedgerows are oriented in north-south direction (Figure 1). The distance between hedgerows varies between 24, 48 and 96 m.

Photosynthetic parameters of both tree species were obtained via two portable H_2O/CO_2-porometer systems (Li-Cor 6400, Li-Cor Inc., USA, Figure 2). Steady-state light response curves of leaf net photosynthesis were measured at different temperatures on field grown trees. Based on the *in-situ* measurements of leaf gas exchange we used an entirely empirical photosynthesis model (Küppers et al. 2017) to estimate the annual net carbon fluxes of sun and shade on/in leaves of poplar and black locust. The model consists of four sub-models: (i) the effect of leaf temperature on respiration in the dark and (ii) on light-saturated net photosynthesis is calculated separately; (iii) the effect of leaf-to-air vapour concentration is taken into account assuming that this effect is mediated by partial stomatal closure resulting in a relative reduction of the CO_2-uptake and (iv) all these single effects are combined in a light-response of net photosynthesis. The photosynthesis model is driven by microclimatic data, which have been recorded locally throughout the year.

Figure 2: In situ gas exchange measurements.

The leaf area index (LAI) was obtained by a SunScan SS1 LAI meter (Delta-T Devices Ltd, Cambridge, UK) and measurements were replicated at three points per each row (total n=9 per plot). The measurements were conducted during a sunny day, on 2nd of September 2017. Tree heights and breast height diameters were measured at end of October. Light interception in the poplar and black locust trees was measured with quantum-sensors (Li-Cor Quantum sensor) mounted at four different light classes in the canopy and below. PAR was recorded in 2 minutes' intervals by data-loggers and related to a reference sensor exposed on the open field.

Results and discussion

In fully expanded leaves, the light was the major factor determining daily carbon balances. The highest observed daily carbon gain in sun leaves was of 748.9 mmol CO_2 m^{-2} d^{-1} in poplar and of 536.3 mmol CO_2 m^{-2} d^{-1} in black locust. The much higher seasonal carbon gain in sun leaves of poplar hybrid *P. nigra* x *P. maximowiczii* (66,803 mol CO_2 m^{-2}) compared to *R. pseudoacacia* (46,824 mol CO_2 m^{-2}) results from its much longer leaf period, therefore larger total intercepted light. Although the leaf nitrogen content is higher in black locust (2.8% - 4.0%, Veste et al. 2013), poplar leaves showed a much higher photosynthetic capacity (Küppers et al. 2017), which contributed to the higher carbon gain of the species. Differences in light intercepted by the crown varied between the two species and resulted in drastic implications for the photosynthesis, leaf development, and stand structure. Leaves in the lower Robinia crown rendered positive carbon balances when sufficient light reached the ground. From June onwards, the canopy became so dense that predominantly negative daily C-balances were observed and leaf fall commenced. This observation emphasized the importance of light interception in the mono-stands for the productivity of the agroforestry stands. In *Populus*, a higher light fraction penetrated into the understory compared to *Robinia*.

Structural differences between outer and inner rows of the trees can be observed during the second rotation. The height of poplar trees peaked at 7.81 m on the east-facing site, decreasing to 6.00 - 6.41 m in the inner rows and 5.07 m at the west-facing (wind-warts oriented) rows (Figure 3). Robinia reached mean tree heights between 4.97 and 6.48 m (Figure 4) with no differences between outer and inner rows.

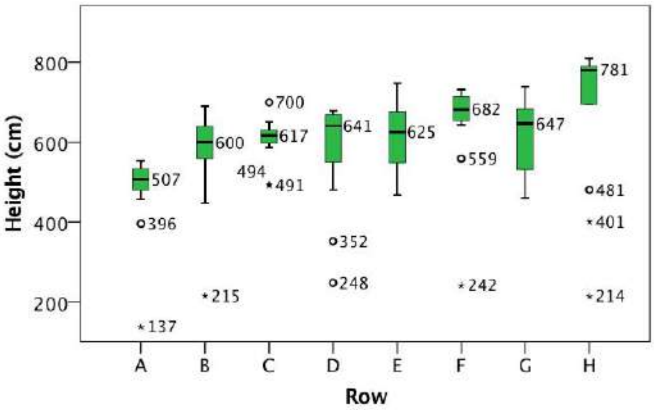


Figure 3: Tree height poplar trees in different rows of an alley-cropping system (A west, H east).

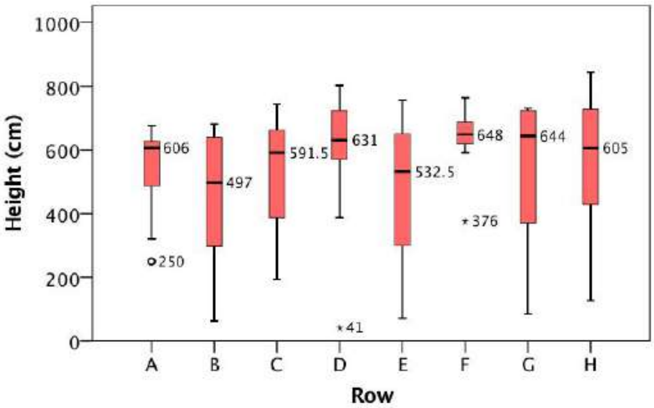


Figure 4: Tree height black locust trees in different rows of an alley-cropping system (A west, H east).

The LAI of poplar trees followed the same declining pattern of the tree heights. The edge effect could also be observed for the LAI of black locust stands, where the outer and sun-exposed crown reached a higher LAI (Figure 5). The access to groundwater enabled the trees for a fast grow and poplar trees at the outer rows (2nd rotation) reached similar heights as the trees in the inner rows (1st rotation, not harvested). Light availability promoted tree growth in the outer rows.

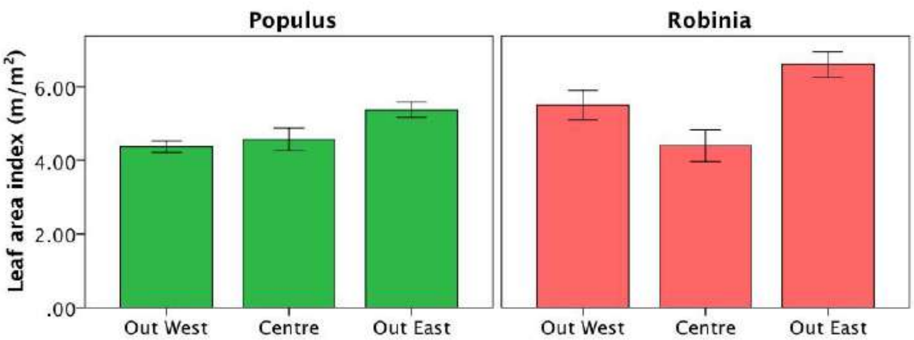


Figure 5: Leaf area index of poplar and black locust in different rows of a alley-cropping system.

Our results emphasized that light competition and stand structure are important factors for the architectural patterns (Küppers 1989) and for the growth performance of agroforestry systems on former agricultural fields. From an agroforestry management viewpoint, this strongly contributes to the question of optimum stand densities for either maximum single tree or stand biomass production, and how far can tree growth reactions be triggered by thinning. The latter contributes to the question to what extent can stand density reactions be compensated by an increased growth of the remaining trees.

This is not only important for short rotation biomass production, but also in midi- and maxi-rotation agroforestry, where single stem wood production can be a production goal. Furthermore, the edge effect along alley-cropping agroforestry systems enhances tree production at the outer rows and we assume that this might contribute to a higher Land Equivalent Ratio of the trees compared to short-rotation coppices (Seserman et al. 2018, this volume).

Acknowledgments

The authors thank the students of the University of Hohenheim for their help during the field measurements and the colleagues from BTU for providing information. Additionally, we are grateful to the Agrargenossenschaft Forst e.G. for their promotion and management of the agroforestry system. The ecophysiological work was supported by the University of Hohenheim.

References

Kanzler M, Böhm C, Mirck J, Schmitt D, Veste M (2016) Agroforstliche Landnutzung als Anpassungsstrategie an den Klimawandel. Mitteilungen der Gesellschaft für Pflanzenbau 28:126-127.

Küppers M (1988) Changes in plant ecophysiology across a Central European Hedgerow Ecotone. In: Hansen AJ, Di Castri F (eds) Landscape boundaries. Ecological studies, vol 92. Springer, Heidelberg, pp 285–303

Küppers M (1989) Ecological significance of above-ground architectural patterns in woody plants: A question of cost-benefit relationships. Trends Ecol Evol 4: 375-379.

Küppers M, Schmitt D, Liner S, Böhm C, Kanzler M, Veste M (2017) Photosynthetic characteristics and simulation of annual leaf carbon gains of hybrid poplar (Populus nigra L. x P. maximowiczii Henry) and black locust (Robinia pseudoacacia L.) in a temperate agroforestry system. Agrofor Syst. https://doi.org/10.1007/s10457-017-0071-z

Mantovani D, Veste M, Boldt-Burisch K, Fritsch S, Koning L, Freese D (2015a) Carbon allocation, nodulation, and biological nitrogen fixation of black locust (Robinia pseudoacacia L.) under soil water limitation. Ann For Res 58 : 259-274.

Mantovani D, Veste M, Böhm C, Vignudelli M, Freese D (2015b) Drought impact on the spatial and temporal variation of growth performance and plant water status of black locust (Robinia pseudoacacia L.) in agroforestry systems in Lower Lusatia (Germany). iForest - J. Bioge For 8: 743-747.

Veste M, Böhm C, Quinkenstein A, Freese D, (2013). Biologische Stickstoff-Fixierung der Robinie. AFZ-Der Wald 2/2013: 40-42.

Veste M and Halke C (2017) Ökophysiologische Plastizität der Photosynthese von Robinien (Robinia pseudoacacia L.) und Hybrid-Pappeln (Populus nigra L. x P. maximowiczii Henry) bei Hitzestress und Sommertrockenheit in der Niederlausitz. In: Böhm, C. (Hrsg.) Bäume in der Land(wirt)schaft – von der Theorie in die Praxis, 5. Agroforstforum, Tagungsband, Cottbus, pp.144-157.

Veste M and Böhm C (2018) Agrarholz - Schnellwachsende Bäume in der Landwirtschaft. Springer, Heidelberg.

Session

Agroforestry and multiple products value chain

IMPACT OF POLLARDING ON GROWTH AND DEVELOPMENT OF ADULT AGROFORESTRY WALNUT TREES

Dufour L[1*], Gosme M[1], Le Bec J[1], Dupraz C[1]

(1) INRA, UMR system, University of Montpellier, Montpellier, France

*Corresponding author: lydie.dufour@inra.fr

Abstract

In temperate alley cropping agroforestry systems, light competition often limits the crop yield. The trees pruning and particularly pollarding reduces this competition. This practice results in three productions on the same field: crop, fuel or others purposes wood and timber wood. To be profitable, pollarding must not affect too much the trunks growth in diameter and the trees provide enough branches biomass when they are cut. In our experiment on adult walnut trees, during the 4 years after pollarding, the diameter growth of the pollards was 2.8 ± 0.9 cm for the pollards *vs* 3.2 ± 0.9 cm for the control and they produced, in average, 81 kg of branches biomass per tree. The question is now to know how if repeated cuttings will not be affected trees growth and survival.

Keywords: alley cropping; light competition; pollards; trees growth; wood production

Introduction

Pollarding is a traditional practice consisting in topping the trunk of a tree and pruning steadily all branches (Chesney 2012). It results in a distinctive thick bushy appearance of the tree. The tree size and leaf area are dramatically reduced during the first years after pollarding. This management was frequently practiced for fodder or firewood collection (Sjolund and Jump 2013). In an alley cropping system, pollarding the trees may reduce the light and water competition of the trees, and consequently may enhance crop yield (Dufour et al. 2016). If the trunk diameter growth of the timber tree were not too severely impacted, pollarding would be a smart way to yield three products simultaneously in an agroforestry field: annual crops, branch and leaves biomass for energy, fodder or wooden chips (Valipour et al. 2014), and timber wood (Mansion 2010). Even though pollarding is an age-old practice that converged over the world from farmers and foresters' good sense (Thomas 2000), the growth and physiological responses of pollards have rarely been studied, even less in an agroforestry context. Our objective was to assess the impact of pollarding on the growth, both in trunk diameter and branch biomass, and development (phenology) of hybrid walnut trees, which are not traditionally pollarded, in an alley-cropping agroforestry system.

Materials and methods

The study was conducted on adult hybrid walnut trees in a cereal-based agroforestry system under a Mediterranean climate. Fifty trees placed on two adjacent tree lines were pollarded in December 2013 in an agroforestry plot planted in 1995 with East-West tree lines separated by 13 m. The trees were topped at 4 m height, using a mobile platform lift. The cropped alley was 12 m wide and the intercrops were winter field crops (durum wheat, barley and pea). Control trees, always pruned up to 4 m height, were selected in the 8 remaining tree lines of the plot, so that each pollard was paired with a control tree with the same height and trunk girth in 2013. Pollarding was repeated in October 2017.

The height and diameter at breast height (DBH) of each tree (pollard and control: a total of 100 trees) were measured yearly. The DBH growth of each tree was monitored once every two weeks, with microdendrometers, starting from the 6th of May 2014. The phenology of the 100 trees was recorded at the same time, documenting 4 stages: budburst, end of short shoots expansion, end of long shoots expansion and leaf fall. The number and the basal diameter of each cut branch were measured at the second pollarding. At the same time, the dry biomass of a sample of branches covering the full range of diameters was measured. This allowed us to establish an allometric equation relating branch basal diameter and dry biomass, and thus to estimate the branch biomass of each tree. The sky mask resulting from the trees canopies was estimated as 100 minus the gap fraction obtained by the software Winscanopy (Regent Instruments) from hemispherical photographs taken on 14/06/2014, 19/06/2015 and 21/06/2016 at 2.5 m from the trunks on the Northern side.

Data were analysed using R statistical software. The paired data of height, DBH and their yearly increment were analysed using paired t tests for each year separately. For the analysis of the intra-annual DBH growth, each year was divided into 3 periods (summer: May15th->July15th, autumn: July16th->November 15th, and winter: November 15th->May15th), and the daily increment in DBH was analysed for each year-period separately using a mixed model with type of tree (pollard vs control) as a fixed effect and tree identifier as a random effect, to take into account repeated measurements.

Results

Pollarding changed tree phenology: budburst was delayed during the first, third and fourth year after pollarding, leaf fall was noticeably delayed for pollards compared to control trees the second year after pollarding. As a result, the time when the trees had leaves was extended by 26 days in 2015 (Table 1).

Table 1: Comparison of non-pollarded and pollarded trees phenology.

Year	Budburst		Leaf fall		Growing season duration	
	Control	Pollard	Control	Pollard	Control	Pollard
2014	30 April	6 May	13 November	27 November	197	205
2015	13 May	13 May	12 November	26 November	183	197
2016	9 May	16 May	16 November	23 November	191	191
2017	3 May	10May	2 November	NA	183	

Pollards had a significantly higher height growth than control trees ($p<0.0001$ in 2014 and 2015, and $p=0.0002$ in 2016) and their diameter growth was not much slower than the control trees, except during the first year (Table 2, Figure 1). The diameter increment was significantly reduced for pollards only during the first year ($p=0.01$in 2004, $p=0.43$ and 0.44 in 2015 and 2016). DBH growth of pollards was significantly reduced in both summer and autumn in 2014 ($p<0.0001$). In 2015 and 2016, DBH growth of pollards was smaller than control in summer but higher in autumn, and in 2017, it was not significantly different neither in summer nor in autumn ($p=0.6$ and 0.2 respectively). Pollarding reduced the sky mask of the trees canopies by 60% in 2014, 13% in 2015 not in 2016 (increase of 3% of the mask).

Table 2: Trees height and DBH and their annual increase, *in italics*. The intervals are the standard errors. Stars indicate that the difference between control and pollarded trees was significant.

Year	Total height (cm)				DBH (cm)			
	Control		Pollard		Control		Pollard	
2012	959±35		948±33		19.8±0.8		20.0±0.8	
2013	1011±36	*53±6*	400*		21.1±0.8	*1.3±0.1*	21.2±0.9	
2014	1040±37	*29±9*	664±14*	*264±14**	22.0±0.9	*0.9±0.2*	21.6±0.8*	*0.4±0.1**
2015	1040±37	*0±8*	794±14*	*130±10**	22.2±0.9	*0.3±0.2*	22.1±0.9*	*0.5±0.1*
2016	1112±40	*72±12*	929±22*	*135±12**	23.0±0.9	*0.7±0.1*	22.8±0.9*	*0.7±0.1*

The number of branches cut at the second pollarding was 29.6±0.4 (mean, standard error) per tree, with a mean branch diameter of 4.5±0.07 cm. The allometric equation between the branches circumference and their dry biomass allowed us to estimate the biomass of branches produced between the two pollardings to 80.9±7.6 kg per tree.

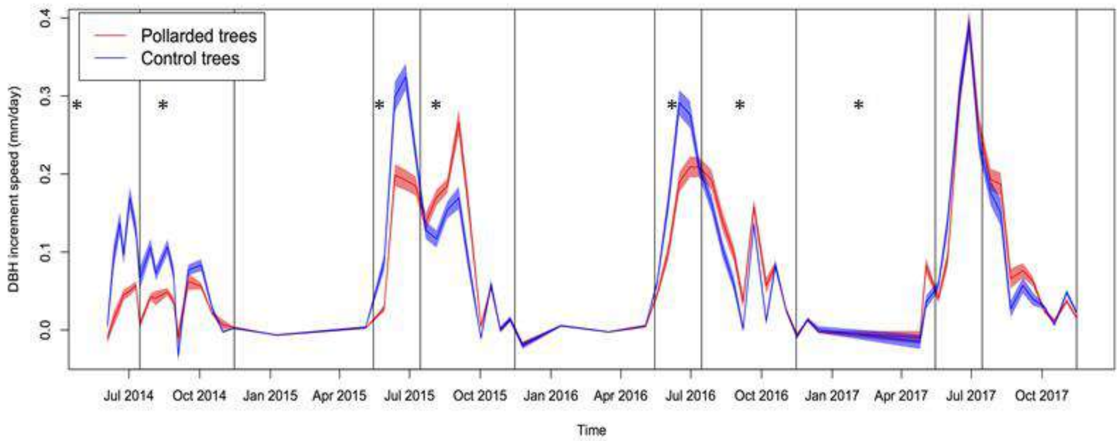


Figure 1: Speed of DBH growth measured with the microdendrometers on pollarded (red) and control (blue) trees as a function of time. The shaded areas indicate ± standard error. The vertical lines indicate the periods (summer: May15th->July15th, autumn: July16th->November 15th, winter: November 15th->May15th). Stars indicate when the effect of pollarding on DBH increment was significant.

Discussion

The first pollarding of adult walnut trees reduced their diameter growth while the height growth was boosted. The tree canopy was quickly replenished and the benefit for the crop yield only transient. The ability of the tree to grow back quickly after a total removal of its branches is due to very high reiteration capacity and was the result of numerous epicormic buds differentiation. High nutrients reserves in the trunk, stump and coarse roots probably helped the fast recovery. We may question if this compensation can operate several times, allowing the tree to keep growing in diameter (producing timber wood) while also producing branch biomass. Ghahramany et al. (2017) showed that Lebanon oaks (*Quercus libani* Oliv.) pollarded every 3 or 4 years had the same diameter growth until 55 years old. On the opposite, Lang et al. (2015) found that poplar pollarding resulted in a significant reduction in diameter growth and significantly increased the occurrence of stem rot. Future measurements will be made after the second pollarding to see if our walnut trees can produce both timber and branch wood through repeated pollarding.

Pollards kept their leaves for a longer period as compared to control trees during the four years, and this is often related to the lack of water stress (Delpierre et al. 2017). The leaves are also deep green, suggesting a high content in nitrogen. Both aspects may explain the high efficiency of pollards in recovering. Pollards may avoid stresses that full grown trees could face in summer thanks to their reduced leaf area and water needs, while they benefit from an extended rooting system.

Branch biomass production estimated in our study (20.2 kg of dry matter per tree and per year) is comparable to some estimates found in the literature for other fast growing species (AGROOF 2011): 29 kg/tree/year, with ash (*Fraxinus intermedia)* and oak trees (*Quercus robur)*, 21 kg/tree/year with white mulberry (*Morus alba)*.

Pollarding trees could be an option to produce additional biomass from branches, increasing the agroforestry field productivity. But pollarding may deplete soil nutrients due to the export of nutrient pools in the removed branches. This may increase the competition for nutrients with the crop. Furthermore, the rapid regrowth of the branches and their very dense shade increase light competition with the crop as soon as the third year after pollarding. More studies are needed to optimize the trade-offs between trunk (timber wood), branches (fuelwood or fodder) and crop (agricultural production) productivities as a function of the frequency of pollarding and the density of pollards on the field. The frequency of pollarding should also be adapted to the intended use of the branch biomass. The branches can be ground to make ramial chipped wood used as mulching and improving soil fertility should be obtained from branches smaller than 7 cm in diameter. In our experiment, 4 years after pollarding 83% of the branches representing only 31% of the total biomass were fit for this use.

In conclusion, pollarding can be a way to improve the productivity of agroforestry systems, but a long term study must be conducted to ensure the sustainability of the timber production.

References

AGROOF (2011) CASDAR Agroforesterie 2009-2011 « Améliorer l'Efficacité Agro-environnementale des Systèmes Agroforestiers » Groupe de Travail 3–SOL Délivrable 3.2 -Bilan Sols Expériences Passées.

Chesney P.E.K (2012) Shoot Pruning and Impact on Functional Equilibrium between Shoots and Roots in Simultaneous Agroforestry Systems. Agroforestry for Biodiversity and Ecosystem Services. In: Kaonga ML (ed) Agroforestry for Biodiversity and Ecosystem Services – Science and Practice, Croatia, pp. 87-112. www.intechopen.com (accessed 23/04/2018).

Delpierre N, Guillemot J, Dufrene E, Cecchini S, Nicolas, M (2017) Tree phenological ranks repeat from year to year and correlate with growth in temperate deciduous forests. Agric For Meteorol 234: 1-10.

Dufour L, André J, Le Bec J, Dupraz C (2016) Influence of tree pollarding on crop yield in a Mediterranean agroforestry system. 3rd European Agroforestry Conference. Montpellier, France.

Ghahramany L, Shakeri Z, Ghalavand E, Ghazanfari H (2017) Does diameter increment of Lebanon oak trees (Quercus libani Oliv.) affected by pollarding in Northern Zagros, Iran? Agrofor Syst 91: 741-748.

Lang P, Jeschke M, Wommelsdorf T, Backes T, Lv C, Zhang X, Thomas FM (2015) Wood harvest by pollarding exerts long-term effects on Populus euphratica stands in riparian forests at the Tarim River, NW China. For Ecol Manage 353: 87-96.

Mansion D (2010) Les trognes : L'arbre paysan aux mille usages, Ouest-France.

Sjolund MJ, Jump AS (2013) The benefits and hazards of exploiting vegetative regeneration for forest conservation management in a warming world. Forestry 86: 503-513.

Thomas P (2000) Trees: their natural history. Cambridge University Press, Cambridge., UK. https//:doi.org 10.1017/CBO9780511790522 (accessed 23/04/2018).

Valipour A, Plieninger T, Shakeri Z, Ghazanfari H, Namiranian M, Lexer MJ (2014) Traditional silvopastoral management and its effects on forest stand structure in northern Zagros, Iran. For Ecol Manage 327: 221-230.

FOOD VALUE, THE ONLINE MARKETPLACE THAT REALLY MAKES LOCAL FOOD CHAINS TAKE OFF

Karssen M[1]*, Koster S[2], Dolmans L[3], Wentink H[4], van Dooren N[5]

(1) The Plant, Voorst gem Voorst, The Netherlands (2) Ortus Foundation, Arnhem, The Netherlands (stichting Ortus) (3) From Field to Forest Foundation, Bemmel, The Netherlands (stichting van Akker naar Bos) (4) City of Arnhem, Arnhem, The Netherlands (Gemeente Arnhem) (5) Van Hall Larenstein University of Applied Science, Velp, The Netherlands

*Corresponding author: info@theplant.nl

Abstract

If we want more farmers to change from mainstream farming to a polyculture/agroforestry approach, then we must deal with the fact that selling the produce can become a serious hindrance. Food Value, an online marketplace software, can help on the level of sales, marketing, and administration. Food value can create continuity and service for customers. This may contribute in using the land in a more sustainable and biodiverse way since, with this local market model, earning a proper income can become easier, transportation would be shorter and therefore more sustainable, and the relation between farmers/rural areas and the city could improve. Food Value allows groups of farmers, professionals and consumers in the city to be organized as a group that works together. Food Value groups will stay in charge of their own data because the software will be owned by a cooperation and each group can become a member.

Keywords: social; online marketplace; local; food chain

Introduction

- if more and more farmers can no longer make a living,
- if the landscape loses all its biodiversity,
- if soil fertility is heading towards zero,
- if sustainability becomes a necessity,
- if population - and recreational pressure becomes ever greater,
- and if public health issues are growing

How long can we maintain the habit, in densely populated areas of Europe, to use our land to produce for a global market?

If the few farmers we still have could produce with an agro-ecological approach, including agroforestry, for costumers in the same city or neighborhood, this might allow using the land in a more sustainable and biodiverse way, since transportation would be shorter distance and therefore more sustainable, and the relation between farmers/rural areas and the city could improve.

But, how can such an ecological local food chain be organized?

The necessity of an online marketplace

Every city or region has different circumstances, players and activities, but marketplace software plays a major role everywhere. In fact, one of the biggest obstacles to the development of local and direct (from farmer directly to consumer) markets is the administrative hassle that arises when farmers start selling their produce directly to many different customers. Another issue is that the local market needs to have enough scale and continuity, when seen from a customer perspective. "Food Value" is a software designed to tackle these two challenges. The aim of Food Value is to serve as many local food groups as well and as quickly as possible with software developed as efficiently as possible. This will allow more food groups to start and to organize themselves together, thus creating new scale for local and regional agriculture. With Food Value, farmers, food processors (butchers, bakers etc.), caterers, restaurants, shops and consumers can organize themselves into various types of groups around their offers and demands. Together they form a trust-based chain of professionals and customers that ensures a viable long-term market for local food production.

Materials and methods

What is and what can Food Value do?

Food Value is online marketplace software that enables local food chains to fully organize themselves at a very low cost. Food Value is an open source and cooperatively organized tool. The software is capable of automating administration and payments and facilitates communication between the members of the group in many ways.

How the tool works

In Food Value, farmers have their own shop (Figure 1). There they can publish their produce and decide on things like stock and price. They become vendors in the system. For the customers, whether they are professional middlemen or final consumer, the platform looks like a webshop (Figure 2). They can buy from all the little shops as if it were a single shop. The system deals with all the administration, payments, margins and communicates with the chosen logistic partner or partners. Margins and logistic systems can be implemented according to the wishes of the group. Al participants in the group, whether they are vendors or customers, are members. Apart from the webshop, participants can also communicate with each other and form subgroups. For example: a restaurant can discuss the menu with its suppliers.

More information about the tool and a working demo can be found at: https://foodvalue.nl/ (also in English)

Technical background

Food Value is based on an Open Source software: Wordpress. This ensures that development costs will stay low, and that development will continue to happen within the community and that developers will be continue to be available. Before releasing it, Food Value was tested with real farmers, shops and logistics partners. Currently the tool is ready to use, but it must be further developed in order to become open source itself as well.

Organisational structure

Food Value has been developed by the company "The Plant" and tested in cooperation with the above-mentioned partners. Now it is ready for use. To ensure that the original vision and the data of its users is fully protected, The Plant will hand over its ownership rights to a cooperation. All groups using Food Value for their local food chain administration will become members.

Discussion

From the experience of co-designing and improving Food Value it was concluded that a successful Food Value group should arrange the following things well:

The group should have **sufficient size**. The professional parties must know and trust each other and want to work together. There must be a sufficient and diverse range of vendors in the group to ensure continuity in the offering part of the marketplace. And there must be enough buyers in the system to be economically interesting for the vendors and the whole marketplace. Of course, the required critical mass can be achieved gradually, but it is important to set a goal.

The reaching of this goal must be monitored by a **professional coordinator**. This coordinator must dedicate sufficient time (at least one day/week) to the job, and should be preferably not a vendor in the system.

Each group must have a **pre-agreed logistics system**. From our experience, tests and brainstorming, two systems have emerged. In one system, the farmer owns a refrigerated van and drives around to pick up and deliver. This system works very well if there is just one or a few big clients in the group (e.g. a big canteen or just a few restaurants). The other system is to work with a central hub in each city. Farmers bring their harvest to this hub at least once a week. The hub owner preferably uses an electric vehicle and delivers the produce around the city. The shipping costs in the system are paid by this logistics partner. Of course, city residents can also pick up their orders at the hub themselves.

Muriël Simonis Msc Antropology conducted research on group behavior and group forming during the project and her research report is published here, in Dutch.

https://drive.google.com/drive/folders/1uNpeyEa44WzmrJIFYVA6Nbxdqq0cerBO?usp=sharing

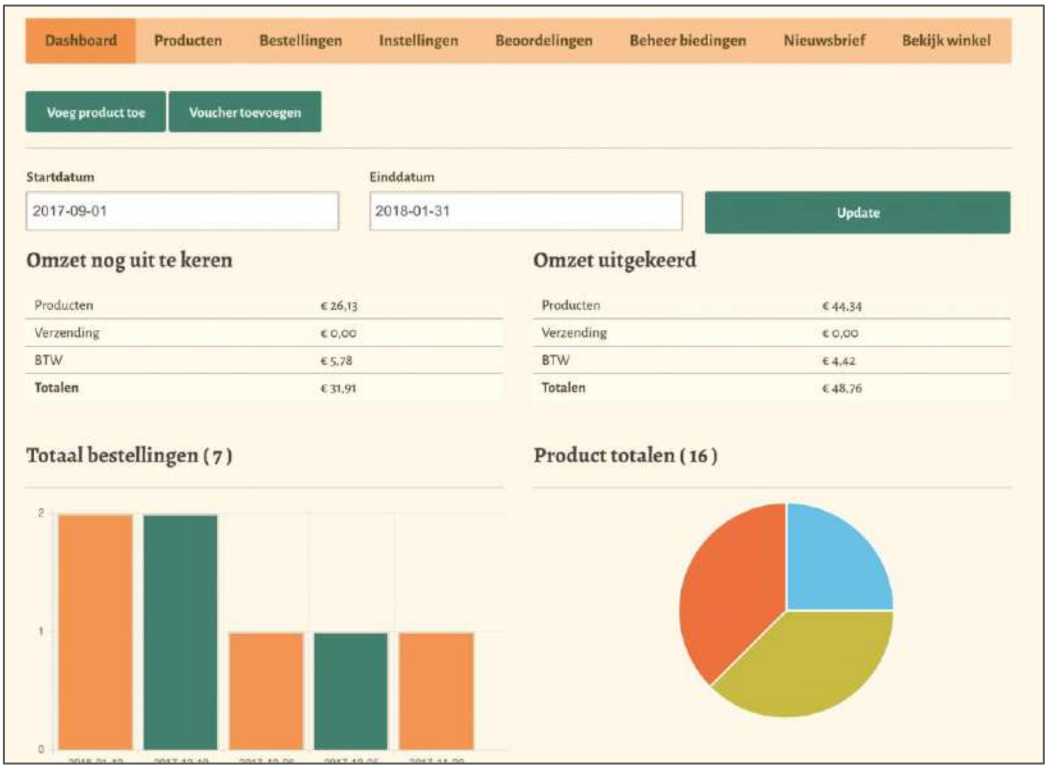


Figure 1: Example of the vendor/farmer dashboard. The farmer can completely control his products and prices and get an overview of the revenues.

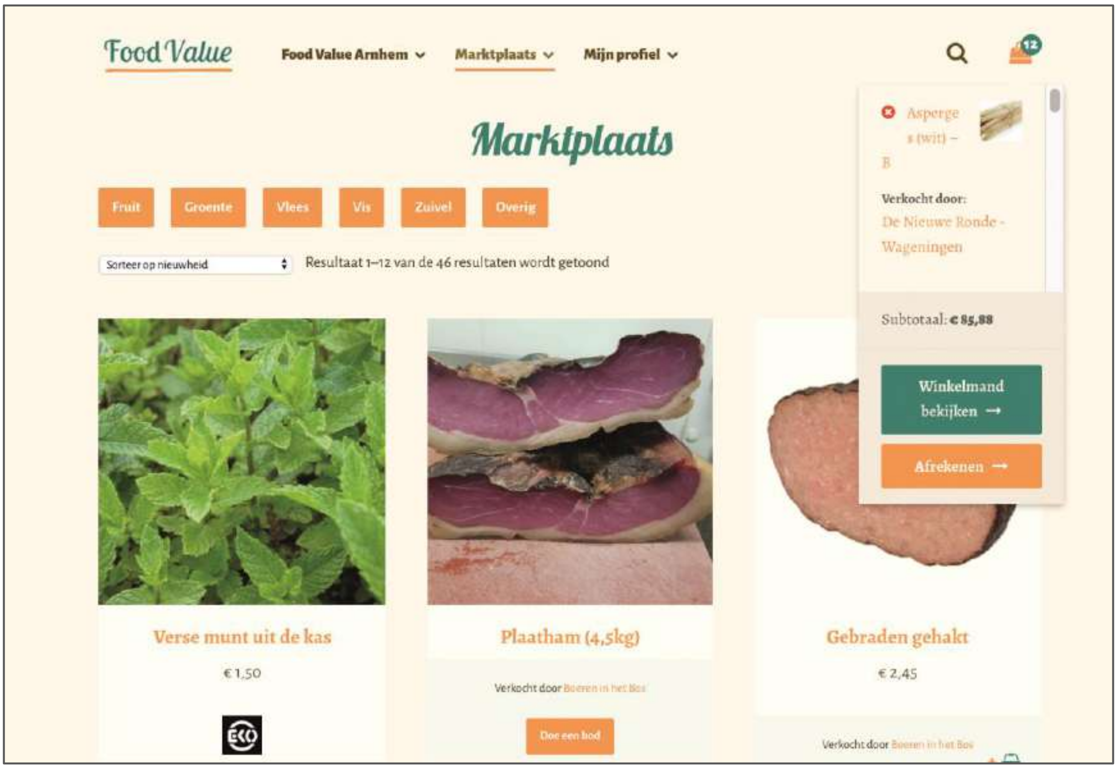


Figure 2: Example of the webshop/marketplace where all the shops of all he farmers come together.

DURUM WHEAT IN OLIVE ORCHARD: MORE INCOME FOR THE FARMERS?

Panozzo A[1], Desclaux D[1*]

(1) DiaScope- Inra–Domaine de Melgueil-34130 Mauguio, France

*Corresponding author: dominique.desclaux@inra.fr

Abstract

The present study arises from the difficult sustainability of organic olive orchards in Mediterranean areas that present usually a low productivity. Literature provides examples of increased olive productivity when associated to understorey crops but mainly cover crops. This study highlights that, (i) it is possible to grow field crops in an abandoned olive orchard without ploughing to avoid olive root damages, (ii) agroforestry can improve the olive orchard profitability by implementing a crop rotation based on durum wheat and legumes. Since they are yearly pruned, Olive trees increased progressively their productivity and the associated durum wheat provides an additional source of income to the farmer. Furthermore, if durum wheat varieties adapted to agroforestry conditions would be provided by breeders, they could reach higher yield when associated with olives and thus increasing the orchard sustainability.

Keywords: agroforestry; oil market, breeding; sustainability

Introduction

Olives and olive oil are the key basis in the healthy Mediterranean diet and the demand is increasing for such products coming from sustainable and organic farming (Afidol 2015). Most often organic orchards are zero input ancient orchards located in extensive hilly and mountainous areas susceptible to soil erosion (Taguas et al. 2010). These low-density olive orchards present a low productivity and therefore are progressively abandoned (as described in the EU Olivero project: Duarte et al. 2008). High-density olive orchards have been spreading over flat Mediterranean regions in order to get advantages from fertile lands and better condition for agricultural practices (Pastor et al. 2007). But, they usually need the use of chemical treatments and are therefore not totally compatible with the organic regulation. Moreover, despite the increasing production, this system does not always ensure better farm profitability because of the increasing volatility of olive oil market prices and because of the fruit-bearing alternance.

Traditional or high-yielding Olive orchards present most often large space between tree rows (5m to 9m). To face the above issues and also the growing needs for (i) arable land use optimization, (ii) sun radiation use maximisation and (iii) erosion limitation, sowing an associated crop in the olive tree inter-rows could be a relevant solution. As organic durum wheat and chickpea are also typical Mediterranean crops, cultivated over the same environmental conditions than olive trees, they represent interesting alternatives to be the associated crops. The aim of this paper is to answer the following questions: (i) Is-it possible to grow field crops in an abandoned olive orchard without ploughing to avoid olive root damages? (ii) What is the impact on the olives production? (iii) May this agroforestry system produce additional income for farmers?

Materials and methods

Experimental design

The olive orchard, located at INRA station DiaScope in Mauguio, France (43º35’N, 3º45’E), was planted in 2002 in a 6 x 6m design (Figure 1- left). The olive trees CV. Picholine) have never been pruned neither treated until the year 2012 when the orchard has been officially converted into organic. Then trees were seriously pruned for the first time to reconstruct the canopy structure. From 2014 to 2017 trees have been yearly pruned during the spring period and olives have been hand-harvested at the beginning of November each year.

A part of this orchard was in association with durum wheat or legumes (Agroforestry treatment) (Figure 1- left) and another part was covered by natural grasses (“forest” control), as the soil has never been ploughed neither drilled.

Crop association management

From October 2014 to 2017, 25 varieties of durum wheat have been sown in an annual rotation with legumes (chickpea, fababean, forage mix) between olive trees rows (Figure 1-right, yellow parts) just after olive fruit harvest. The soil was drilled only in the first 10 cm followed by a rotary harrow passage. Weeds were controlled with a rotary hoe during early season. By respecting organic regulation, no treatment has been done to the crop and the tree for the whole period, neither protection neither fertilization products were added. Wheat plots have been sown annually during autumn (November /December) and harvested at the end of June. The straws were grounded in September and incorporated into the soil.

Each year and for each tree, the total amount of olive was weighed, the number of olives fallen on the soil surface was estimated visually and samples of 100 counted olives were weighed.

Figure 1: Olive tree orchard (google earth capture – left photo) and same orchard with durum wheat crop associated (right photo). Left photo legend: yellow areas = agroforestry (AF) treatment; green areas = “Forest” control.

Economic impact of association

Profitability of introducing durum wheat crop cultivation into an organic olive orchard has been evaluated. The economic analysis has been carried on for the two components of the system: additional income given by durum wheat selling and olive trees productivity.

The gross profit of durum wheat production was calculated by multiplying the average yield of the 25 genotypes with the average (2014-2017 period) organic durum wheat selling prices in the South of France. Direct profit has been deduced by eliminating the production charges. It was compared with the average yield reached in the open-field control. Concerning the olive production, the average yield registered in some zone of the yellow part (AF treatment as shown in fig.1) was compared with those registered in some zones showing same fertility level in the green part (natural grass – Forest control). The price references used in the analysis arises from South of France organic olive market (MarketOlea 2016).

Results and discussion

Impact on olive production

The olive orchard showed a heterogeneous production according to space and time. In 2014, while intercropping (AF) was not yet implemented, olive production was highly variable between rows (from 220 g for row A to 1416 g for row H) and generally very low. Two zones showing differentiated olives productivity in 2014 were highlighted (Figure 2) and their evolutions over time were compared according to the treatment (Agroforestry or "Forest" control) (Table 1).

A	B	C	D	E	F	G	H
P71	P30	P08	P35	P35	P21	P28	P28
P71	P71	P18	P28	P21	P49	P18	P21
P71	P30	P28	P35	P49	P30	P30	P18
P08	P18	P08	P35	P21	P28	P21	P35
P18	P21	P18	P28	P49	P08	P30	P08
P08	P71	P28	P71	P71	X	P66	P35
P18	P28	P30	P66	P30	P08	P18	P66
P71	P49	P21	P71	P21	P66	P30	P49
P49	P35	P71	P66	P49	P30	P49	P35
P49	X	X	P35	P30	P66	P18	P35
P08	P21	P18	X	P28	P08		

Legend
Initial average productivity
Low (400 g/tree)
High(700 g/tree)
Inter-row management
Agroforestry
"Forest" control

Figure 2: Zones of fertility on the olive tree orchard determined in 2014 by weighing olive production tree per tree.

Considering the low fertility zones, the agroforestry zones reached a higher olive fruits yield in 2017 than the grassed zones (Forest control). However, in the high fertility zones, no difference was noticed. The average increase of productivity over the 2014-2017 period was + 393% when crop is associated and +294% in the grassed zones.

Table 1: Evolution of the olive trees productivity, according to the fertility zones and to the treatment.

Fertility Zones		Yield of olive tree, g (mean)				Increasing yield, %
Productivity level (in 2014)	Treatment	2014	2015	2016	2017	(2014/2017)
Low	Agroforestry	385 a	2673 a	3114 a	19987 a	+ 503 a
Low	Forest control	425 a	1585 b	1770 b	7605 b	+ 304 b
High	Agroforestry	671 a	1822 a	3208 a	12494 a	+ 282 a
High	Forest control	762 a	1791 a	2976 a	13494 a	+ 285 a

The weight of 100 olives decreased from 2015 to 2017, while the yield increased. In association with durum wheat, the weight of 100 olives went from 481 g in 2015 to 263 g in 2017, and a similar decrease is noted on the grasses zones: 457 g/100 olives in 2015 and 300 g/100 olives in 2017.

Economic impact of agroforestry

- **Organic olive orchard**

In high fertility zones, Olive production was not reduced by crop association. And in low fertility zones, a difference of 25% was noticed between the yield increase in agroforestry treatment and in forest control. A farmer can expect at least the same production or in some cases get an additional income (until 1250 €/ha) when intercropping an associated crop in the olive orchard.

Yield organic Picholine olive orchard t/ha	**Additional Yield in organic agroforestry** t/ha	**Olive oil from additional productivity** litres	**Organic olive oil market price** euros per litre	**Additional gross profit** euros/ha
4-10	**1-2.5**	**100-250**	**5€**	**500-1250€**
Average Yield obtained in non-irrigated or irrigated conditions in the South of France territory (Afidol 2015)	25% of increasing yield compared to control (our results period 2014-2017)	Additional litres produced (10 kg Picholine olives = 1 litre of olive oil) (Afidol 2015)		Yield x market price

➢ **Organic durum wheat**

Economic profitability arising from durum wheat in agroforestry system

Yield in organic full sun t/ha	**Yield in organic agroforestr y** t/ha	**Organic durum wheat price** euros per ton	**Gross profit** euros/ha	**Production costs** euros/ha	**Direct profit** euros/ha
1.8	**1**	**390 €**	**390 €**	**260 €**	**130 €**
Average Yield of the 25 varieties grown as sole crop (2015-2017)	Average yield of the 25 varieties grown in agroforestry (2015- 2017) 44% of reduction comparing to full sun	335-445 €/ton Average price (2014/2017) revenuagricole.fr	Yield x price	130 €/ton inputs 130 €/ton mechanical operations threshold cost to be competitive (Arvalis 2013)	(= Gross profit- Production costs)

The yield of durum wheat cultivated between olive tree rows was estimated at 1t/ha, showing a reduction (44%) compared to sole durum wheat grown in full sun conditions. The production costs and the market prices come from local references in organic farming context. A direct profit of 130€/ha may be reached thanks to the durum wheat association. This estimation doesn’t integrate the other crops of the rotation and the eventual need of workforce, and considers a level of yield reduction equal to 44%. But this reduction can be lower according to the choice of the durum wheat genotypes (less than 7% of reduction with agroforestry-adapted cvs) (Desclaux et al. 2016), and therefore the farmer may obtain higher income.

Finally, by adding the profitability arising from the additional olive tree productivity (500 to 1250 €/ha) and from the organic durum wheat sold (130 € per hectare, not considering the ground space hosting olive tree rows), we can estimate a potential adding profitability coming from the whole agroforestry system between 630 and 1380 €/h.

Conclusion

The present study arises from the difficult sustainability of organic olive orchards in Mediterranean areas, usually mainly associated to low productivity. Literature provides examples of increasing olive productivity when associated to understorey crops but mainly cover crops (Martínez Raya et al. in 2006; Correia et al. 2015). This study highlights that, by implementing a crop rotation based on durum wheat and legumes, agroforestry can improve the olive orchard profitability. Since they are yearly pruned, Olive trees increased progressively their productivity and the associated durum wheat provides an additional source of income to the farmer. Furthermore, if durum wheat varieties adapted to agroforestry conditions would be provided by breeders, they could reach higher yield when associated with olives and thus increasing the orchard sustainability.

References

Afidol (2015) Guide du planteur d’oliviers en Languedoc-Roussillon. Version 5.

Arvalis (2013) Analyse de la compétitivité du blé dur en AB; periodical journal.

Correia CM, Brito C, Sampaio A, Dias aa, Bacelar E, Gonçalve B, Ferreira H, Mountinho-Pereira J, Rodriges MA (2015) Leguminous cover crops improve the profitability and the sustainability of rainfed olive (Olea europaea L.) orchards: from soil biology to physiology of yield determination. Procedia Environ Sci 29: 282-283.

Desclaux D, Huang HY, Bernazeau B, Lavene P (2016) Agroforestry: New Challenge for field crop Breeding? 3rd European Agroforestry Conference, Montpellier, France.

Duarte F, Jones N, Fleskens L (2008) Traditional olive orchards on sloping land: Sustainability or abandonment? J Environ Manage 89: 86-98.

Martínez JRF, Durán Zuazo VH, Martínez Raya A (2006) Environmental impact from mountainous olive orchards under different soil-management systems (SE Spain). Sci Total Environ 358: 46-60.

Pastor, M, García-Vila M, Soriano MA, Vega V, Fereres V (2007) Productivity of olive orchards in response to tree density. J Hortic Sci Biotechnol 82: 555-562.

Taguas EV, Peña A, Ayuso JL, Pérez R, Yuan Y, Giráldez JV (2010) Rainfall variability and hydrological and erosive response of an olive tree microcatchment under no-tillage with a spontaneous grass cover in Spain. Earth Surf Proc Land 35: 750-760.

AGROFORESTRY FOR FOOD IN THE U.S. CORN BELT: KEY ASPECTS OF TREE CROP IMPROVEMENT TO ENABLE NOVEL SYSTEMS

Revord RS[1, 2, 3*], Lovell ST[1, 2], Mattia C[1], Molnar TJ[4], Wolz KJ[3, 5]

(1) Department of Crop Science, University of Illinois, Champaign-Urbana, United State (2) Institute for Sustainable Energy and Environment, University of Illinois, Champaign-Urbana, United States (3) Savanna Institute, Madison, WI, United States (4) Plant Biology Department, Rutgers University School of Environmental and Biological Sciences, New Brunswick, New Jersey, United States (5) French National Institute for Agriculture Research, Montpellier, France

*Corresponding author: Revord1@illinois.edu

Abstract

Numerous tree crop species are available for integration into agroforestry. To best guide this integration, a systematic process is needed to understand the transferability of improved tree crop selections beyond the specific environments in which they were breed and tested. In the U.S., the integration of tree crops will largely be constrained to the marginal land-types of maize. Thus, fundamental to understanding the prospective environmental transferability of tree crops is discerning the overlap between their suitable land-types and those that are marginal (to maize). Defining of this “overlap” can the guide integration of existing breeding selections and more importantly define the target environments for continued variety improvement.

Keywords: tree crops; breeding; decentralized; target environment

Introduction

The benefits of agroforestry’s regulatory services are well characterized in the Midwest U.S. Select systems can even improve farm-level profitability when strategically integrated into the agricultural landscape (Brandes et al. 2016; Brandes et al. 2017; Wolz 2018), bringing pragmatism to the strategic diversification within U.S. Corn Belt. Nevertheless, adoption of agroforestry systems continues to be relatively minimal throughout this region.

A growing body of literature suggests a path to increase the adoption potential of U.S. agroforestry systems lies in the integration of food producing tree crops (henceforth referred to as tree crops) (Jose 2009; Lovell et al. 2017; Mattia et al. 2016; Mattia 2017; Molnar et al. 2013; Mori et al. 2017; Rhodes et al. 2016; Wolz et al. 2017; Wolz and DeLucia 2018). Such systems, described as Multifunctional Woody Polycultures (Lovell et al. 2017), provide a unique opportunity to integrate new food production capacity into the Corn Belt simultaneous to the addition of regulatory services (Lovell et al. 2017; Wolz et al. 2017). While these agroforestry systems are studied and considered for adoption, the extent is limited by the availability of improved and adapted tree cop germplasm.

Numerous tree crop species are available for integration into agroforestry systems (Molnar et al. 2013); however, they are often underutilized species and have varying degrees of assembled genetic resources. Additionally, the development of these tree crops will in many cases be constrained to the marginal land-types of maize. Presently, the discrete classification of these marginal land-types as they relate to the productive potential of the tree crops of interest is not known. These realities present a gap in which to focus agroforestry development for the U.S. Corn Belt.

Fortunately, select tree crops of interest are rather amendable to schematic breeding and have wild relatives endemic to the range of the U.S. Corn Belt. Here, we present key aspects to systematically exploit these tree crops and their wild relatives to adapted cultivated germplasm to targeted marginal environments of the U.S. Corn Belt and as a result enable the integration of new agroforestry systems.

Key aspects of tree crop improvement

Tree crop wild relatives (TWRs) have a large role to play in the extent to which agroforestry development integrates into the U.S. Corn Belt. Three key roles of tree crop wild relatives that are essential to recognize are:

i. The suitable habitats of tree crop wild relatives can help inform the marginal lands that agroforestry research targets development.

ii. Tree crops wild relatives are often a rich source of novel diversity that is exploitable (Migicovsky and Myles 2017; Miller and Gross, 2011) and can create new opportunity for agroforestry (Molnar et al. 2013).

iii. Steps i. and ii. allow breeders to decentralized selection to the identified target environments; the fundamental step towards expanding agroforestry's potential integration.

Defining target environments for tree crop adaptation

In the Central U.S., target environments for tree crop adaptation are primarily constrained to environments where the maize-soybean rotation is low-yielding. This constraint muddies expectations regarding the respective availability and scale of environments that are suited to tree crops. Additionally, the abiotic characteristics of low-yielding land can vary significantly from one farm to another, which results in many discrete target environments. Adaptability traits to these target environments can be leveraged from tree crop wild relatives and introgressed into cultivated selections, but executing this scheme requires a framework to define and prioritize target environments. Here, we conceptually define the target environments and lay forth a systematic framework to identify the characteristics of these environments concerning the tree crop of interest.

Target environments will be structured base upon deviations from the soil and rainfall parameters that are suitable to the cultivated selections. Therefore, it is first necessary to define discrete classes of suitability. The classes are as follows, as presented in Kidd et al. (2015):

i. Well suited – no limitation to productivity

ii. Suited – minor limitation to productivity

iii. Marginally suited – moderate limitations to productivity

iv. Unsuited – serve limitations to productivity

Limitations reflect known constraints in soil, rainfall, or topography that influence productivity of cultivated selections of the tree crop. These parameters are contextualized using hazelnut as example in Table 1 (adapted from Kidd et al. 2015).

Table 1: Suitability parameters of cultivated hazelnut (adapted from Kidd et al. 2015).

Suitability class	Soil depth (cm)	pH (0-15cm)	EC (ds/m) (0-15cm)	Clay % (0-15 cm)	Soil drainage class	Stone % (>20 cm)	Rainfall , mean August (mm)
Well suited	>50	>6.5	<0.15	30-50	Well to moderate	<10	<80
Suited	40-50	5.5-6.5	<0.15	30-50	Imperfect	10-20	<50
Marginally suited	30-40	6.5-7.1	<0.15	30-50	Imperfect	10-20	<50
Unsuited	<30	<5.5 or >7.1	<0.15	>50 or <10	Poor to very poor	>20	>50

Detailed characterization of the target environment is, of course, a species-specific task, and it will largely be dependent upon geospatial mapping to identify overlap between the conditions suitable to the tree crop of interest (and its relevant wild relatives) that also render maize low-yielding. As mapping distinguishes prospective target environments, their respective sizes and amenability to germplasm improvement can guide the priority in which they are targeted. While conceptually straightforward, discrete characterization of the target environments will expose the most pertinent abiotic limitations to tree crop adaptation as well as the corresponding TWR adaptive traits need for development pipelines. Specifically, the output of geospatial mapping would inform: i) target environments presently well suited or suited for initial testing of breeding selections ii) and exploitation of corresponding TWR accessions to improve the adaptability of cultivated selections to respective target environments.

Conclusion

Diversifying the availability of adapted and improved tree crops provides Midwest U.S. farmers with more options for adopting agroforestry. However, the broad integration of tree crops will be most successful only if the tree crops' productivity is maintained on unproductive row-crop acreage. This talk lays forth a systematic framework to accomplish tree crop adaption and improvement in this regard and provides examples using hazelnut.

References

Brandes E, Mcnunn, G S, Schulte L A, Bonner I J, Muth D, Babcock B A, Sharma B, Heaton EA (2016) Subfield profitability analysis reveals an economic case for cropland diversification. Environ Res Lett 11: 014009.

Brandes E, Mcnunn GS, Schulte LA, Muth DJ, Vanloocke A, Heaton EA (2017) Targeted subfield switchgrass integration could improve the farm economy, water quality, and bioenergy feedstock production. GCB Bioenergy.

Jose S (2009) Agroforestry for ecosystem services and environmental benefits: an overview. Agrofor Syst 76: 1-10.

Kidd D, Webb M, Malone B, Minasny B, Mcbratney A (2015) Digital soil assessment of agricultural suitability, versatility and capital in Tasmania, Australia. Geoderma Regional 6: 7-21.

Lovell ST, Dupraz C, Gold M, Jose S, Revord R, Stanek E, Wolz KJ (2017) Temperate agroforestry research: considering multifunctional woody polycultures and the design of long-term field trials. Agrofor Syst 1-19.

Mattia, CM, Lovell ST, Davis A (2016) Identifying barriers and motivators for adoption of multifunctional perennial cropping systems by landowners in the Upper Sangamon River Watershed, Illinois. Agrofor Syst 1-15. https://doi.org/10.1007/s10457-016-0053-6.

Mattia CM (2017) Identifying targets for multifunctional perennial cropping systems implementation through a landowner adoption preferences survey and a spatial suitability analysis. https://www.ideals.illinois.edu/handle/2142/97482 (acessed 06/04/2018).

Migicovsky Z, Myles S (2017) Exploiting wild relatives for genomics-assisted breeding of perennial crops. Front Plant Sci 8: 460.

Miller AJ, Gross BL (2011) From forest to field: Perennial fruit crop domestication. Am J Bot 98: 1389-1414.

Molnar TJ, Kahn PC, Ford TM, Funk CJ, Funk CR (2013) Tree crops, a permanent agriculture: Concepts from the past for a sustainable future. Resources 2: 457-488.

Mori G O, Gold M, Jose S (2017) Specialty Crops in Temperate Agroforestry Systems: Sustainable Management, Marketing and Promotion for the Midwest Region of the USA. Integrating Landscapes: Agroforestry for Biodiversity Conservation and Food Sovereignty. Springer.

Rhodes TK, Aguilar FX, Jose S, Gold M (2016) Factors influencing the adoption of riparian forest buffers in the Tuttle Creek Reservoir watershed of Kansas, USA. Agrofor Syst 1-19 https://doi.org/10.1007/s10457-016-0045-6.

Wolz KJ, Lovell ST, Branham BE, Eddy WC, Keeley K, Revord RS, Wander MM, Yang WH, Delucia EH (2017) Frontiers in alley cropping: Transformative solutions for temperate agriculture. Glob Change Biol 24: 883-894.

Wolz KJ (2018) Frontiers in alley cropping: transformative solutions for temperate agriculture. Doctorate Dissertation, University of Illinois at Urbana-Champaign.

Wolz KJ, Delucia EH (2018) Alley cropping: Global patterns of species composition and function. Agr Ecosyst Environ 252: 61-68.

THE EMERGING PRACTICE OF FOOD FOREST - A PROMISE FOR A SUSTAINABLE URBAN FOOD SYSTEM?

Van Dooren N[1*], Oosterhof G[1], Stobbelaar D[1], Van Dorp D[1]

(1) Professorship Sustainable Foodscapes in Urban Regions, Van Hall Larenstein University of Applied Sciences, Velp, The Netherlands

*Corresponding author: noel.vandooren@hvhl.nl

Abstract

In the Netherlands, “food forests” recently became very popular. The broader perspective is that of agroforestry. This paper explores in a speculative way the starting points for a range of projects in our professorship. Taking a landscape perspective, we ask what role food forests can have in regional food systems, and how a large-scale development of food forests could be spatially organized.

Keywords: food forest; landscape; agroforestry; food system; design

Introduction

In the Netherlands, a growing number of initiatives can be noted that address themselves as “voedselbos” or food forest, partly building upon international examples and experience, as for example provided by Hart (1996), Crawford (2010), and Shepard (2013). We consciously use “food forest” here, and not the broader term agroforestry, as will be explained. Most of the newly planned or realized initiatives in the Netherlands measure about 0.5 to 5 hectares, with Van Eck's Ketelbroek near the city of Nijmegen as one of the leading examples. Food forest as a conceptual idea combines trees, shrubs, perennials and annuals in a variety much larger than in common agriculture. The variety of plants, and the organization in different layers, is said to contribute to a system that sustains itself with a minimum input of external energy and human effort, and a minimum output of waste. Generally, the production of food is seen as one of the goals, but ecosystem services and social services are put forward just as much as benefits of food forests.

New initiatives are started by farmers wanting to transform their enterprise, and to develop a food forest on (part of) their land, but just as often the initiators stem from other backgrounds. This also implies that it is not always land in agricultural use that is transformed; it is today also urban green areas, wasteland, estate or even nature areas that are transformed into food forests.

Aim

Our professorship starts from the larger question of how western metropolises will feed themselves in the future, in the context of a circular economic system, and with the requirement of an accessible, attractive, healthy landscape. It is in that context that we study alternative approaches to food production for their possible contribution to such sustainable regional food systems. Food forests, or agroforestry, may be such an alternative approach. In the Netherlands, with its very intensive agricultural system, such views had and have no strong position. Today, however, both from the side of farmers seeking for alternative roads, and of non-farmers with a wide range of backgrounds, food forests are seen as an attractive new model. And perhaps the relatively small scale of these new initiatives help to literally find a place within the very intensive agricultural system. From a research perspective, we cooperate with these new initiatives, to find out how they function and why they succeed or fail. This addresses several questions, ranging from clarifying the theoretical background to proposing feasible business models, to developing alternative logistic chains, and to assessing ecological value, but always in the context of landscape and design. Our professorship seeks to interpret potential effects on landscape, and engages via design, by which we mean actively creating the conditions for such new initiatives, visualizing what they would look like, and integrating them in the larger spatial system.

Seen from the aim of regional and sustainable food systems, many of the current initiatives are too small to make a difference. Therefore in a speculative way we think of food forest systems on a very large scale – be it in large numbers of small enterprises of a few hectares, or big ones of 200-1000 hectares. Then, food forests can make a difference, and the perceived advantages in comparison to today's agriculture can be played out.

As the research projects and the food forest initiatives related to this are in their starting phase, this paper wants to give an overview of the thoughts that drive these projects.

Larger frame

The larger frame for our food forest engagement is a strong concern for sustainable food production, and a desire for a sustainable way of treating the earth. Today's agriculture comes with big problems, from land degradation, extinction of species and pollution of ground water to larger societal problems such as obesity, injustice and alienation of nature. New roads are seen in different directions. High tech production in closed systems, allowing for maximum health, minimal input and zero waste, or a more multifunctional agriculture, serving more goals at the same time, such as wildlife management. Often the global system is blamed to be a major cause and as a response it is said that our food system should be organized more on a regional scale (i.e.50-300 kilometres around major cities).

Food forests, as an idea, could fit in some of the perceived solutions, as a manifestation of a broader phenomenon that is best addressed with the word agroforestry. In the Netherlands, currently, the term 'food forest' is much more in use. Apart from the linguistic debate this has an economical dimension. Food forest is more easily associated with gardening, whereas agroforestry is certainly seen as a commercial agricultural practice, and would be in strong competition with traditional agriculture.

Food forests, but no food?

Whether we should be sceptical or positive, or both at the same time, about such ideas, depends on our expectations. At Van Hall Larenstein, we take as a shared starting point that we want to look at such new initiatives from the viewpoint of food production – that is to say, other social or ecological or economical services we consider of secondary interest. Seen in that way, we discuss with new initiatives their ambitions: how much, and what food ingredients, do you expect to be produced? We note that more often there is a certain shyness to speak about food forests in that way, or even a resistance, as in comparison to common agriculture the production is presumably less, and certainly less quantifiable. This in fact points at a contradiction: due to its multifunctional approach, the isolated question towards measurable produce becomes difficult to answer, especially if we look at it in terms of business models. In some cases it even goes as far as the production of food only being the background for a number of very different services, that guarantee an income –even if that income is often very moderate- and give meaning. For us, however, the food production side is crucial, if only because the word food forest in itself underlines the aspect of food. But primarily it helps us to decide why we should engage in food forests. Speaking about the food production side helps to think of food forests as a potentially sustainable business model. And such sustainable business models imply organization. If food has to be produced in a way that it can be quantified, and harvested efficiently, and planned over the years, we immediately see that this comes with design – such as, for example, an organization in rows that are accessible for machinery – in that sense, alley cropping cannot be too far away from food forests aiming for a serious food production. For us, from a landscape point of view, this is interesting, as it tells something about spatial organization, visual impact, and perhaps accessability.

An urban perspective

In certain parts of the world agroforestry, or food forest, is developed as a new road in agriculture for itself, covering large rural areas. In the Netherlands, such initiatives generally orient themselves on the nearby city, as their legitimacy relates to changed perceptions of food and agriculture within the urban culture. That also means that such initiatives partly have to shape their own market, for various reasons: their products may be niche products with higher prices, they may produce a larger variety, and less known species, so that a bit more curiosity of consumers is required, and they certainly will produce less quantity, so that consumers and producers relate in a more specific way – we will not find the produce in the large supermarkets. In the Netherlands with its high land value and strong competition on every square metre, the perceived legitimacy of such a new way of producing food is essential. From the perspective of landscape this is highly interesting, as it broadens the issue from mere food production or business models to landscape design: accessibility, attractiveness, and identity become important.

In the context of our professorship, studying sustainable foodscapes in relation to cities, we want to take these initiatives seriously, and to carefully search for how these initiatives can become a steady part of the landscape in terms of (agro)economy and planning. That is one of the reasons we want to look for food forests on a much larger scale than the current small initiatives. We are convinced that studying these new perspectives on a regional scale, in terms of hundreds or thousands of hectares, allows to see the specific challenges for planning and landscape design. Therefore, we not only respond to initiatives that look for support in terms of research, but we also intend to *shape* or co-shape initiatives on the larger scale, as a means to study the challenges that come with it.

From idealism to reality

In our experience, many of these new initiatives rely on idealism, or even the strong belief that the road as proposed simply is *good*. This enshrouds what we think is important, and that is a debate on how such food forests would function in a regional food system, and in what way they can be designed to fit in regional landscapes. That requires to rethink such food forests and to describe them as rather regular farming systems, to be compared with other ways of farming and producing food. In a small piece of research, presented in another paper, we studied the transformation of two farms, to be able to be more precise about what is exactly the future business model, and to be able to consider what would happen if such businesses, in all their variety, would be multiplied. The focus on food and the business model does not deny the innovation and wider services such farms bring for nature and society, but enables to understand them as enterprises with an economic rationale. A focus on a regional scale also requires looking at such food forests as components of a bigger landscape, more than the very small experiments we see today in the Netherlands. From the perspective of landscape planning, landscape architecture and urbanism, such food forests become very relevant if they can be upgraded to systems of hundreds of hectares, and convincingly can show to be a serious alternative for traditional farming on a regional scale. If so, they may propose an entirely new agricultural landscape, and in terms of a food system, entirely new chains of food towards the nearby city. Specifically in the Netherlands this is essential, as the high value of land entails a need for a substantial income per unit land area. Currently, we are testing this with research activities carried out in the surroundings of the city of Nijmegen.

We are interested in the fact that perhaps small enterprises in the range of 1-5 hectares work together in larger networks, and together can provide a range of produce. At the same time, we engage in projects for large enterprises, in terms of 100-1000 hectare. The question of whether one strategy (many small) has advantages above the other (few large) is one of our research questions. The same goes for the comparison between food production on areas previously not considered in terms of food, and 'traditional' agricultural land. This happens in our *Vruchtgebruik* project –best translated as 'usufruct'- in which we study the options for public urban green space to produce substantial quantities of fruit, which does not happen, currently. We look at this in terms of planting and management, but it is vital to think through the potential food chains: what are appropriate harvesting techniques, what is the range of produce and what is the market for this produce? For example, on our own estate of 30 hectare we study to what extent the school canteen can integrate produce of a new food forest. What type of produce will we have, how will this develop over time, and what products can be made out of it? Can this be sustainable, also in economic terms, or is it merely a nice hobby without relevance for a food system that also has to be efficient, reliable and relatively cheap? This will be developed as a research project in which we can measure, count and experiment.

Outlook

In the coming 2-3 years we will be engaged in a number of projects all revolving around the words food forest or agroforestry. We will study and work with initiatives on a very small scale, and grouped towards large-scale transformations of landscape. Different cities will be part of such projects, such as Nijmegen and Almere. We cooperate with the cities and universities of Barcelona, Ghent and Coventry to compare our experiences on this, and we will test on our own 30 hectare school estate both planting, managing and harvesting a small-scale food forest as well as the integration of it in the business model of our own canteen. Combining such experiences, we believe to obtain interesting research outcomes.

References

Crawford M (2010) Creating a Forest Garden. Working with Nature to Grow Edible Crops. Green Books Cambridge.
Hart R (1996) Forest Gardening: Rediscovering Nature and Community in a Post-Industrial Age. UIT Cambridge.
Shepard M (2013) Restoration Agriculture. Real world permaculture for farmers. Acres U.S.A., Inc.

OPPORTUNITIES FOR AGROFORESTRY IN FINLAND

den Herder M[1*], Vanhanen H[2], Karvinen P[3], Matila A[4], Mattila I[5], Nuutinen S[6], Ryhänen S[7], Siikavirta K[8], Westerstråhle M[6], Verdonckt P[9], Muñiz Alonso A[10]

(1) European Forest Institute, Joensuu, Finland (2) Natural Resources Institute Finland, Joensuu, Finland (3) Sammallahden tila, Viinijärvi, Finland (4) Tapio Oy, Helsinki, Finland (5) Kilpiän tila, Pusula, Finland (6) Putkisalon kartano, Rantasalmi, Finland (7) Rural Women's Advisory Organisation, South Savo Region, Mikkeli, Finland (8) Etelä-Savon elinkeino-, liikenne- ja ympäristökeskus, Mikkeli, Finland (9) INAGRO, Rumbeke-Beitem, Belgium (10) Fundación Empresa-Universidad Gallega (FEUGA), Santiago de Compostela, Spain

*Corresponding author: michael.denherder@efi.int

Abstract

Agroforestry has a long tradition in Finland. Examples include reindeer husbandry and the collection of berries and mushrooms. Grazing of wood pastures was common in the 1930s, but disappeared almost completely due to intensification of agriculture and forestry. Government support is nowadays the main source of income for farms managing traditional rural landscapes by grazing but there would be opportunities to generate additional income through e.g. ecotourism, well-being services, wild berry and mushroom cultivation, honey production, bioenergy production and direct sales. The AFINET project established Regional Agroforestry Innovation Networks in nine European countries. The Finnish network collected 18 ideas for agroforestry innovations. Management of young spruce stands by grazing, growing hops in agroforestry, and holistic farm management fully utilizing the grazing area as part of a viable business operation, are examples of promising innovations. Promising innovations are taken forward through active networking, information exchange, farm demonstrations and education days.

Keywords: innovations; stakeholders; agroforestry practice; northern Europe; wood pasture; arable agroforestry

Agroforestry in Finland

Although agroforestry is not very often associated to northern European climatic zones, agroforestry has a long tradition in Finland (Uusitalo and Peltola 2015). The most well-known examples of agroforestry practices in northern Fennoscandia are reindeer husbandry and the collection of non-wood forest products such as berries, mushrooms and wild herbs. Even though the climate in Finland is harsh, there would also be opportunities for vegetable production, although this is much less common. The purity of agricultural products in Finland is considered a main advantage. Due to the harsh climate, pests rarely reduce the quality of vegetables, which decreases the use of pesticides and opens opportunities for organic production (Anttila 2012; European Food Safety Authority 2013). In northern Finland, vegetable production has been decreasing and currently there is very little production of vegetables grown in outdoor conditions. Supply is far from covering the demand, especially since locally grown-food ideology has grown in recent years (Räty and Kajalo 2015). Therefore, studying and developing short and local food supply chains would provide opportunities for agroforestry in Finland in the future.

Grazing of forests and wood pastures is another agroforestry practice found in Finland (Uusitalo and Laurila 2015) (Figure 1). Forest and wood pasture grazing was still common in Finland in the 1930s, but disappeared almost completely in the 1950s with the intensification of agriculture and forestry. Forest and wood pastures are shaped when animals are grazing in the forest. Selective grazing of cattle modifies forest vegetation to a more meadow-like vegetation and speeds up nutrient turnover. An appropriate grazing pressure is important as grazing at intermediate pressure has in general a positive impact on biodiversity. In Finland, there were still about 2 million hectares of forest and wood pastures in the 1950s. Since then, the area of wood pastures (In Finnish: hakamaita) has decreased to about 1900-3300 ha and the area of forest pastures (In Finnish: metsälaitumia) to about 5000-9000 ha (Schulman et al. 2008). The quality of the remaining woody traditional biotopes has deteriorated considerably due to eutrophication and forestry operations. However, the maintenance of traditional biotopes, their landscape values and delivered ecosystem services provide opportunities for entrepreneurship and development of modern silvopastoral systems. Government support is until now the main source of income for farms managing key biotopes and traditional rural landscapes by grazing (Uusitalo and Laurila 2015). Nevertheless, there would be a range of opportunities to develop additional sources of side- or main income such as e.g. ecotourism, therapy and well-being services (Greencare), wild berry and mushroom cultivation, honey production, bioenergy production and direct sales of pasture meat (Uusitalo and Laurila 2015).

Figure 1: Traditional Finnish wood pasture with Scots pine (*Pinus silvestris*) and grazing horses.

The AFINET project – Agroforestry Innovation Networks

In the AFINET project (AFINET 2017), nine Regional Agroforestry Innovation Networks (RAIN) were created in nine countries (Spain, Portugal, Italy, Belgium, United Kingdom, Finland, Hungary, France and Poland) during the summer of 2017. The RAINs mainly consist of practitioners of agroforestry, complemented by experts from various fields and other stakeholders (e.g. technical advisors, associations, extension services, entrepreneurs, NGO's, administration, policy advisors), depending on the focus of the network events. The main objectives of the RAINs are: 1) to improve knowledge exchange between scientists, practitioners and other agroforestry stakeholders on agricultural and forestry practice, supporting innovation-driven research and ensuring a wide transfer of knowledge towards the end-users, 2) to co-create new knowledge, and 3) to put insufficiently exploited research results into practice.

Objectives and activities of the Finnish Regional Agroforestry Innovation Network

The main aim of the Finnish RAIN would be to increase the uptake of agroforestry in Finland by taking some of the identified agroforestry innovations forward. During the RAIN workshops, we will collect ideas for innovative agroforestry practices, their benefits and opportunities and identify bottlenecks, challenges and barriers for uptake of the innovations. In addition, the RAIN will also identify possible knowledge gaps and search for solutions to overcome the possible challenges. When a promising new innovation or existing bottleneck or barrier for uptake has been identified, existing scientific and practical literature will be examined to provide the state-of-the art knowledge to the RAIN members and to see if possible solutions to existing problems can be found. In addition, external experts can be invited to the following RAIN meetings to give a lecture on a certain topic of interest what has been identified by the RAIN members.

Another aim of the Finnish RAIN is to increase awareness on agroforestry in Finland. In Finland, agroforestry (In Finnish "agrometsätalous") is not a commonly known concept and most people have never heard of it. On the other hand, reindeer husbandry, forest grazing, beekeeping, hedgerows, shelterbelts, buffer strips and forest farming such as collecting berries and mushrooms are agroforestry practices which are very well known in Finland. Raising general awareness on the concept "agroforestry" would already be a huge step forward in promoting this sustainable land use practice.

Some examples of identified innovations

The first Finnish Regional Agroforestry Innovation Network meeting took place in September 2017. During the meeting, the participants collected 18 ideas for agroforestry innovations. Some examples of some of the most promising ideas are described below:

Management of seedling/sapling stands by grazing

Pre-commercial thinning is beneficial for future stand development as it speeds up wood production. Pre-commercial thinning is often performed by a forest contractor but in many cases management is delayed or neglected completely which affects the future productivity of the stand. However, understory and shrub vegetation in young seedling/sapling stands can also be managed by grazing animals. This would work best in spruce and pine sapling stands as most grazers do not prefer spruce/pine. Grazing of seedling and sapling stand could possibly save costs for pre-commercial thinning and improve nutrient cycling which is beneficial for future stand development.

Challenges for the implementation of this practice include the cost of fencing and herding, finding the appropriate grazing pressure and possible damages to the planted seedlings or saplings. Before implementation of this practice we would need more knowledge on the optimal grazing pressure in relation to different tree species and a cost benefit analysis. One proposed solution to overcome the challenges would be to establish some experimental or demonstration sites in a well-planned experimental design which could serve as an example to other farmers.

Growing hops in an agroforestry system

Hops (*Humulus lupulus*) can be grown on stalks in field boundaries or on forest boundaries supported by trees. Hop production in an agroforestry setting can fulfil the needs of local micro-breweries. Micro-breweries are interested in delivering a local and organic product. However, locally grown hops are not available on the market in Finland and almost all hops are imported from Germany or other central European countries or the USA. Local or "agroforestry beer" might be an attractive product for many "beer connaiseurs".

The main challenges for implementing this innovation would be to find the markets and make agreements with a small-scale brewery. Another challenge would be to upscale hop production so that micro-breweries would have a guaranteed stable supply of raw material. In a new research project, the Natural Resources Institute Finland has collected close to one thousand old Finnish hop varieties from different provenances in order to select those varieties combining a satisfactory yield and a good taste for beer making (Natural Resources Institute Finland 2017a; 2017b; 2018). In order to take this innovation forward and grow hops in an agroforestry system, we would need more knowledge and research on growing techniques and the effect of tree shade on hop yield and quality.

Landscape grazing and fully utilizing the grazing area as part of a viable business operation

Grazers can be used in landscape management by shaping attractive landscapes. This would create opportunities for rural and farm tourism, for example scenic farm-landscape cafeteria's, hiking trails and touristic routes through the farm landscape. The idea is to create an economic sustainable business model combining wood production from forests and livestock grazing in combination with other entrepreneurial activities (e.g. tourism, Greencare, non-wood forest products, bioenergy, direct sales of farm products).

The main challenges include agreements between the land owner and the owner of the animals, initial investments and the continuity and long-term vision of supporting policies. In order to take this practice forward, networking and information sharing between farmers, land and animal owners should be facilitated. In addition, it would be useful to develop a benchmarking system where the performance of different farms and their activities can be compared.

Future plans

In the Finnish Regional Agroforestry Innovation Network, the plan is to take some of the most promising innovations forward. This can be achieved by active networking, where the Finnish innovation network would facilitate interactions between the farmers and other supply chain actors, for example extension services, processors and retailers. In addition, there exist the possibility of trailing some of the most promising innovations. In Finland, currently there exists no Operational Group related to agroforestry. One idea would be to apply for, and if the application is successful set up a new Operational Group where the most feasible and promising innovations can be tested. Finally, currently there exists no Finnish Agroforestry Association. The Finnish RAIN will consider setting up a Finnish Agroforestry Association, if it turns out during the RAIN workshops that there exists some regulatory or policy barriers for agroforestry implementation in Finland. A Finnish Agroforestry Association should be in a better position to influence decision making and the development of a regulatory framework allowing more successful implementation of agroforestry as a sustainable land use.

References

AFINET (2017) Agroforestry Innovation Networks. http://www.agroforestry.eu/afinet (accessed 14/12/2017).

Anttila P (2012) Lapin ilmanlaatu 2000–luvun alussa. In: Peltola R and Sarala P (eds) Pohjoinen puhtaus. Acta Lapponica Fenniae 24, Lapin tutkimusseura. http://www.lapintutkimusseura.fi/files/Acta%20Lapponica%20Fenniae%2024.pdf (accessed 9/04/2018).

European Food Safety Authority (2013) The 2010 European Union Report on Pesticide Residues in Food. EFSA Journal 11:3130. 808 pp. www.efsa.europa.eu/efsajournal (accessed 27/04/2018).

Natural Resources Institute Finland (2017a) Finnish hops to the world - LukeLEADS. Natural Resources Institute Finland. https://www.luke.fi/projektit/finn-hops/ (accessed 10/042018).

Natural Resources Institute Finland (2017b) Puutarhan vanhat aromihumalat panimoiden käyttöön. Natural Resources Institute Finland. https://www.luke.fi/projektit/aromihumala/ (accessed 10/04/2018).

Natural Resources Institute Finland (2018) Suomalaista pohjoista humalaa markkinoille. Natural Resources Institute Finland. https://www.luke.fi/projektit/polar-hops/ (accessed 10/04/2018).

Räty A, Kajalo M (2015) Pohjoisia vihanneksia lautasille. In: Uusitalo M and Peltola R (eds) Pohjoisen uusiutuvista luonnonvaroista kasvua ja kannattavuutta - Agrometsä- ja puutarhatalouden mahdollisuudet Pohjois-Suomessa. Luonnonvara- ja biotalouden tutkimus 24: 90-97.

Schulman A, Alanen A, Hæggström C-A, Huhta A-P, Jantunen J, Kekäläinen H, Lehtomaa L, Pykälä J, Vainio M (2008) Perinnebiotoopit. In: Raunio A, Schulman A, Kontula T (eds) Suomen luontotyyppien uhanalaisuus – Part 2: Luontotyyppien kuvaukset. Suomen ympäristökeskus, Helsinki. Suomen ympäristö 8: 397–465.

Uusitalo M, Peltola R (2015) Pohjoisen uusiutuvista luonnonvaroista kasvua ja kannattavuutta - Agrometsä- ja puutarhatalouden mahdollisuudet Pohjois-Suomessa. Luonnonvara- ja biotalouden tutkimus 24/2015.

Uusitalo M, Laurila M (2015). Metsälaidunnus ja paimenten uusi tuleminen? In: Uusitalo M and Peltola R (eds) Pohjoisen uusiutuvista luonnonvaroista kasvua ja kannattavuutta - Agrometsä- ja puutarhatalouden mahdollisuudet Pohjois-Suomessa. Luonnonvara- ja biotalouden tutkimus 24: 42-55.

A QUALITATIVE STUDY TO DEVELOP AN "AGROFORESTRY" BRAND: THE CASE OF THE SPANISH DEHESAS

Escribano M[1], Gaspar P[1], Maestre LM[1], Elghannam A[1], Mesías FJ[1]*

(1) Research Institute of Agricultural Resources (INURA). University of Extremadura. Avda. Adolfo Suarez, s/n – 06007 Badajoz (Spain)

*Corresponding author: fjmesias@unex.es

Abstract

This paper has focused on dehesa agroforestry systems, where the main productions are locally appreciated but often consumers are not able to identify and therefore, are not willing to pay a premium for. In this context, it was considered that the development of a brand covering dehesa products could be a useful tool to boost these systems, as long as it could evoke the set of benefits that dehesas provide. This research analyses consumers' view about the feasibility of a brand covering the products derived from dehesas using projective techniques. Results have shown that dehesa as a term to be used to label foods or other products would possess some positive meanings such as "natural" or "quality". However, it lacks other interesting connotations that are linked to more "modern" concepts. In order to make the brand more attractive to consumers, it should include additional concepts such as sustainability or socially responsible production.

Keywords: brand, dehesa, qualitative research, projective techniques

Introduction

Agroforestry systems provide numerous products and services to the citizens, who often are not aware of them, as they are not commercial products/services or, when found in the markets, are just considered as "another" product with no additional values and characteristics. Among the different alternatives to overcome these constraints that threaten Agroforestry systems, one of the most promising is the development of brands which could help consumers identify those products generated in these systems. In previous studies, stakeholders have stressed the need to explore new opportunities regarding product diversification and adaptation to market demands. It is considered that in this way agroforestry products would be valorized and therefore, it could be possible to increase the revenues for these systems.

If we focus on dehesa agroforestry systems (rangelands in the SW of the Iberian Peninsula), an additional issue is that the main products provided are animal products raised in extensive conditions. They are appreciated in their original regions, but in many cases they are commodities that consumers are not able to identify and therefore, are not able to valorize and pay a premium for.

In this context, it was considered that the development of a brand for products from agroforestry systems could be a useful tool to reach the abovementioned objectives, taking as a first approach the Spanish dehesas.

Due to the nature of this task, with different products covered and many subjective issues having to be considered, it was decided that the way to deal with this chore was a mixed qualitative methodology, using projective techniques within the framework of discussion groups that would allow participants to discuss the results of the preliminary tasks.

Qualitative research is a type of research used to approach a concern and its motivating factors and it is the most flexible and versatile type of research (Stewart et al. 1994) and has often been applied in agricultural and forestry systems (Islam et al. 2015; Tadesse et al. 2014). Within qualitative research techniques, projective techniques are one of the most frequently used (Donoghue 2000). The use of these techniques comes from the idea that when consumers face unstructured and ambiguous stimulus it is easier for them to convey opinions, points of view, motivations and attitudes (Donoghue 2000).

In this study, the general purpose was to use projective techniques to get a glimpse both of the inner concepts that a brand covering dehesa products should include and also of other general aspects that could be interesting for the consumers and producers.

Materials and methods

Six research sessions with consumers were carried out in municipalities with different characteristics in Extremadura between March and July 2017. In total 48 consumers participated, the main criterion for the selection of the participants being their willingness to participate in the study, since no special feature or previous knowledge about agroforestry or "dehesas" was required. The number of participants varied between 7 and 10 per session. The sociodemographic characteristics of the participants appear in Figure 1.

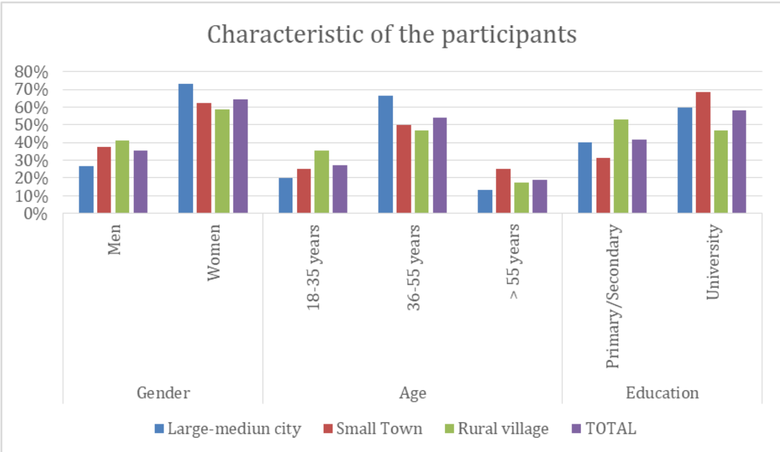


Figure 1: Socio-demographic characteristics of the participants

All sessions were led by an expert and recorded on video for later analysis. The work sessions were developed following a common protocol which included different projective techniques (word association, sentence completion and brand personification) with intermediate discussion and sharing of the results.

Projective techniques

Word association

In word association participants are requested to say the first thing that comes to mind when hearing some words. In this research the word association task involved four concepts (traditional production foods, sustainable production foods, organic foods and dehesa foods) in order to compare the different associations that they arouse.

Sentence completion

In sentence completion respondents are provided with incomplete sentences and are asked to complete them, usually with the first word or sentence that comes to mind (Eldesouky et al. 2015). In this task, participants were asked to complete a sentence regarding them finding a food product in a supermarket labelled with a quality brand "Dehesa".

Brand Personification

In this technique participants were asked to attribute personality characteristics (age, sex, origin, hobbies, etc.) to brands, and imagine them as if they were people or individuals. In this chore, different brands were presented to the consumers (Dehesa Brand, Sustainable Production Brand, Traditional food Brand and Socially responsible production Brand) that would gather the main features of agroforestry products in southwestern Spain. The objective was to get a comparison of the attributes assigned to the different concepts in order to identify those constraints associated to the agroforestry systems by themselves and those positive aspects linked to the other ideas but which are also related to dehesas.

Results

Firstly, Table 1 shows the results of the word association task. The size the different concepts are shown reflects their frequency of mention.

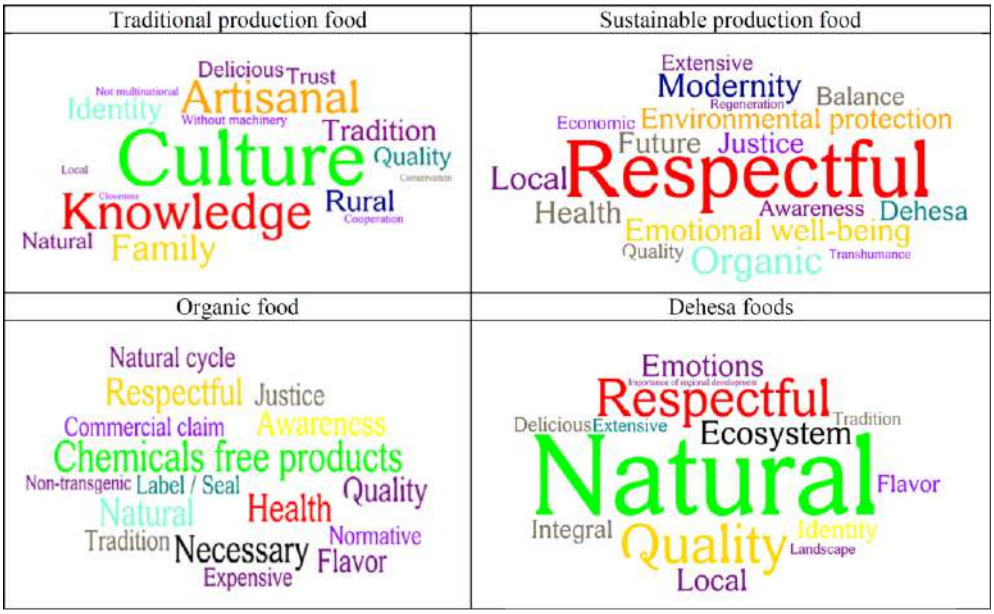


Figure 2: Main concepts identified through word association.

As Figure 2 reveals, a great variety of concepts have been identified, and although it should be expected that some of them would be shared by the four types of foods, it is clear that consumers have in their minds plainly different images when some terms are mentioned, such as the association of organic with “free of chemicals” or that of sustainability with terms like “respectful, environment, justice or modernity”.

Table 1 shows the results of the Completion task where participants were asked to complete the following sentence: If I am in a supermarket and I find a food product with a quality brand named "Dehesa" I ....

Table 1: Categories identified in sentence completion task

Categories identified	**Frequencies of mention (%)**	**Examples**
I will buy it	25,6	*"I would buy it without hesitation. Although the price would be higher "*
I value it, but it is not decisive	23,1	*"It strikes me; You may buy it; I think it has more value (quality, environment) "*
I think about quality	17,9	*"I perceive that it has been prepared and processed in such an environment and therefore guarantees quality"*
I'm looking for more information	10,3	*"... I keep reading, who produces it, where it comes from ..."*
I value it but it is not determinant, it also price	10,3	*"I would try to buy it as long as it was not excessively expensive"*
I think "it's natural"	10,3	*"I understand that it has occurred naturally in the middle of the dehesa"*

As it can be observed, a high percentage of participants (25.6 %) showed recognition towards a Dehesa brand and were favourably disposed to purchase it. However, sometimes the Dehesa brand can be related with products having a high price. Likewise, 23.1 % of participants value the attributes of environment and quality that the brand can convey but they are not decisive factors in the purchase.

Finally, Table 2 shows the results of the Brand Personification study.

Table 2: Brand personification

Characteristics	**Brand dehesa**	**Brand sustainability**	**Brand Traditional product**	**Brand Socially responsible production**
Age	More than 50 yo	Less than 30 yo	More than 50 yo	Less than 30 yo
Sex	Male	Indifferent	Female	Female
Job	Farmer	Environmental professional	Farmer	Liberal professional, civil servant
Origin	Rural	Urban	Rural	Urban, cosmopolitan, European
Character and personality	Quiet, kind and nice	Cheerful, kind, nice and enthusiastic	Cheerful, kind, nice and enthusiastic	Cheerful, kind, nice and enthusiastic
Physical appearance	Traditional, rural	Serious and informal	Traditional, rustic, tough	Intellectual, serious, caring
Hobbies	Landscaping and ornithology	Walking in the countriside, landscaping	Family and hobbies linked to the environment	Walking in the countriside, landscaping, reading Hiking and sports in nature Activities with friends

Table 2 shows the main results of the Brand Personification study. As it can be observed, when analyzing the different aspects of the personality some brands complemented each other, while others showed totally opposite aspects. This is an interesting finding to highlight, since the brand image should be attractive to as many consumers as possible.

So much so that, for example, it was appreciated that while Dehesa or Traditional Product Brands conveyed an image of mature-older people (47.62% in the Dehesa brand and 83.37% in Traditional Product), this result was in contrast with the Sustainability and Socially Responsible Brands, whose images were fresher or oriented towards young consumers. On the other hand, Dehesa brand is related to the male sex in 60.87%, while the other brands are associated with women or are indifferent regarding sex.

Discussion and conclusion

The word association shows that dehesa as a term to be used to label foods or other products would possess some positive meanings such as “natural” or “quality”. However, it lacks other interesting connotations that are linked to more “modern” concepts, for example, the protection of the environment or the contribution towards consumers’ health and wellbeing.

Brand personification has shown that character and personality are similar in the four brands, while the physical appearance conveys a traditional and rural image in the first two brands, as opposed to Sustainability which is associated with a dynamic, young and informal character, while at the same time serious and socially committed with the natural environment. These aspects are reinforced by the association of the first two brands with rural environments, as opposed to Sustainability and Socially Responsible Brands, clearly considered as urban and cosmopolitan brands.

Finally, it can be seen that all the brands are closely linked with hobbies related to the natural environment and healthy life, which are element of great value when considering the development of a brand for agroforestry products.

To conclude, it should be taken into account that these results, due to the qualitative nature of the study and its convenience sampling, must not be considered as definitive. Further quantitative research with representative samples would be needed in order to extend the outcomes of this paper to the whole market.

Acknowledgments

Research funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD through the Research Project AGFORWARD (Grant Agreement N◦613520; www.agforward.eu)

References

Donoghue (2000) Projective techniques in consumer research. J Fam Ecol Consum Sci 28: 47–53.

Eldesouky A, Pulido AF, Mesias FJ (2015) The role of packaging and presentation format in consumers’ preferences for food: an application of projective techniques. J Sens Stud 30: 360-369.

Islam KK, Jose S, Tani M, Hyakumura K, Krott M, Sato N, (2015) Does actor power impede outcomes in participatory agroforestry approach? Evidence from Sal forests area, Bangladesh. Agrofor Syst 89: 885–899.

Stewart B, Olson D, Goody C, Tinsley A (1994) Converting focus group data on food choices into a quantitative instrument. J Nutr Educ 26: 34-36.

Tadesse G, Zavaleta E, Shennan C (2014) Effects of land-use changes on woody species distribution and above-ground carbon storage of forest-coffee systems. Agr Ecosyst Environ 197: 21–30.

HYBRID ASPEN AND PERENNIAL GRASS AGROFORESTRY SYSTEM INTERACTIONS

Lazdina D[*1], Rancane S[2], Makovskis K[1], Sarkanabols T[1], Dumins K[1]

(1) Forest regeneration and establishment, plantation forests, Latvian State Forest Research Institute Silava, Salaspils, Latvia (2) Research institute of Agronomy, Latvia University of life sciences and technologies, Jelgava, Latvia

*Corresponding author: dagnija.lazdina@silava.lv

Abstract

This research´s aim is to determine productivity of hybrid aspen (*Populus tremula* L. *x Populus tremuloides* Michx.) at the fifth year rotation period after managing it as agroforestry system together with perennial crops–reed canary grass (*Phalaris arundinacea* L.), festulolium (*Festulolium pabulare*) and fodder galega (*Galega orientalis* Lam.) as intercrop and fertilized by digestate waste water sludge and wood ash. It is recognized that best effect on tree growth for both clones is by fertilizing with digestate and waste water sludge, on average 30–31% better tree height compared to control. The best effect on tree growth is obtained with red canary grass and fodder galega intercrop, comparing to control the average tree height is 16% higher. Hybrid aspen clone No 4 is significantly (+33%) more productive than clone No 28. The clone selection has the most important impact on plantation productivity. All kinds of fertilizers significantly increased seed yield of festulolium by 30%, but fodder galega showed positive response just to wood ash fertilization resulted to +15% of seeds yield.

Keywords: aspen hybrid; perennial grass; agroforestry; galega; festolium; reed canary grass; inter copping

Introduction

In order to diminish usage of fosil fuel and to increase usage of local renewable energy sources there is a need for alternative energy sources (AES). Biomass is considered as one of the most perspective in Latvia. Hybrid aspen is one of the fastest tree growing species used for biomass production in short rotation coppice cultures in Latvia and *Populus spp*. is one of three SRC which are financially supported by government within direct support scheme. As a solution for the need of AES are agroforestry systems, which balancing economical and ecological needs provides sustainable land management.

Since 2011 aspen is an eligible agriculture energy crop with a rotation period up to five years in Latvia. In previous studies we found that inter-crop system allows to make positive cash flow already at 2-3 year after establishing these systems, if grasses are used as seed producers. The research´s aim is to determine productivity of hybrid aspen (*Populus tremula* L. *x Populus tremuloides* Michx.) at the fifth year rotation period after managing it as agroforestry system together with perennial crops seed producers and biomass plants as intercrop and fertilized by biogas fermentation residues, waste water sludge and wood ash.

Material and methods

The study area is located in central Latvia, region of Skrīveri (56°41 N 25°08 E). The experimental plot is established in 2011 on drained mineral soil. Average carbon (C) content in soil plough layer 21.3–25.4 g kg^{-1}, K_2O 136.8 mg kg^{-1}; P_2O_5 277.1 mg kg^{-1} and average pH_{KCl} of soil is 6.1 (Rancane et al. 2014). In the current study, system with trees of high growth rate hybrid aspen, by choosing clones with significantly different productivity were used (No 4 high yield and No 28 low yield, both were used as reference clones for breeding of hybrid aspen).

The trees were planted in the 2.5×5 m planting design with ~3 m wide intercrop stripes between tree rows (Figure 1).

Figure 1: Small scale demo agroforestry system Hybrid aspen and Festolium (foto D. Lazdina).

Plantation of hybrid aspen (*Populus tremula* L. x *Populus tremuloides* Michx.) was established within 4 replicates for each fertilizer, (waste water sludge 10 t_{DM} ha^{-1}, wood ash 6 t_{DM} ha^{-1} and digestate 30 t ha^{-1}). Intercrops Galega (*Galega orientalis* Lam.), Reed canary grass (*Phalaris arundinacea* L.), Blue lupin (*Lupinus polyphyllus* Lindl.), Festolium (*Festulolium pabulare*) were sown between rows of trees for seed production and biomass (Figure 2). Intercrops sown in strips which are double of harvesting width of experimental seed harvesting machine owned by Institute of Agriculture.

control	**ash**	**sludge**	**digestate**	**control**	**sludge**	**digestate**	**ash**	**control**	**digestate**	**ash**	**sludge**	**control**	**digestate**	**sludge**	**ash**
Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen
Galega	Galega	Galega	Galega	RCG	RCG	RCG	RCG	Lupin	Lupin	Lupin	Lupin	Festolium	Festolium	Festolium	Festolium
Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen
Galega	Galega	Galega	Galega	RCG	RCG	RCG	RCG	Lupin	Lupin	Lupin	Lupin	Festolium	Festolium	Festolium	Festolium
Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen

Figure 2: Design of experimental plantation agroforestry system intercropping (tree rows 5 to 2.5 m intercrop 3m wide strips).

During the work were measured heights, diameters at breast height (DBH) and biomass to aspen clones No 4 and No 28 (*Populus tremula x tremuloides*) with three different perennial intercrops reed canary grass (*Phalaris arundinacea* L.), festulolium (*Festulolium pabulare*) and fodder galega (*Galega orientalis* Lam.), each divided into four replicates with different fertilisers biogas fermentation residues (digestate) 30 t ha^{-1}, waste water sludge 10 t ha^{-1}, stabilized wood ash 6 t ha^{-1} and one replicate with no fertiliser control. Planting density was 800 trees ha^{-1}. Biomass equations were estimated using six representative trees per clone, sample trees were selected by considering average tree height. The moisture was determined weighing naturally wet biomass of wood samples and again after drying samples till constant weight in 105^0C. Carbon amount in biomass was determined using established quotients for hybrid aspen trunk and branches (Muiznieks and Liepins 2006). In order to determine average carbon amount in tree the quotients were recalculated using trunk and branches proportion. Estimated quotient is 511.33 g C kg^{-1}. From amount of carbon in absolutely dry wood biomass using IPCC Guidelines for National Greenhouse Gas Inventories (2006), the amount of stocked CO_2 in plantation was calculated. The experimental data were statistically processed by using two-way analysis of variance, the differences among means was detected by LSD at the 0.05 probability level.

Results and discussion

During the work it was recognized that the best effect on the tree growth and only relevant difference among control to the aspen hybrid No 4 gives the fodder galega and reed canary grass. Average tree height ranges from 661 cm with reed canary grass intercrop and waste water sludge fertilizer and 615 cm with fodder galega intercrop and digestate fertilizer while in control with no intercrop only 387 cm. Aspen clone No 4 is significantly more productive than No 28, even the most productive 28^{th} clone stand does not reach the average tree height of 4^{th} clone, therefore in future analysis is considered only the 4^{th} clone. All of researched fertilizers give positive impact on the hybrid aspen tree growth. The best effect is observed with digestate fertilizer, comparing to control averagely for 31% higher results and waste water sludge fertilizer averagely for 30% (Table 1).

Table 1: Hybrid aspen 4^{th} clone biomass harvest comparison

	Intercrop	Survival	Naturally wet wood biomass at real survival t ha-1	Absolutely dry wood biomass at real survival t ha-1
Digestate	Festulolium	96	6*	3.2
	Fodder galega	85	12.7**	6.9
	Control	89	6.5	3.5
	Reed canary grass	96	15.7**	8.5
Sludge	Festulolium	81	6.6*	3.5
	Fodder galega	81	7.4*	4
	Control	93	6.4	3.4
	Reed canary grass	96	15.7**	8.4
Ash	Festulolium	81	3.1*	1.6
	Fodder galega	89	7.1**	3.7
	Control	81	2.7	1.4
	Reed canary grass	96	10.7**	5.6
Control	Festulolium	89	2.3**	1.2
	Fodder galega	74	5**	2.6
	Control	81	2.5	1.3
	Reed canary grass	82	5.2**	2.7

* = P>0.05 ** = P<0.05

There were estimated the possibility of growing herbaceous plants between rows of tree plantations with the aim to harvest seed production in first years after establishment, and thus at least partially compensate invested funds. The average seed yield in first two years of use for all species was estimated as good. *Festulolium* produced from 688 kg ha^{-1} without use of any fertilizers (control) to 908 kg ha^{-1} in variant of mineral fertilizers; galega produced from 285 kg ha^{-1} (control) to 470 kg ha^{-1} (wood ash) on average, what is good result also taking into account the meteorological conditions and the characteristics of this species. Numerous rainy days during the vegetation period in the 1st year of use adversely affected the pollination of galega flowers and thereby made a negative effect on the seed yield formation (Figure 3).

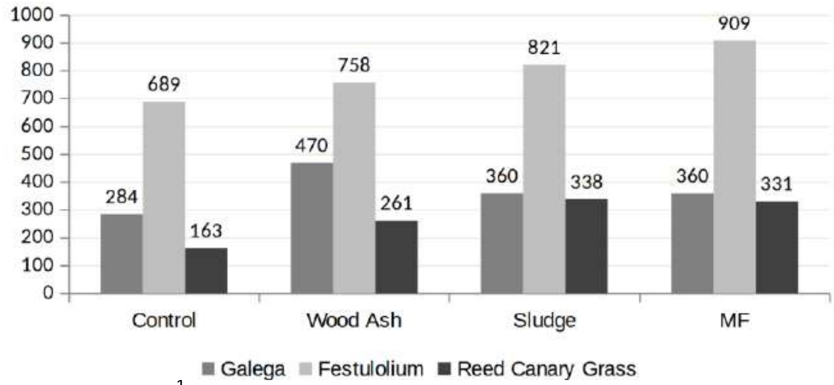


Figure 3: Seed yield (kg ha^{-1}) of herbaceous plants on average in two years of use (2012-2013).

However, in the second year of use weather condition was more favorable for galega flower pollination and seed development, hence the average seed yield of two years of use can be evaluated as satisfactory. Relatively lower seed yields on average in 1st and 2nd year of use obtained from RCG sowings from 163 kg ha^{-1} without use of any fertilizer to 338 kg ha^{-1} using sewage sludge. However, the seed production of RCG in general is complicated due to the fact that seed often shatter from the upper branches while seed at the base is still immature (Baltensperger and Kalton 1959). For this reason the average seed yield of RCG usually fluctuates around 200 kg ha^{-1} and hence we can conclude that harvested yields in fertilized variants between tree rows are sufficiently high (Figure 3).

The results of two years indicate that the use of different bio-energy and municipal waste products as fertilizers in general contributed the formation of higher seed yields for all three species. However the influence of fertilizers under research on the species was different. The greatest increase in seed yield on average in two years provided applying of sewage sludge for RCG; mineral fertilizers for festulolium; and wood ash for galega.

Conclusion

It is recognized that best effect on tree growth for both clones was achieved by fertilizing with biogas fermentation residue and waste water sludge, on average giving 30–31% better tree height compared to control. The best effect on tree growth is achieved with a Reed canary grass and fodder galega intercrop, compared to control the average tree height is 16% higher. It is recognized that hybrid aspen clone No 4 is significantly (+33%) more productive than clone No 28. The most important impact on plantation productivity is achieved by clone selection, although there was relevant impact on the tree growth from fertilizer and intercrop as well. All kinds of fertilizer significantly increased seed yield of festulolium by 30%, but fodder galega showed positive response just to wood ash fertilization resulted with a 15% increase in seed yield.

References

Baltensperger A, Kalton R (1959) Variability in Reed Canarygrass, *Phalaris arundinacea* L. II. Seed shattering. Agron J 51: 37-48.

Muižnieks E, Liepiņš J (2006) Carbon content in biomass of the most common tree species in latvia Latvian state forest research institute “Silava”.

Rancāne S, Makovskis K, Lazdiņa D, Daugaviete M, Gūtmane I, Bērziņš P (2014) Analysis of economical, social and environmental aspects of agroforestry systems of trees and perennial herbaceous plants. Agron Res 12: 589-602.

IPCC (2006) IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Agriculture, Forestry and Other Land Use. www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html (accessed 18/04/2018).

THE BIOMASS POTENTIAL OF EXISTING LINEAR WOODY-FEATURES IN THE AGRICULTURAL LANDSCAPE

Tsonkova P[1]*, Böhm C[1], Hübner R[2]

(1) Chair of Soil Protection and Recultivation, Brandenburg University of Technology Cottbus-Senftenberg, Cottbus, Germany (2) Chair for Strategic Landscape Planning and Management, Technical University of Munich, Freising, Germany

*Corresponding author: penka.tsonkova@b-tu.de

Abstract

Linear woody-features, such as hedgerows, windbreaks, and riparian buffer strips, composed of trees and/or shrubs are anthropogenic features, established in the past for different purposes, such as provision of field boundaries, protection from wind and supply of fuelwood. Today, they are primarily valued for their ecological benefit, while their production function has received rather little attention. This study assessed the biomass potential of existing linear woody-features in a study area in southern Brandenburg, Germany. The merchantable tree volume of the measured woody-features ranged between 240 m^3 ha^{-1} and 710 m^3 ha^{-1}, depending on the relative proportion of trees and shrubs. The results suggest that the biomass potential of linear woody-features with predominant tree proportion per hectare can be higher than this of forests. A strategy for utilising the production function of these woody-features should take into account the provision of benefits such as wind protection, habitat provision and landscape aesthetics.

Keywords: hedgerows; merchantable tree volume; production function; utilization strategy

Introduction

Linear woody-features, such as hedgerows, windbreaks, and riparian buffer strips, composed of trees and/or shrubs are anthropogenic features, established in the past within agricultural landscapes for different purposes, such as provision of field boundaries, protection from wind, and supply of fuel wood and other products (Baudry et al. 2000). Due to mechanization and intensification of agriculture, in the past, they were perceived as obstacles to agricultural production and have increasingly been removed from the landscape (Nerlich et al. 2013). The ecological benefit of trees outside the forest, including linear woody-features, is more widely recognized in today's' agricultural policy. For example, farmers can register hedges and wooded strips as landscape features which are recognised as Ecological Focus Area (EFA) under Pillar 1 of the Common Agricultural Policy (CAP). In addition, several options in the Rural Development Regulation (Pillar 2) of the CAP support the restoration and maintenance of traditional hedgerow systems or parkland trees. However, within these options there is little emphasis on managing tree-based systems for their productivity. Throughout Europe such semi-natural features of high nature value are threatened by both intensification and land abandonment (Plieninger 2012).

According to Schleyer and Plieninger (2011), among the obstacles for farmers in the German province of Saxony to enter a payment scheme that supports woody-features were high production and opportunity costs for land use, contractual uncertainties and land-tenure implications. Administrative and economic considerations were among the main reasons for the low registration of EFA options such as landscape features and buffers strips in Germany (Zinngrebe et al. 2017). Moreover, farmers in Germany are not allowed to harvest existing linear woody-features, even if they are not financially supported by the CAP, because they stand under protection by local regulations. However, as man-made features, they need to be preserved, managed and maintained continuously for the adequate provision of ecosystem functions and services (Baudry et al. 2000; Schleyer and Plieninger 2011). The aim of this study was to estimate the biomass potential of existing linear woody-features in the agricultural landscape, not registered for subsidies under the CAP, in order to assess the production function of these features.

Materials and methods

Study area

The study area is located in the southern part of the eastern German province of Brandenburg within the administrative district of Kleine Elster and the municipalities Sonnewalde and Finsterwalde (Figure 1). In 2015, the linear woody-features (not classified as forest area or registered for subsidies under the CAP) adjacent to agricultural landscapes in this area, were digitized based on the crown visible in digital orthophotos (40 cm-resolution) obtained from the Brandenburg Surveying and Geoinformation Office (LGB). These images are also accessible to farmers and form the basis of their annual agricultural declarations. Within the region a 4 km^2 (~1% from the total area) representative study area was selected, which was comparatively rich in linear woody-features. Within this area the woody-features were classified on-site according to their woody vegetation cover (tree cover (0-33%, 33-66%, and 66-100%) and shrub cover (0-33%, 33-66%, and 66-100%)) and their density (closed, with small gaps (1-33% of the woody-feature), with large gaps (>33% of the woody-feature)). From these classes up to three linear woody-features representing each combination were randomly selected for biomass assessment (Figure 1).

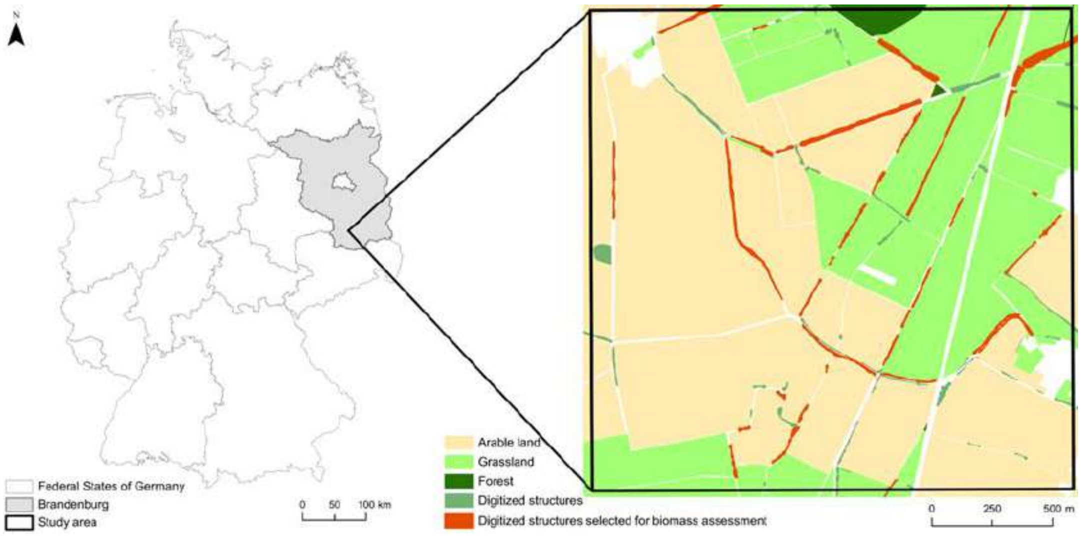


Figure 1: Map of Germany with the study area in the province of Brandenburg, main land use and the digitized linear woody-features, highlighting those randomly selected for biomass assessment (n=37).

Biomass potential

In the selected linear woody-features, measurements of tree height, diameter at breast height (DBH) when it was wider than 7 cm, together with the tree species were recorded. For woody-features longer than 100 m the measurements took place in five plots, each 20 m long, which were equally distributed throughout the total length. For woody-features shorter than 100 m the whole feature was recorded. The measurements were used to determine the theoretical biomass potential, i.e. the maximal biomass potential of these features. The merchantable tree volume (V) in m^3 is the product of tree basal area (g [m^2]), tree height (h [m]) and a form factor (f) that converts total tree volume to merchantable tree volume (Kramer and Akça 2008):

$$V = g \times h \times f \qquad [1]$$

$$g = \frac{\pi}{4} \times DBH^2 \qquad [2]$$

Results and discussion

Linear woody-feature description

The average length of the woody-features was 200 m, while the average width was 5 m. Although the width of the measured woody-features was predominantly below the threshold of 10 m set by Regulation (EU) No 639/2014 for landscape features, such as hedges and wooded strips, they were not registered as such. The distribution of tree species according to their DBH is shown in Figure 2. The most common species were *Alnus glutinosa*, *Populus spp*. and *Quercus robur* composing 52%, 17% and 13% of the tree species recorded, respectively. *Alnus glutinosa* is typically grown along ditches. Accordingly, the highest proportion of the digitized features were riparian buffer strips. The rest of these features could be classified as hedgerows and windbreaks.

In the period between 1950 and 1980 planting fast growing trees such as *Alnus glutinosa* and *Populus* was common in Germany (Reif and Achtziger 2000). The main purpose was protection from wind and erosion as well as production of wood. Non-native hybrid poplar trees were often planted, which were since then neither harvested nor managed and currently these aged trees cause problems in the management of adjacent agricultural areas by breakage of tree branches and logs lying in the fields (DVL 2006). These features were typically monotonous which is consistent with the species recorded within the study area. More than half of the woody-features consisted of one or two tree species amounting to 28% and 39%, respectively. Besides hybrid poplar a non-native species to the area was *Quercus rubra* which however accounted for less than 1% of the tree species.

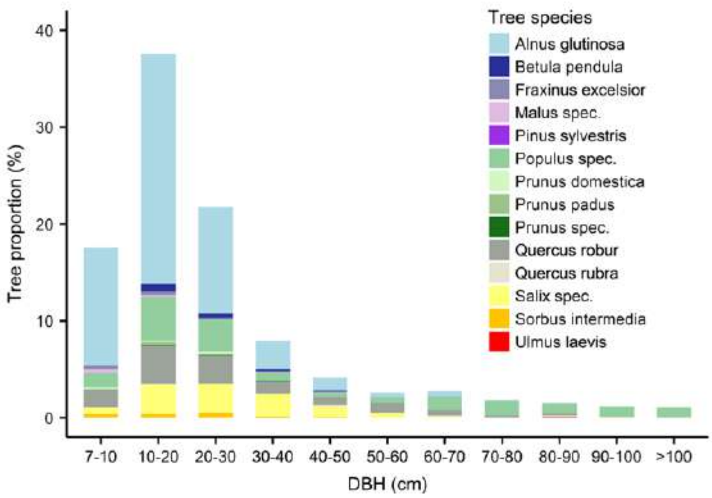


Figure 2: Distribution of tree species according to their diameter at breast height (DBH) measured in cm (n=1277).

Theoretical biomass potential

The area of all digitized linear woody-features amounted to 2.9% of the agricultural area. The mean and standard error of the 37 woody-features ranged between 25±5 cm and 49±16 cm for DBH and between 10±1 m and 18±3 m for height. The form factor was extracted from yield tables for the main tree species in the area (Schober 1995). The calculated mean biomass potential of the linear woody-features according to the proportion of trees and shrubs is presented in Table 1. The merchantable tree volume ranged between 240 m^3 ha^{-1} and 710 m^3 ha^{-1} with weighted average over the area amounting to 540 m^3 ha^{-1}. The calculated potential per hectare woody area was higher than the average stocks of biomass in German forests of 330 m^3 ha^{-1}, reported by the Third National Forest Inventory (TI 2012). The biomass potential of these woody-features was more comparable with the biomass stock of older forest, such as this estimated in the province of Schleswig-Holstein, amounting to 550 m^3 ha^{-1} (TI 2012). The high biomass potential of woody-features with predominately tree proportion could be due to the fact that trees receive more light as compared to forest conditions and can be planted in higher density. The stem number per hectare in the woody-features was up to 1500 stems ha^{-1}, consequently, also higher as compared to forests, where the highest stem number of ~900 stems ha^{-1} was found in Brandenburg. However, it has to be considered that the linear woody-features within the landscape are widely spread and their total area can be comparatively small. In the study area, it amounted to 10.6 ha.

Table 1: Estimated theoretical biomass potential (mean ± SE) of the linear woody-features according to the relative proportion of trees and shrubs (n=37)

Vegetation cover [%]		n	Merchantable tree volume [m^3 ha^{-1}] mean (±SE)	Total area of all woody-features [ha]
Shrubs	**Trees**			
0-33	0-33	3	250 (±80)	0.3
0-33	33-66	6	430 (±140)	1.6
0-33	66-100	7	690 (±190)	4.3
33-66	0-33	1	350 (NA)	0.2
33-66	33-66	7	310 (±40)	1.0
33-66	66-100	4	710 (±30)	1.2
66-100	0-33	6	240 (±110)	0.7
66-100	33-66	0	NA	0.0
66-100	66-100	3	470 (±80)	1.3

The initial results suggest a high biomass potential of linear woody-features in the agricultural landscape. In addition to production function, the assessment of woody-features should consider ecosystem functions such as wind protection, provision of habitat and landscape aesthetics (Hübner 2016). A management strategy should be developed, considering which species should be primarily harvested, prioritizing non-native species and which species should be used for replanting to enhance the ecological function of existing woody-features, as it was demonstrated by Romer et al. (2016). The management and maintenance of these features for the balanced provision of functions should be considered at the landscape scale. Only a small proportion of the biomass should be harvested annually with the aim of preserving linear woody-features for improved ecosystem functions.

Conclusion

The study estimated the theoretical biomass potential of existing linear woody-features in an agricultural landscape in southern Brandenburg. The initial results suggested that the potential of woody-features with predominating tree proportion per hectare can be higher than this of forests. The area of woody-features is however comparatively small and they can be widely spread in the landscape. Nevertheless, it is necessary to develop a management strategy for using the production function of these features. Moreover, maintaining woody-features through regular harvests, as it was practiced in the past, would improve their condition and enhance the provision of ecosystem functions, such as landscape aesthetics, habitat for biodiversity, and soil protection.

Acknowledgements

The AUFWERTEN project (Reference No 033L129AN) is funded by the Federal Ministry of Education and Research (BMBF).

References

Baudry J, Bunce RGH, Burel F (2000) Hedgerows: an international perspective on their origin, function and management. J Environ Man 60, 7–22.

Deutscher Verband für Landschaftspflege (DVL) e.V. (2006) Landschaftselemente in der Agrarstruktur - Entstehung, Neuanlage und Erhalt. DVL-Schriftenreihe "Landschaftals Lebensraum", Heft 9, p. 122.

Hübner R (2016) Management von Flurgehölzen in der Agrarlandschaft. Praxisinnovationstag: Standortspezifisches Konzept zur Weiterentwicklung und Nutzung bestehender Agroforststrukturen. Dollenchen, 26. September 2016.

Kramer H, Akça A (2008) Leitfaden zur Waldmesslehre. 5 Aufl. J.D.Sauerländer's Verlag, Bad Orb, p. 226.

Nerlich K, Graeff-Hönninger S, Claupein W (2013) Agroforestry in Europe: a review of the disappearance of traditional systems and development of modern agroforestry practices, with emphasis on experiences in Germany. Agrof Syst 87: 475–492.

Plieninger T (2012) Monitoring directions and rates of change in trees outside forests through multitemporal analysis of map sequences. Appl Geogr 32(2): 566–576.

Reif A, Achtziger R (2000) XI-2.2. Gebüsche, Hecken, Waldmäntel, Feldgehölze (Strauchformationen). In: Konold W, Böcker R, Hampicke U (eds) Handbuch Naturschutz und Landschaftspflege. Ecomed, Landsberg, pp 1–45

Romer T, Kaufman T, Kammermeier M (2016) Ökonomische Wertigkeit von Flurgehölzen und Kurzumtriebsplantagen in der Agrarlandschaft. Bachelorprojekt an der Studienfakultät Forstwissenschaft und Ressourcenmanagement der Technischen Universität München, p. 47.

Schleyer C, Plieninger T (2011) Obstacles and options for the design and implementation of payment schemes for ecosystem services provided through farm trees in Saxony, Germany. Environ Conserv 38(4):454–463.

Schober R (1995) Ertragstafeln wichtiger Baumarten bei verschiedener Durchforstung, J.D.Sauerländer Verlag, Frankfurt am Main, p. 166.

Thünen-Institut (TI) (2012) Dritte Bundeswaldinventur - Ergebnisdatenbank, https://bwi.info, [Last accessed: 12.12.2017]

Zinngrebe Y, Pe’er G, Schueler S, Schmitt J, Schmidt J, Lakner S (2017) The EU’s ecological focus areas – How experts explain farmers’ choices in Germany. Land Use Policy 65, 93-108.

Session

Education and tools to investigate agroforestry

IDENTIFYING BOTTLENECKS AND GATEWAYS FOR AGROFORESTRY DEVELOPMENT IN POLAND

Borek R[1]*, Gałczyńska M[1]

(1) Department of Bioeconomy and Systems Analysis, Institute of Soil Science and Plant Cultivation - State Research Institute, Puławy, Poland

*Corresponding author: rborek@iung.pulawy.pl

Abstract

The paper presents results from the Regional Agroforestry Innovation Network (RAIN) established in Poland, as part of the Horizon 2020 AFINET Project. Participants were asked to list most important barriers for agroforestry (AF) development in Poland in five categories and suggest priority ways to tackle these barriers. The development and implementation of agroforestry is blocked by existing legislation regarding trees outside forest: primarily relating to protection orders for individual trees, and the responsibility for trees in spatial plans is in the hands of municipalities. More knowledge about agroforestry and collaboration between experts, local decision makers and practitioners is needed to develop local markets of innovative AF products. Support programs for AF technologies/products and introducing guarantee instruments for origin or awarding system could make AF development easier. Participants agreed that education, promotion and DSS systems concerning AF are crucial.

Keywords: agroforestry in Poland; land use policy; forestry policy; trees outside forest; rural innovation networks

Introduction

The development and implementation of innovations in agriculture require both reliable information and a willingness on the part of farmers to learn. Knowledge transfers among farmers, researchers, experts and agricultural advisors is crucial for sustainable growth in food and non-food production under competitive conditions and in the long term. Increasing the importance of tree resources into agriculture will improve stability and resilience of crop and livestock production in terms of climate change (Olejnik et al. 2001; Kędziora et al. 2001). The paper presents results from the transdisciplinary Regional Agroforestry Innovation Network (RAIN) established in Poland, as part of the Horizon 2020 AFINET Project. RAINS have been established in 9 EU countries. A team from Institute of Soil Science and Plant Cultivation (IUNG-PIB) is facilitating the Polish regional network. These initial results from the Polish RAIN workshops identify bottlenecks and propose solutions to resolve problems. The bottom-up process helped to formulate the needs for agroforestry (AF) innovations under the country conditions.

Materials and methods

The data were acquired using a multi-actor approach. Key actors (stakeholders) with complementary types of knowledge (scientific and practical, agronomists and foresters, officials and representatives of NGO sector; technology developers and scientific consultants) were invited. Innovation Broker (person purposefully catalyzing innovation through bringing together actors and facilitating their interaction) played a key role in discussions on identification bottlenecks of agroforestry development in Poland. Participants were asked to give five most important barriers for them in five categories: communication and awareness raising, economic barriers, technical barriers, administration and legal barriers, barriers for chain development and commercialization. Twenty-eight experts and farmers participated in the meeting. After the workshop with stakeholders, an survey online was provided to participants to confirm their views on ways to tackle the issues raised during the meeting and to introduce AF innovations.

Results and discussion

Barriers to adoption

Communication and awareness raising - Lack of coherent action for educating on options for afforestation and agroforestry. Agroforestry systems are not familiar to farmers and advisors. Hence, there is weak collaboration between advisors/educators and, even, organic farmers, who should constitute an important group of agroforestry practitioners. "Agroforestry" is a term not recognized by agricultural producers and decision makers. The extent of agroforestry in Poland is also not known. Shelterbelts systems in Wielkopolskie province and riparian buffers are well known in Poland. There are a number of different social actions aimed at planting trees on rural areas carried out by NGO (FER, Klub Gaja) and research studies related to trees on farming lands (e.g. Ryszkowski 2001; Orłowski and Nowak 2007; Zajączkowski and Zajączkowski 2009; Kędziora et al. 2012). Nonetheless, lack of unequivocal definitions considering trees on agricultural land, particularly trees management rules (Borek 2015, 2016; Kujawa et al. 2017) discourage farmers to plant trees. A negative perception among farmers of the role trees and shrubs on agricultural land. There is also a lack of information on guidelines for AF development (what, where, how and when).

Economic barriers - A lack of financial support for AF practices. The government did not implement Article 23 of the EU RD Regulation which supports the establishment and maintenance of AF areas (Lawson et al. 2016). More information on cost benefit analysis of planting different species and the consequences of scattered trees on the basic (i.e. CAP Pillar I) payments farmers receive is needed. AF is not included in the measures for EFA within CAP Policy (EC 2015). Country regulations do not include support for trees on agricultural land (e.g. environmental programs; favourable tax provisions).

Technical barriers - Physical conditions are difficult for farming in Poland: in the majority of cases with poor soil quality, low size and high fragmentation of farms/parcels. This restricts agroforestry to marginal areas and large fields in more agroforestry-friendly farms. When planting trees it is important to select species and provenances which are appropriate to the soil and location. The spacing and planting patterns should match the intended balance between agricultural and timber production and be appropriate for the existing land use, climate and soil conditions.

Administration and legal barriers - There is a lack of a clear definition and legal regulations relating to agroforestry. The Forest Act is a barrier for the introduction of silvopastoral systems**,** including the case when permanent pasture parcel (particularly of low size) partly covered by trees canopy can be considered as a land under forest. Absence of tree policies in Spatial Management Plans of communes and problems with complicated ownership characteristics of many land parcels in terms of inheritance also hampers implementation of AF systems. In opinion of RAIN stakeholders some aspects of policy regarding cutting trees outside forest, micro-installations using local biomass and timber market are also unclear.

Barriers for chain development and commercialization - Because of lack of development of local entrepreneurships using agroforestry products and raw materials (forest products vs. organic products), AF products are not recognized as an ecolabel in Poland.

Paths forward – towards agroforestry innovations

Participants of the workshops were asked to indicate the most relevant solutions to tackle problems of agroforestry development in Poland (Table 1). The innovations were rated and the highest score has been given to developing and dissemination of knowledge of AF practices.

The second important issue is to undertake actions to support legal regulations on trees on agricultural farms.

Psychological and social barriers seen as the most important can be tackled through developing and dissemination the best practices of design, management, species selection/combination. Due to the fact, that decisions on trees are often in the hands of local administration units, it is necessary to supporting training of local officials on all policies relevant to trees. Another important aspect mentioned was establishing pilot projects demonstrating AF experiments belonging to research units or AF practices on farms allowing farmers visits to the objects and knowledge exchange. All participants agreed to create a Decision Support Systems for farmers interested in agroforestry.

Policy support of agroforestry was considered as one of the most crucial to tackle. Most of participants agreed that there is urgent need to clarify the rules of EU CAP to reduce limitations as allowed number of trees on agricultural land unit and introduce financial support for the establishment and maintenance of AF systems. However, a change of Polish Acts on Forest and Nature Protection are also necessary, in the first case due to the fact the document does not allow grazing animals in the forest, and the second includes comprehensive rules on cutting trees by farmers or municipalities. Indeed, local authorities are responsible for spatial planning on their territory and in practice often decide about land use, sometimes in opinion of stakeholders don’t respecting the property rights of the landowner. Hence, lobbying activities at the level of municipalities are necessary to facilitate tree planting on farmland. Municipalities should develop systems of tree strips of shelterbels in collaboration with farmers within the framework of Local Spatial Development Plan. Some farmers said they need to increase the freedom of wood production outside forest but they feel high-quality wood sell is restricted by competitive products of the larger forest supplier. Stakeholders highlighted stable policy for profitable woody biomass production on farms is necessary i.e. positive incentives for prosumers being small producers of renewable energy on the domestic market. Management plans for agroforestry are suggested to be set up, following Forest Management Plans measures in force for a period 10 years for all forests in Poland.

All participants stated the need to develop guarantee instruments for origin of AF products or AF awarding system. The development of local market of woody products is connected to creating direct sells models, requiring diagnosis of local societies and simplifications and facilitations in Polish law. Database of producers selling agroforestry products and direct selling systems of agroforestry products are mentioned also. The support for AF systems should be particularly targeted on organic farmers, hence linked to organic agriculture policy. Stakeholders agreed to promote AF and take education activities considering environmental threats and role of trees to mitigate them.

Table 1: Strategic solutions recommended by RAIN stakeholders to tackle problems of AF development in Poland.

Recommended solution (number of stakeholders votes in %)	Activities recommended by stakeholders
Developing and dissemination of the best AF practices of design, management, species selection/combination (43.7)	Knowledge dissemination through: - farmer networks, - collaboration between advisory centres and local authorities; - adapting university curricula. Conducting dissemination activities towards advisors and farmers through Innovation Rural Network and Regional Advisory Centres: - workshops, trainings, field trips, website. Trainings for officials representing local authorities. Publishing scientific results on efficiency of good AF practices and best species combinations. Developing AF demonstration farms and experimental sites, including developing efficient silvopastoral systems on problematic agricultural areas (including LFA). Designing locally efficient systems of tree vegetation in combination with apiary sites. Decision Support Systems on costs and benefits of agroforestry; software with AF design modules.
AF policy suport (31.2)	Developing financial support systems for agroforestry farmers to encourage them to plant trees on a farm, maintain and protect them. Introduction of "agroforestry" term into the Polish legislative framework. Establishment of regulations to facilitate use of forestry and agricultural lands for agroforestry in terms of given conditions. Including trees policy into Local Spatial Development Plans of municipalities
Supporting innovativeness of organic and "integrated" (i.e. combining food and non-food production) farms (16.9)	Developing the diagnosis of local societies. Certification of agroforestry technologies. Building a regional consolidated and trustworthy brand of agroforestry products. Development of local AF value chains through social cooperatives, direct sells model etc. Setup of internet database of agroforestry producers. Development of local models to use woody residues from trees in a sustainable way.
Supporting trees for biodiversity (2.5)	Educating farmers, advisors, educators, teachers, students how to manage and take care of trees.
Protection against water and wind erosion (2.5)	Strengthening collaboration between researchers, local authorities, NGO and farmers towards AF promotion on agricultural areas susceptible to drought and on lands with intensified production (5.6)
Protection of local water balance (1.2)	
Micro-climate regulation trough AF (1.2)	
Water quality protection (0.6)	

Conclusion

The first results, originating from AFINET RAIN surveys point that there is much to do in the area of agroforestry in Poland. The development and implementation of agroforestry systems is blocked at the level of legislative acts. Renewable energy support systems including bioenergy crops need significant changes. Regulations regarding trees outside forest primarily relate to protection orders for individual trees, and the responsibility for trees in spatial plans is in the hands of municipalities, who are not aware of opportunities for agroforestry. More knowledge about agroforestry, and collaboration between experts, local decision makers and practitioners is needed in order to develop local markets of innovative AF products. Support programs for AF technologies/products and introducing guarantee instruments for origin or awarding system could make AF development easier. All partners agreed that education, promotion and DSS systems concerning AF are crucial. Moreover, a set of good agricultural practices in agroforestry should be developed for Polish conditions.

Acknowledgements

We acknowledge support of the European Commission through the AFINET Horizon2020 project (contract 613520). The views and opinions expressed in this report are purely those of writers and may not in any circumstances be regarded as stating an official position of the European Commission.

References

Borek R (2015) Agroforestry systems in Poland. A preliminary identification. Papers on Global Change 22: 37-51.
Borek R (2016) Agroforestry in Poland - the current state and policy perspectives. 3rd European Agroforestry Conference, Montpellier, France, pp: 439-441.
EC (2015) Direct payments post 2014. Decisions taken by Member States by 1 August 2014. State of play on 07.05.2015. Information Note.
FER (Eco-Development Foundation) http://aleje.org.pl/en/ (accessed 22/04/2018).
Kędziora A, Olejnik J, Elenstein F (2001) Water balance in agricultural landscape and options for its management by change in plant cover structure and landscape. In: Ryszkowski L (ed) Landscape ecology in agroecosystems management, CRC Press, pp. 57-110.
Kędziora A, Kujawa K, Gołdyn H, Karg J, Bernacki Z, Kujawa A, Bałazy S, Oleszczuk M, Rybacki M, Arczyńska-Chudy E, Tkaczuk C. (2012) Impact of Land-Use and Climate on Biodiversity in an Agricultural Landscape, Biodiversity Enrichment in a Diverse World Gbolagade Akeem Lameed, IntechOpen, DOI: 10.5772/48653. https://www.intechopen.com/books/biodiversity-enrichment-in-a-diverse-world/impact-of-land-use-and-climate-on-biodiversity-in-an-agricultural-landscape (accessed 22/04/2018).
Kujawa K, Orczewska A, Kras M, Kujawa A (2017) Importance of trees and bushes on non-forest land. Are we allowed to liberalize trees and bushes cutting? Technical Report (in Polish). https://www.researchgate.net/publication/313854238 (accessed 22/04/2018).
Klub Gaja http://swietodrzewa.pl/ (accessed 22/04/2018).
Lawson GJ, Balaguer F, Palma JHN, Papanastis V (2016) Options for agroforestry in the CAP 2014-2020. Book of abstracts. 3rd European Agroforestry Conference, Montpellier, France, pp. 424-427.
Olejnik J, Kędziora A, Eulenstein F (2001) Mitigation of radiation and heat balance structure by plant cover structure. In: Ryszkowski L ed. Landscape ecology in agroecosystems management. CRC Press, pp. 29-56.
Orłowski G, Nowak L (2007) The importance of marginal habitats for the conservation of old trees in agricultural landscapes. Landscape and Urban Plan 79: 77-83.
Ryszkowski L ed. Landscape ecology in agroecosystems management. CRC Press, pp. 29-56.
Zajączkowski J, Zajączkowski K (2009) Farmland afforestations: new goals and guidelines for Poland. Folia Forestalia Polonica Vol. 51: 5–11.

EDUCATION ON AGROFORESTRY IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

Hübner-Rosenau D[1], Koch O[2], Hofmann P[2], Große, F[2], Bloch R[2], Cremer T[1*]

(1) Department of Forest Utilization and Timber Markets, Eberswalde University for Sustainable Development, Eberswalde, Germany (2) Department of Agricultural Use, Eberswalde University for Sustainable Development, Eberswalde, Germany

*Corresponding author: tobias.cremer@hnee.de

Abstract

In order to foster agroforestry in Germany, the Eberswalde University for Sustainable Development (EUSD) initiated a agroforestry project in Löwenberger Land (Brandenburg, Germany), the Ackerbau(m)-Project. In this project, a silvoarable agroforestry system was established as a pilot project, serving as a model for practitioners and decision makers. The practical implementation and long-term monitoring of the project is embedded in an interdisciplinary module on agroforestry at the EUSD. The module has a strong practical focus, while mainly being organized by students, cooperating with practitioners and experienced scientists. In the first run of the module, a high value timber tree system was established, along with the start of additional (research) activities in other areas of the project (e.g. soil, microclimate or public relations). In doing so, the students developed professional competence, social competence and self-competence, a crucial set of competences needed to act as change makers for sustainable development.

Keywords: agroforestry; ecosystem services; education; competences; curriculum development

Introduction

Agroforestry systems feature several ecosystem services with the potential of improving landscape ecology as well as offering economic benefits. There has been a number of studies depicting the potential contributions of agroforestry to combat climate change, control erosion, reduce nutrient leaching and enhance soil fertility (Quickenstein et al. 2009, Assmann and Oelke 2010, Huber et al. 2013). However, the practical implementation of agroforestry in Germany is yet due to pick up pace. According to Den Herder et al. (2016), only 1.6% of the whole agricultural areas in Germany are agroforestry systems. As reasons lacking national agricultural regulations supporting agroforestry, missing experience and demonstration objects as well as insufficient education on agroforestry can be named (Böhm et al. 2017, Unseld et al. 2011).

For this reason, the Eberswalde University for Sustainable Development (EUSD) started a holistically planned agroforestry project in Löwenberger Land (Brandenburg, Germany), the “Ackerbau(m)”-Project. In their final thesis, Hofmann and Hübner-Rosenau (2016) designed a multifunctional, silvoarable agroforestry system, integrating the stakeholders' interests in a participatory process. The aim was to design an inspiring pilot project demonstrating the various advantages of agroforestry. At the same time, it should serve as a long-term monitoring plot for further research. In order to ensure continuous monitoring as well as meeting the raising demand for education on agroforestry among the students of the EUSD, a trans-disciplinary module was established at the University. Hence, the module has a strong practical focus while mainly being organized by students, cooperating with practitioners and experienced scientists.

Setup of the pilot-project

The Sustainable Development Goals (SDG) of the UN declare, “by 2030, all learners [should] acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles [...]” (UN 2015). According to de Haan (2008), students need to have certain shaping skills to act as change makers. As shaping skills, de Haan (2008) distinguishes between professional competence (e.g. thinking anticipatory), social competence (e.g. collaborative planning and acting) and self-competence (e.g. working independently). Thus, in order to become places of change, universities have to enable students to acquire the skills they need to actively shape their future.

In the design process of the agroforestry site in the Löwenberger Land, the different interests of stakeholders where considered by Hofmann and Hübner-Rosenau (2016). The stakeholder analysis was based on qualitative interviews with the farmer´s and the land owner. The design was developed in close cooperation with different German agroforestry experts. Furthermore, it was important to analyse the ecological characteristics of the location as well as to consider possible arising conflicts with agricultural and nature conservation authorities. The stakeholders where kept involved during the whole planning process. After having finished the thesis, a team of students designed the concept of the module “ILL Agroforst: Modellprojekt in Brandenburg” in cooperation with the professors supervising the module.

The module on agroforestry follows the ideas of an innovative teaching and learning concept (German: “Innovative Lehr- und Lernform”, ILL). As agroforestry itself is a trans-disciplinary approach, integrating agriculture and forestry amongst others, it seems reasonable to reflect this in the structure of the module. This is implemented by encouraging students from different relevant study programmes of the faculties “Forest and Environment”, “Landscape Management and Nature Conservation”, “Wood Engineering” and “Sustainable Business” to participate. Furthermore, the module is planned and coordinated by students, which function as tutors: they decide in agreement with the professors on the structure, content and frequency of the sessions, as well as facilitating them. The participating students can also decide on additional inputs that might be needed during the module. After a common introduction into agroforestry, scientific data-collection and project-management, the students decide which project related topics they want to further work on in small working groups. With the support of the tutors the students work self-organized within the groups. The students are introduced to the project-management-tool Sociocracy, that contains integrating tools for decision-making and cooperative, value-driven project-management (Buck and Endenburg 2012).

Results

Design of the agroforestry system

The agroforestry system in the Löwenberger Land is a silvoarable system with high value timber trees planted in alleys, partly combined with fruiting shrubs. The 10 ha plot was planted with 346 trees in 8 rows (Figure 1). Additionally, 246 shrubs were planted. The tree and shrub species were chosen in accordance with Hofmann and Hübner-Rosenau (2016), by preferring dry-tolerant species with a low demand on nutrients which are able to successfully grow on sandy soil. As value timber trees, i.e. trees whose timber is known as especially valuable, the species *Corylus colurna, Pyrus pyraster, Quercus rubra, Quercus petreae, Sorbus domestica* and *Sorbus torminalis* were selected. A rotation period of approx. 60 years is planned for these trees. They were planted in pairs of three each, with an intra-row distance of 13 m and an inter-row distance of 38 m, aligned to the farmer´s maximum working width. The shrubs species *Hippophae rhamnoides* and *Aronia melanocarpa* were planted between the trees as fruit crops, serving as an additional income source for the farmer in the first years after establishment, when the crowns of the timber trees are not fully established, thus adding to the productivity of the system (Hofmann and Hübner-Rosenau 2016). The arable rows are farmed conventionally with a crop rotation of 3-5 sequences consisting of winter wheat (*Triticul aestivum*), Triticale, rye (*Secale cereale*) and winter oilseed rape (*Brassica napus*).

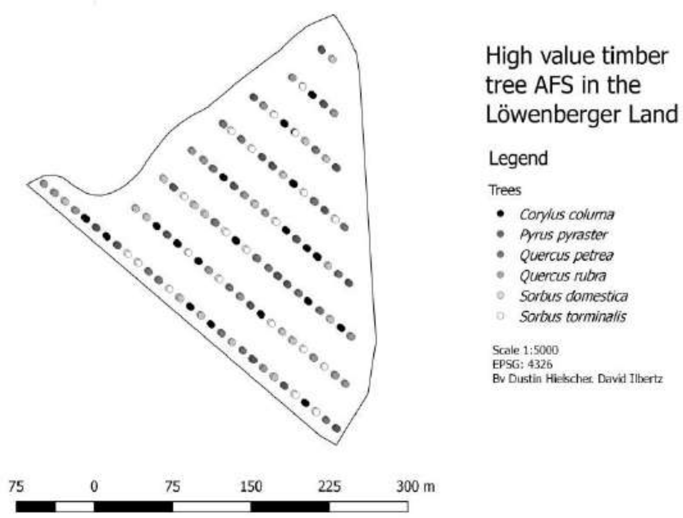


Figure 1: Design of the silvoarable agroforestry site in the Löwenberger Land

Another 10 ha agroforestry system on the site is still in the planning process. With the support of experts, students are working on a design to research if a ramial-chipped-wood-mulch on the arable field between rows of fast growing trees is enhancing the soil fertility, as found by Lemieux and Germain (2000).

Challenges in the design process

During the design and planning process, some challenges were arising, just to name a few: The farmer didn´t want to neither spend extra work on the agroforestry system nor have big changes in his regular farm work. In order to meet his expectations, the design was kept as simple as possible: it occupies only approx. 5% of the farmer´s total area and the distance between the tree rows is in accordance to his maximum working width. Furthermore the planning and planting of the agroforestry system was carried out by students. As agroforestry is only marginally considered and mostly not applying to the German implementation of the EAGF-funding (Böhm et al. 2017), the tree stripes are not applicable for direct CAP payments. In our case, the landowner – who is in favour of agroforestry – compensates the thereby arising financial loss of the farmer.

Organization of Data Acquisition and Working Groups

In the first semester the 25 participants of the study module formed 7 groups, working on different areas within the project. According to their skills and interests the students decided which topic they wanted to focus on. Therewith, a monitoring scheme for plant health and microclimate was designed, baseline data on soil was acquired, PR-platforms where installed, press releases and articles were published, a GIS project was established and approaches for the marketing of the fruit crops where lined out by the students. Generally, the participants of the module where highly motivated which is reflected in the very good results of the semester.

The activities of the semester are published in a biannual synthesis report, facilitating the research process with regularly changing actors. Moreover a data management plan is designed in order to manage the long-term research process. Parallel to the module a number of Bachelor- and Master-theses is being prepared in the context of the project.

Establishment of the agroforestry system

The planting of the agroforestry system in the Löwenberger Land in autumn 2017 can serve as an example for the mode of operation of the module. After being briefed on the design and on the general plan of the planting process by the tutors, the working group being responsible for preparation and facilitation of planting, became acquainted with the tasks to fulfil during the planting process and prepared a task schedule of the planting. Moreover the working group was instructing the participants of the module and volunteers on the public planting days, contributing to the educational character of the process. The planting process was filmed and documented by the PR-Group (Figure 2). The trees were planted in spade-dug holes along with a mixture of compost, rock flour, and mycorrhizal inoculant. To prevent browsing by game, each tree was protected by a TUBEX ventex shell. In the end a 20 cm wood-chip-mulch layer was applied around each tree and shrub to prevent losses by summer drought and weeds in the first years, as recommended by the agroforestry-pioneer Götsch (1994).

Figure 2: Planting of the high value timber tree rows (EUSD, Gauly, J.-P.)

In the feedback for the module, participants highlighted the synergy-effects of the Ackerbau(m)-Project bringing together the skills of the different faculties of the EUSD as well as of the stakeholders involved. The practical hands-on approach of the project sparked a general excitement for agroforestry among students and the initiative to stay involved and forward the practical implementation in a broad range of ways. Despite the overall positive feedback, there were still topics to improve on, such as the organisational and conceptional processes that were still in early stages, in some areas of activity influencing the working process.

Putting in place a long-term data acquisition carried out by changing actors makes documentation crucial, thus being the foundation for future semesters to build upon. Despite the positive experience of the past semester, it is crucial to consider the limited temporal capacities that can be put in to the project by students, as well as the varying levels of expertise among participants in the research design and its complexity. Further good briefing of the working groups is key in order to obtain valid data on long-term basis.

Conclusion and outlook

The interdisciplinary approach of the module brings together key competences of the faculties “Forest and Environment”, “Landscape Management and Nature Conservation”, “Wood Engineering” and “Sustainable Business” assembled at the EUSD. With its hands-on approach and through its high level of involvement of student initiative, the module aims at enabling students to get a basic understanding of agroforestry systems while actively contributing to a scientific research process. During the course of the module the students acquired new knowledge and developed competences for shaping the future (“Gestaltungskompetenz”) which is a crucial set of competences for sustainable development. Thus with their competences on agroforestry, self-organized education and project-management the participants of the module are enabled to act as change makers, forwarding the implementation of agroforestry in Europe. Further steps are the implementation of the agroforestry module regularly in the curriculum, the establishment of a well-working communication system between the annually changing participants and the securing of a continuous care for the project site.

References

Assmann S, Oelke M (2010) AFS als Erosionsschutz. In: Spiecker H (ed) Multifunktionale Bewertung von Agroforstsystemen. Freiburg, pp 16-37. https://www.dbu.de/OPAC/ab/DBU-Abschlussbericht-AZ-257kaeser86.pdf (accessed 06/04/2018).

Böhm C, Tsonkova P, Zehlius-Eckrst W (2017) Wie können Agroforstsysteme praktikabel in das deutsche Agrarförderrecht eingebunden werden?. In: Böhm C. (ed) Bäume in der Land(wirt)schaft. Von der Theorie in die Praxis. Tagungsband 5. Forum Agroforstsysteme. BTU Cottbus.

Buck J, Endenburg C (2012) Sociocracy: The creative forces of self-organization. Sociocratic Center, Rotterdam.

de Haan G. (2008) Gestaltungskompetenz als Kompetenzkonzept für Bildung für nachhaltige Entwicklung. In: BormannI, de Haan G (eds) (2008) Kompetenzen der Bildung für nachhaltige Entwicklung, Wiesbaden, pp 23–44.

den Herder M, Moreno G, Mosquera-Losada MR, Palma JHN, Sidiropoulou A, Santiago Freijanes JJ, Crous-Duran J, Paulo J, Tomé M, Pantera A, Papanastasis V, Mantzanas K, Pachana P, Papadopoulos A, Plieninger T, Burgess PJ (2016) Current extent and trends of agroforestry in the EU27. https://www.agforward.eu/index.php/de/current-extent-and-trends-of-agroforestry-in-the-eu27.html (accessed 06/04/2018)

Götsch E (1994) Break-Through in Agriculture. Fazenda Tres Colinas, Bahia.

Hofmann P, Hübner-Rosenau D (2016) Agroforst-Modellprojekt im Löwenberger Land. Eine Konzeption im Spannungsfeld zwischen wissenschaftlicher Aussagekraft, landwirtschaftlicher Praktikabilität und komplexer Multifunktionalität. Bachelorarbeit Hochschule für nachhaltige Entwicklung Eberswalde.

Huber J, Schmid H, Häberle KH, Blaschke H, Hülsbergen KJ (2013) Kohlenstoffbindung in ökologisch und integriert bewirtschafteten Agroforstsystemen der Versuchsstation Scheyern/ Bayern. Mitt Ges Pflanzenbauwiss 25: 118-119.

Lemieux G, Germain D (2000) Ramial chipped wood - the clue to a sustainable fertile soil. Université Laval, Quebec.

UN (2015) Transforming our World: The 2030 Agenda for Sustainable development A/RES/70/1. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf (accessed 06/04/2018).

Unseld R, Reppin N, Eckstein K, Zehlius-Eckert W, Hoffmann H, Huber T (2011) Leitfaden Agroforstsysteme. Möglichkeiten zur naturschutzgerechten Etablierung von Agroforstsystemen. TU München, Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt (eds) Bayerische Landesanstalt für Wald und Forstwirtschaft.

EXPERIENCES WITH STAKEHOLDER SPECIFIC FORMATS OF PARTICIPATION TO FOSTER AGROFORESTRY

Hübner R[1*], Pukall K[2], Zehlius-Eckert W[1]

(1) Chair for Strategic Landscape Planning and Management, Technical University of Munich, Freising, Germany (2) Chair of Forest and Environmental Policy, Technical University of Munich, Freising, Germany

*Corresponding author: rico.huebner@tum.de

Abstract

Agroforestry is lagging behind its possibilities in Germany. In order to foster their establishment different formats of participation are employed to include stakeholders and understand their reasoning for or against this novel, thus largely unknown land-use system. A multi-method approach is carried out under the framework of regional governance. Since each group has their own interest each need their own format of information. Farmers, for instance are interested primarily in the economic revenues compared to cash-crops thus plot-specific analysis are needed, whereas environmentalists are concerned with possible changes of the currently existing protected species. The complex set of interests and different lobby groups in land-use call for a complex set of formats, an up-to-date knowledge base on agroforestry systems and administrative and human resources to meet the increasing demand for information. The goal is to create regional governance networks that are able to fulfil these tasks in the future.

Keywords: participatory planning; regional governance; social network analyses; agroforestry; land use

Introduction

The Innovation Group AUFWERTEN (Agroforestry for Environmental Services, Energy Production and Added Value funded by the German Federal Ministry of Education and Research) analyses the factors which promote or hinder the adoption of such innovative land-use concepts (Hübner and Pukall 2017). We hereby utilize the concept of governance, which is almost seen as an antonym to government, since it does not emphasize the hierarchical form of government, but rather focuses on network structures. Furthermore, governance forms a counter-term to control, a generic term of "all social forms of social action coordination" (Kilper 2010; Kooiman 2003). Based on the concept of regional governance – a concept successfully applied in the field of regional development (Böcher 2008) – we actively influence and analyse the study area of Finsterwalde, State of Brandenburg, to find out which structures and processes govern the implementation of agroforestry. The multi-method approach is carried out in accordance with Hogl et al. (2008) and includes the following axes: 1) Participation of experts and lay people; 2) Inter-sectoral and multilevel coordination; 3) Adaptive and iterative planning and 4) Use of democratic and accountable expertise.

The application of a regional governance framework is a major outcome of the first analysis based on the methodology developed by Hübner et al. (2014).

In the following the stakeholder groups are outlined, the specific formats are briefly introduced and our own experience within the process is portrayed. After conducting the initial surveys, we were basically able to distinguish two main group-sets to classify the agroforestry sector in the research area: Firstly, stakeholders of the agroforestry value chains that are directly involved, and secondly, stakeholders who indirectly participate around the agroforestry issue. Both groups are nevertheless highly diverse which complicate the participation process. Since different target groups need different forms and content of information.

Initial rapid assessment: stakeholder networks and a "future workshop"

Social Network Analyses (SNA) was applied in beginning of the project to get an overview about the originally present interest in agroforestry in the area (Hübner et al. 2009). The acquisition of all relevant stakeholders and the systematization of the stakeholder landscape were conducted during the kick-off conference. By using visual and mathematical analysis of relationships among each other (i.e. sociogrammes) it was aimed to understand inter-sectoral and multilevel coordination with respect to the second axis of the regional governance framework (Wasserman and Faust 1999). From that, it was possible to draw a stakeholder matrix covering all possible stakeholders and interest groups which formed the base for the invitation to the future workshop. Becoming our main strategy to involve stakeholders, this methodology is able to involve citizens in the planning process (Jungk and Müllert 1994). Led by the authors as moderators the process is characterized by five distinct phases:

• Preparation-phase: Start and Incoming: Group founding, confidence building;

• Phase I: Complaint and Criticism; Inventory for further work;

• Phase II: Imagination phase and Utopia: Here one should and can fantasize;

• Phase III: Realization and Practice: Linking Phase I and II, possibly involving experts;

• Post-processing: What's next? Feedback round;

Until now, Phase III and the post-processing is still future work of AUFWERTEN that will be undertaken starting in 2018.

Stakeholders in the agroforestry value chain

Farmers and producers

Farmers are by far the most important stakeholder group when it comes to the implementation of agroforestry. In the beginning of the project, we quickly realized from narrative interviews at farms (Helfferich 2005; Hussy et al. 2010) and expert workshops with farmers from the region, that plot specific information on the suitability of agroforestry backed-up by an economic prediction is the most important information leading to a decision. At first, the vague idea of the decision support tool, including a plethora of ecosystem functions, was therefore significantly extended towards the farmers expectations (Hübner et al. 2017). The tool works on the field block or the specific plot-level in order to help planning agroforestry for the farmers. Of major concern were the economic revenues compared to cash-crops, so the growth rates of different tree species with respect to the site conditions and expected yields were included, too. Secondly, a spreadsheet-based calculation tool was developed and provided for free on the project homepage. Both tools foster the third axis relevant for regional governance: the adaptive and iterative planning approach. While some innovative farmers or pioneers already start to plant short-rotation-strips primarily to prevent wind erosion, the majority of the farmers are still reluctant to change their management strategies. Due to the relative big farms, economy was the strongest determinant amongst the farmers in our project region.

Other companies and service providers

Representatives of service providers and associated companies, such as private extension and consulting and members of the forestry sector where also interviewed. For our study area, it turned out that the relatively high amount of woody material at a cheap price will decrease the profitability of agroforestry with an energy focus. Two communities can be classified as particularly wooded (63% forest). But also in the other communities of the region, the proportion of forest is high, so that here is a stronger influence of the forest sector than initially anticipated.

Stakeholders who indirectly participate in agroforestry

General public

The participation of lay people, namely residents and visitors to the region, was a major aim of the project. The interest in participation in the future workshop by non-experts was rather limited. Therefore, we have chosen to directly address the general public through in-situ questionnaires. Taking into account the agroforestry standard types defined by Hübner et al. (2016) and the underlying hypotheses for the perception of the landscape image, photorealistic synthetic images were created using image editing software, based on photographs of landscapes in the model region. The pictures were printed on folder size photo paper format and shown to the participants at seven locations in the model region. In addition to the preference query for each image series, an open question was asked about the reasons for the assessment. In total the survey included the opinion of 93 residents and tourists (52 f., 41 m). In the project time remaining, workshops with lay people associations or clubs are planned, in order to further understand the preference rankings for agroforestry systems and collect the explanatory arguments. Overall, the support for agroforestry is evident and we do not expect a negative public debate as Germany has experienced with the increase of biogas sector some years ago.

Societies and associations

Included in this stakeholder group are all interest and lobby groups, e.g. nature and environmental NGOs, soil and water associations and the farmers union. The NGOs representatives mainly argued for biodiversity and landscape protection. However, since the German nature conservation activists are often close to an opposing position towards a number of mainstream developments in modern agriculture, the support towards new measures of agroforestry is also under pressure, even within the NGOs associated with the project. The fear of a further intensification, especially on marginal land, is expressed in interviews and during the project work. Albeit few studies showing advantages for biodiversity compared to conventional farming without trees and shrubs (e.g. Torralba et al. 2016), the research in this area should be intensified, in order to put judgements on solid ground. For example, the presence of earthworms and soil organisms rebuilding humus in the soil, the effect for insects generally serving for pollination services, bats, birds etc. Furthermore, within the started participation process it became obvious that the maintenance of already existing agroforestry systems, such as shelterbelts which were planted during the communist era is a central issue for several actors (Tsonkova et al. 2018). Here problems of inter-sectoral and multi-level coordination have to be solved.

Policy and administration

This includes politicians and political parties as well as higher administrations and ministries and local governments and lower authorities. While the influence on the Common Agricultural Policy (CAP) is rather limited we focused on the *Länder* level, namely the Ministry for Rural Development, Environment and Agriculture (MLUL) of Brandenburg, and at the federal level, the Federal Ministry of Food and Agriculture (BMEL). This important part of policy lobbying will be of main emphasis during the remaining project time. These accounts for the fourth axis of regional governance: the use of democratic and accountable expertise.

Final remarks

The network in the studied region and beyond combines actors from communities, enterprises within the energy market and farmers, but increasingly administrations, officials and politicians. Also, the AUFWERTEN-project team is – temporarily – member of this network. The applied tools and formats should foster the idea of regional governance and the project team is excited about to find out, whether the main objective of the activities within AUFWERTEN, namely the promotion of informal networks in the sense of regional governance, will finally lead to a climate mitigation and adaptation process to establish more agroforestry systems.

Acknowledgements

The AUFWERTEN project (Reference No 033L129AN) is funded by the Federal Ministry of Education and Research (BMBF).

References

Böcher M. (2008) Regional Governance and Rural Development in Germany: the Implementation of LEADER+. Sociologia Ruralis 48: 372-388.

Helfferich C (2005) Die Qualität qualitativer Daten. Manual für die Durchführung qualitativer Interviews. VS Verlag, Wiesbaden.

Hogl K, Nordbeck R, Pregernig M. (2008) GoFOR–New Modes of Governance for Sustainable Forestry in Europe. Specific Targeted Research or Innovation Project: Thematic Priority 81: “Sustainable Management of Europe’s Natural Resources” Publishable Final Activity Report.

Hübner R, Kantelhardt J, Schaller L (2009) Climate protection–land use in peat-land areas Network analysis as a method in actors and systems analysis. In: Daub C-H, Burger P, Scherrer Y (eds) Creating Values for Sustainable Development - Proceedings of the 2nd International Sustainability Conference, Basel, Switzerland.

Hübner R, Pukall K, Zehlius-Eckert W. (2014) Steuern oder Kooperieren? Bearbeitung von Governance-Fragen im Forschungsprojekt AUFWERTEN (Agroforstliche Umweltleistungen für Wertschöpfung und Energie). 4 Forum Agroforstwirtschaft, Dornburg, Germany.

Hübner R, Härtl J, Zehlius-Eckert W, Pukall K. (2016) Definition von Agroforsttypen und Bewertung der landschaftsästhetischen Wirkung durch Laien. 5 Forum Agroforstsysteme – Bäume in der Land(wirt)schaft – von der Theorie in die Praxis. Innovationsgruppe AUFWERTEN, Senftenberg.

Hübner R, Busch G, Tsonkova P, Böhm C (2017) Development of a GIS-based decision support system for agroforestry and insights to its application. 15th North American Agroforestry Conference, Blacksburg, VA, USA.

Hübner R, Pukall K. (2017) Promoting and hindering factors for the implementation of agroforestry systems in Germany. In: Wingeld MJ (ed) IUFRO - Interconnecting forests, science and people, Proceedings of the 125th IUFRO Conference 2017, Freiburg.

Hussy W, Schreier M, Echterhoff G (2010) Forschungsmethoden in Psychologie und Sozialwissenschaften. Springer Verlag, Berlin.

Jungk R, Müllert NR (1994) Zukunftswerkstätten mit Phantasie gegen Routine und Resignation. Heyne, München.

Kilper H (2010) Governance und Raum. Nomos Verlagsgesellschaft, Baden-Baden.

Kooiman J (2003) Governing as Governance. Erasmus University, Rotterdam.

Torralba M, Fagerholm N, Burgess PJ, Moreno G, Plieninger T (2016) Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. Agr Ecosyst Environ 230: 150-161.

Tsonkova P, Böhm C, Hübner R (2018) The biomass potential of existing tree structures in the agricultural landscape. 4th European Agroforestry Conference: Agroforestry as sustainable land use, Nijmegen, The Netherlands.

Wasserman S, Faust K (1999) Social network analysis: methods and applications. Cambridge Univ. Press, Cambridge.

STRATEGIES FOR STIMULATING THE TRANSITION INTO AGROFORESTRY IN QUEBEC, CANADA

Olivier A[1*], Anel B[2], Cogliastro A[3], Rivest D[4]

(1) Département de phytologie, Université Laval, Québec, Canada (2) Laboratoire rural Agroforesterie et paysage, MRC du Rocher-Percé, Chandler, Canada (3) Institut de recherche en biologie végétale, Montréal, Canada (4) Département des sciences naturelles, Université du Québec en Outaouais, Gatineau, Canada

*Corresponding author: alain.olivier@fsaa.ulaval.ca

Abstract

A task force was set up in order to identify the strategies to put in place to stimulate the adoption of agroforestry practices in Quebec, Canada. An inventory of the resources available to farmers and landowners who wish to use agroforestry practices was made out: availability and accessibility of practical knowledge, advice, technical services, materials, training and education resources, research, and institutional and policy support. An analysis of the current situation in view of the challenges faced by the agroecosystem led to six recommendations: the recognition by the public authorities of the potential of agroforestry; an increased technology transfer; the provision of financial support to producers; the creation of new knowledge through research activities; the development of adapted plant material; and an increased dialogue between the various actors of the agriculture, forestry, environment and rural development sectors. The implementation of these recommendations should help the scaling-up of agroforestry in Quebec.

Keywords: agroecosystem; financial support; knowledge; policies; technology transfer

Introduction

In the province of Quebec, Canada, the rate of adoption of agroforestry is still low, although a growing interest toward agroforestry practices is easily observable among various stakeholders of the agricultural, forestry, environment and territorial planning sectors. Such an interest led to the creation, in December 2008, of an Agroforestry Committee supported by the Quebec Reference Center for Agriculture and Agri-food (CRAAQ), a network of experts and organizations aiming at sharing of information and knowledge management and dissemination. The mandate of the Agroforestry Committee, which comprises representatives from Ministries (Agriculture, Forestry), Farmers' and Foresters' Unions, agricultural and forestry advisory groups, universities, and research centers, is to contribute to the development of agroforestry systems offering solutions to the issues of rural territories in Quebec by fostering networking, sharing of information and knowledge transfer.

In the last few years, the Agroforestry Committee organized various events, among which a Forum on Agroforestry (CRAAQ 2010) and a Workshop on Research and Development in Agroforestry (CRAAQ 2013), whose participants identified the absence of recognition at the political level and the lack of financial and technical support as some of the most important constraints to adoption of agroforestry. Thus, a working group stemming from the Agroforestry Committee was set up in February 2014 in order to reflect on the strategies to put in place to stimulate the transition into agroforestry in the province of Quebec. The reflection process, comprising regular meetings, writing sessions and round of comments from the members of the Agroforestry Committee, led to the drawing up of a document entitled "*Une agroforesterie pour le Québec. Document de réflexion et d'orientation*". This 73-pages document was adopted by all members of the Agroforestry Committee in November 2016 and published, in French, together with an executive summary (*Résumé analytique*), in June 2017 (Anel et al. 2017). The present paper focuses on the main results of this process and the most important lessons that can be drawn from it.

The main issues of Quebec's agroecosystem

A few countries have already developed policies or strategies in order to stimulate the scaling-up of agroforestry systems. For the working group, however, it quickly appeared that the strategies for the development of agroforestry in Quebec should not be based on the international literature on the subject, but on the specific challenges faced by the agroecosystem in the Quebec context.

A consultation process led to the identification of six main issues of the agroecosystem in Quebec: soil health, biodiversity, water quality, climate change (mitigation and adaptation), rural landscape and profitability of agricultural land exploitation. All the reflection on the contribution of agroforestry was thus structured in relation to these six issues.

What is agroforestry?

An effort was made in order to define what agroforestry looks like in the Quebec context. Forest farming systems were excluded from the analysis since the challenges faced by these systems are quite different from those encountered in the agricultural landscape. Agroforestry systems were classified in two main groups, agroforestry hedges (trees and shrubs around the fields) and intra-plot agroforestry systems (trees and/or shrubs in the agricultural plot), with an additional category for silvopastoralism.

Synthesis of the knowledge of agroforestry in relation to the issues of the agroecosystem

The possible contribution of agroforestry to the resolution of the six main issues of the agroecosystem was assessed, based on the scientific literature available from studies realised in Quebec or, when necessary, in the neighbouring provinces or other temperate countries. This literature review pointed out the very beneficial effects of agroforestry, in general, for five of the six challenges.

Agroforestry systems are great tools for: maintaining and restoring soil health, since trees are allies for the soil; conserving and restoring biodiversity, through new habitats and beneficial organisms; enhancing water quality; mitigating climate change and adapting to such a change; and making the rural landscape more attractive. However, although the profitability of agroforestry is high for society as a whole, it remains uncertain at the plot or farm level.

Portrait of the presence of agroforestry in the agricultural landscape

The current extent of agroforestry hedges and intra-plot agroforestry systems (including silvopastoral systems) in the agricultural landscape was described. Both individual and collective initiatives coexist. In general, it can be said that initiatives are few, but emerging.

Available resources to support agroforestry

An inventory of the resources available to farmers and landowners who wish to use agroforestry practices was made out. The availability and accessibility of practical knowledge, through documentation and demonstration sites, were estimated. Human resources, technical services, and materials available to farmers were assessed. An evaluation of existing education and training opportunities was performed. Research expertise, experimental designs, scientific events and publications were also described, as well as networking organizations and events.

The study then focused on institutional and policy support. The involvement of different ministries in agroforestry was described, and an inventory of both incentive tools and restrictive policies was made. Support programmes were also studied. Results show that in general, farmers who wish to plant tree rows are still eligible for the main support programmes. However, the level of support can decrease because of a smaller cropped area in favour of trees.

Analysis of the situation

The analysis of the current situation in view of the issues faced by the Quebec's agroecosystem showed that agroforestry offers great solutions to most issues. However, although agroforestry is highly profitable at the global scale, its profitability is still uncertain at the plot or farm level. A financial support is therefore essential. Practical knowledge is sufficient to foresee agroforestry development, but applied research is needed to determine the best options, and cultivars adapted to the agroforestry context should be developed in order to optimize the productivity and profitability of agroforestry at the farm level. The study also points out that only a small proportion of future farmers and their advisors are educated and trained in agroforestry. Active actors work in a diversity of structures and are not associated to a specific professional order. While many documents on agroforestry are available, there is a lack of technical information intended for farmers and a need for a demonstration network at the farm level. Finally, while a number of ministries see agroforestry as a pertinent tool, the Ministry of Agriculture, Fisheries and Food is the only one to deploy concrete means. However, these means are oriented towards agro-environmental aspects only. Moreover, there is no pooling of means nor common vision on agroforestry development.

Conclusion

This analysis brought the working group to make six recommendations: 1) the recognition by the public authorities of the potential of agroforestry and its integration in policies and action plans of the main organizations related to agriculture, private forest, protection of the agricultural environment and rural territory planning; 2) an increased technology transfer through the setting up of a network of agroforestry advisors, the development of information tools, the creation of a network of demonstration sites and the integration of agroforestry in the education of future farmers and advisors; 3) the provision of financial support to producers through a program specifically dedicated to agroforestry, applied to all agroforestry systems, and including all activities from plantation to maintenance of trees, a support that could be reinforced by the integration of the space occupied by trees as agricultural surface eligible for insurance and financial aid programmes; 4) the creation of new knowledge through applied research focusing on productivity and profitability of agroforestry systems, as well as fundamental research regarding the functioning of the systems, their use of resources and their social and environmental impacts; 5) the development of plant material (trees and crops) specifically selected to perform well in agroforestry contexts; and 6) the setting up of a provincial agroforestry networking group comprising representatives from the main institutions related to agriculture, forestry, environment and territorial planning sectors.

The implementation of these recommendations should help the transition into agroforestry in Quebec. In view of the contribution of agroforestry systems to the resolution of the challenges of the agroecosystem, indeed, such a transition is highly advisable.

References

Anel B, Cogliastro A, Olivier A, Rivest D (2017) Une agroforesterie pour le Québec. Document de réflexion et d'orientation. Comité agroforesterie, Centre de référence en agriculture et agroalimentaire du Québec, Québec. 73 p.

CRAAQ (2010) Forum sur l'agroforesterie. Compte rendu du colloque tenu à Québec le 3 mars 2010. Comité agroforesterie, Centre de référence en agriculture et agroalimentaire du Québec, Québec. 33 p.

CRAAQ (2013) Atelier sur la recherche et développement en agroforesterie: « Parcours comparés du Québec et de la France ». Compte rendu du colloque tenu à Drummondville le 8 février 2013. Comité agroforesterie, Centre de référence en agriculture et agroalimentaire du Québec, Québec. 18 p.

EDUCATION IN AGROFORESTRY: PRELIMINARY RESULTS FROM THE AGROF MM – ERASMUS + PROJECT

Pantera A[1*], Burriel C[2], Herdon M[3], Tamás J[3], Lamaison M[4], Musquar C[4], Seeman M[5], Atanassova S[6], Harfouche A[7], Escural JM[8], Fico F[9], Devernay S[10], Lavoyer S[11], Balaguer F[11], Papadopoulos A[1], Papanastasis V[1], Mantzanas K[1]

(1) TEI Stereas Elladas, Karpenissi, Greece (2) AGROSUP DIJON, France (3) University of Debrecen, Hungary (4) ALIENOR EU, Belgium (5) Friends of Nature, Lebanon (6) Trakia University, Bulgaria (7) Universita Degli Studi della Tuscia, Italy (8) CFPPAF de Mirecourt, France (9) AFTD, Albania (10) EPLEFPA Le Valentin, France (11) AFAF, France

*Corresponding author: pantera@teiste.gr

Abstract

Agrof MM, "Training in Agroforestry - Mediterranean - Semi-Arid Zones – Mountain AGROF MM", is a 3-year KA-2 ERASMUS+ educational project that aims to i) train 130 to 150 agricultural professionals in Europe, ii) improve and develop the education tools which will allow agroforestry training to be long-lasting, and iii) develop a unique agroforestry qualification program in each European country. It is coordinated by AgroSup Dijon, France and involves thirteen partners from 10 different countries who contribute to the project with a wide range of knowledge, experiences and ideas to promote education in agroforestry, disseminate this land use and allow the acquisition of new competencies and knowledge for those involved in its practice. So far, it has analysed existing educational systems and further seeks to describe existing training procedures and identify needs, to census and evaluate existing educational tools, and to enrich the European book of professional reference for agroforestry farmers.

Keywords: knowledge transfer; training; farmers; educators

Introduction

Agroforestry is "the deliberate integration of woody vegetation (trees and/or shrubs) as an upper storey on land, with pasture (consumed by animals) or an agricultural crop in the lower storey. The woody species can be evenly or unevenly distributed or occur on the border of plots. The woody species can deliver forestry or agricultural products or other ecosystem services (i.e. provisioning, regulating or cultural)". Agroforestry is a traditional land use system that may be the answer to many present and future environmental problems. However, many farmers that practice agroforestry neither identify its name nor accept such identification. Education must become the "alpha" and "omega" in confronting this problem mainly in enhancing the uptake of agroforestry. In this article the ERASMUS+ AGROF MM project is presented as a contribution to the education in agroforestry.

The project

Agrof MM, "Training in Agroforestry - Mediterranean - Semi-Arid Zones – Mountain AGROF MM", is a 3-year KA-2 ERASMUS+ educational project that aims to i) train 130 to 150 agricultural professionals in Europe, ii) improve and develop the education tools which will allow agroforestry training to be long-lasting, and iii) develop a unique agroforestry qualification program in each European country. It is coordinated by Charles Burriel and supported by Ghislaine Nouallet from AgroSup Dijon, France. Thirteen partners from 10 different countries contribute to the project with a wide range of knowledge, experiences and ideas. They all share the common will and wish to promote education in agroforestry, not only to disseminate this land use but also to allow the acquisition of new competencies and knowledge for those involved in its practice. One of the goals of the AgrofMM project is to create and develop new innovative tools and resources on agroforestry such as a thesaurus specifically dedicated to agroforestry. So far, it has analysed existing educational systems and further seeks to explore more information such as to describe existing training procedures and identify needs, to census and evaluate existing educational tools, and to enrich the European book of professional reference for agroforestry farmers. Created in the framework of the preceding AgroFE project, the book of professional reference describes the tasks that the farmers and foresters who practice agroforestry must be able to achieve. It also supports the transfer of training. Other goals, based on the above findings, include the design of training systems, the production of educational material, including multimedia tools. It also seeks to practically validate the educational systems and analyze and disseminate the obtained results.

Materials and methods

The project aims to reach its goals by applying different types of training such as courses, group work, conferences, field visits and trainings, thematic workshops, and case studies. It is addressed to students, farmers, future farmers, foresters, workers, teachers, agricultural advisors and many other stakeholders.

Figure 1: Trainers trained in Greece, discussing with a stakeholder on his experience on agroforestry.

So far, it has accomplished many of its goals through the active participation of its members through transnational meetings, educators, students and farmers trainings (Figure 1) and field visits (Figure 2).

Figure 2: Stakeholders in a valonia oak silvopastoral system in Xeromero, Grece, during their training in the field.

An important asset of the field visits is the opportunity to interact with farmers, share and acquire their valuable experience. For example, during the field visit in Tornos, a remote mountainous village of Evritania, Greece, the farmer presented his multiple products including mushrooms (Figure 3).

Results

Several trainings have been organized so far by the partners. It is an on-going process and interesting results have been gathered so far. In Greece farmers expressed their concerns on the future of the valonia oak silvopastoral system and their wish for an active involvement of the local authorities for the protection of the system. As mentioned before, a proportion of them did not identify agroforestry as a land use system even if most of them were practising it. Students of the TEI Stereas Elladas who attended a one-week intensive course, shared their enthusiasm on a future adoption of agroforestry. Agroforestry is already taught at the BSc level but many new issues, pursued by the project, will be incorporated to the original syllabus

Figure 3: Mushrooms is only one of the multiple products obtained by the mountainous agroforestry system in Tornos, Evrytania, Greece

In Albania a training week with the agronomy master students was organised. Agroforestry was a whole new concept for almost all participants. The training connected the EU and world experiences with the traditional agroforestry systems existing in the country. The students have gained knowledge and instruments to advance their studies and to start including agroforestry in their professional career. A textbook for the Agri University students has been adapted in Albanian, from well-known agroforestry academic sources. An informative training video, to reach the wide public and the farmers, has been produced and published on the social media. Another video with guidelines for farmers will be realized shortly. The training will continue with the extension/counselling service and farmers in the Korca Region, a territory that has tradition and high potential to increase the presence of agroforestry systems.

In Bulgaria, a course of agroforestry was created and included for the first time in the curriculum of the bachelor degree in Agronomy, Trakia University, Stara Zagora. Additional courses for post-graduate qualification for farmers, advisors and stakeholders were developed.

The University of Debrecen, Hungary, introduced Agroforestry in the agri-environment course at the BSc level. Within the Agrof-MM project 70 students enrolled and passed this course. 25 students are presently enrolled. During this course students learn about domestic and international practice and related research of farm forestry. They get to know the relationship between agricultural land use and forestry systems and learn the major technical details of the agroforestry implementations. The course also covers the agricultural soil protection and amelioration of the role that forestry plays. Students will learn about the natural breeding, pasture management, crop management and organic farming principles of joint realization of the forest during the training.

A lot of important work has been accomplished so far in France. In CFPPA Die, a one week training has been organized since 2010. A substantial number (150) of students have followed agroforestry training since the beginning. Additionally, there is an increase by 25 % of trainees each year, most of them having already installed a project in agroforestry. They are all very motivated on this subject and they come from all over France.

As mentioned before, the other major goal of the project, the *thesaurus,* contains about 150 words linked to agroforestry, from systems to ecosystems. These words are indexed in six main topics: agroforestry systems, agroforestry technics and practices, ecology and dynamics, ecosystem services, economy and law, and design and management. This work is nearly finished and will be published at the end of the project, in several languages and perhaps with a glossary.

The knowledge database has been developed to be used as a tool and training resource and will also integrate existing and future training resources (http://newkdb.agrofmm.eu). Collaborative and dissemination platforms were created and include an official web site (http://agrofmm.eu/index.php/en/), Twitter (https://twitter.com/AgrofMM), a video-conference system and Facebook page have been registered and maintained (https://www.facebook.com/AgrofMMEU/), a mailing list and a Moodle training portal for project documentation (http://moodle.agrofmm.eu/), as well as a Learning Management System.

The Knowledge Databank (KDB) is a component of the project training system. It aims at gathering and sharing a set of documents, resources that partners can use and which learners and public users can access. The knowledge databank enables access to, sharing of and consultation of the resources for training. These resources are in different forms such as Mono document object (like a photo, a text, a diagram) and Composite materials (for example a html web page with images, a pdf file with pictures and diagrams, a video clip with images and sounds). The KDB is based on different professional vocabularies, metadata and thesaurus system (Figure 4) which is used for building the content structure and helping the users in their research.

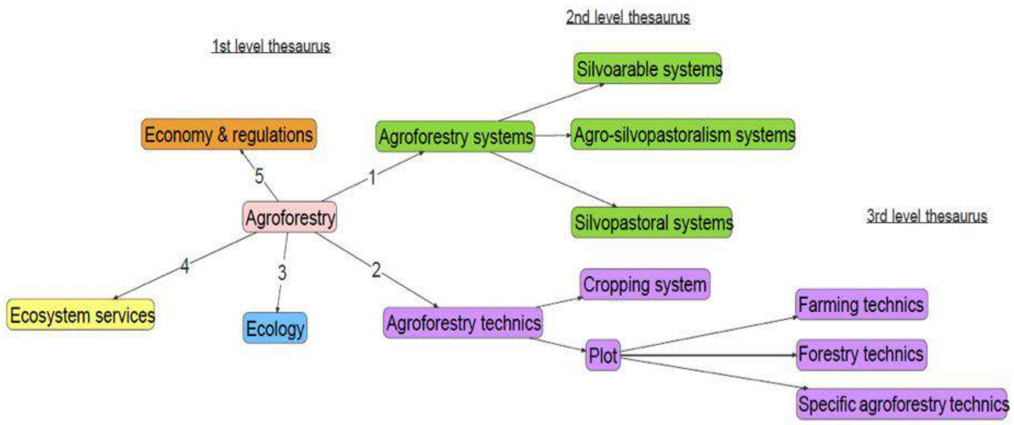


Figure 4. The levels of the thesaurus system for the Agrof-MM KDB (Developped by one of Agrof-MM working groups and composed by Jean-Michel Escurat)

Next steps

Trainings are continuously organised and more results are expected for the following months. An intensive course will be organised by the University of Debrecen in Hungary for students. All partners will organize a national event to present the results from their trainings and training method. Although the project is not over yet, the importance and contribution of education in the future adoption of agroforestry is quite clear. All these will be further evidenced within the next few months with the conclusion of this project.

Acknowledgment

This project has been funded with the support of the European Commission (2015-1-FR01-KA202-015181). This communication only reflects the views of the author, and the Commission cannot be held responsible for any use, which may be made of the information contained therein

References

AGROF MM project, http://agrofmm.eu/_(accessed 16/04/2018)

Burriel C, Herdon M, Tamás J, Várallyai L, 2017, Knowledge databank and repository service for agroforestry. J Agric Informatics 8: 33-40.

HOW TO MAKE AGROFORESTRY SYSTEMS PAY OFF? USING ITS VALUES TO CREATE ECONOMIC DEVELOPMENT PATHWAYS

Borremans L[1, 2*], Reubens B[3], Wauters E[2]

(1) Social Sciences Unit, Institute for Agricultural, Fisheries and Food Research, Burg. Van Gansberghelaan 115 box 2, Merelbeke, Belgium (2) Unit of Landscape Ecology and Plant Production Systems, Université Libre de Bruxelles, Avenue F.D. Roosevelt 50, Brussels, Belgium (3) Plant Sciences Unit, Institute for Agricultural, Fisheries and Food Research, Burg. Van Gansberghelaan 96, Merelbeke, Belgium

*Corresponding author: lieve.borremans@ilvo.vlaanderen.be

Abstract

This uncertainty about the profitability of agroforestry systems is considered one of the main barriers preventing futher adoption by farmers. Therefore, in this study, we brainstormed about different schemes, mechanisms and arrangements that could onvert the benefits and values of agroforestry into direct economic incentives for farmers. Throughout three focus groups a range of different mechanisms were indentified, which were classified in three different groups: government schemes, market schemes and community-based schemes. In Flanders, currently only some of the mechanisms, mainly government mechanisms are put in place. However, some of the mechanisms could represent new economic pathways that reinforce the impact of the already existing mechanisms. Further development and tailoring of these different economic pathways can therefore help to turn AF into a more solid economic investment for farmers.

Keywords: community cooperatives; economic instruments; government incentive schemes; market mechanisms; public policy; temperate agroforestry systems

Introduction

Agroforestry (AF) is increasingly considered as a sustainable agricultural innovation which can address social, ecological, and biodiversity problems in industrialized agricultural regions. Although it has been shown that with careful design and management the overall productivity in AF systems can exceed those of conventional systems (Smith et al. 2012) this is not always translated into economic and financial benefits for the farmer (Palma et al. 2007; Van Vooren et al. 2016). On the one hand, this a result of the long duration between investment costs and pay-off, which greatly exceeds the usual planning horizon of traditional farming systems. Indeed, depending of the desired output of the AF system (wood versus fruits/nuts), it takes up to decades before harvesting can take place. Consequently, the farmer is confronted with a lot of risk and uncertainty. On the other hand the apparent lack of profitability is a result of the way in which agricultural markets function, only allowing for the valorization of productive services. For the many forms of societal value created by AF systems, e.g. biodiversity and landscape values, no compensation towards the farmer is available (Borremans et al. 2018).

Taking this into account, it is no surprise that Flemish farmers consider the uncertainty about the profitability of the farming system to be one of the main barriers to AF adoption (Borremans et al. 2016a). The subsidy program, initiated in 2011 and covering 80% of the plantation costs, may have brought some, already interested farmers on board. However, an agricultural innovation system analysis (Borremans et al. 2018; 2016b) has shown that other mechanisms have to be put in place to scale-up AF beyond its pioneering phase. Therefore, in this study, we brainstormed about different schemes, mechanisms and arrangements - traditional or very innovative and outside the box – that convert the benefits or values of AF into direct economic incentives for farmers. The aim of this study was to classify and analyze these different mechanisms, and to give recommendations which respect to the best economic and policy pathways to further advance AF development in Flanders.

Materials and methods

Ideas were gathered during three focus groups, organized as part of three conferences: (1) the Transdisciplinary Agroecology Meeting (November 2015 in Leuven, Belgium), (2) the North American Agroforestry Conference (July 2017 in Virginia, US), (3) and the Belgian Agroecology meeting (November 2017 in Gembloux, Belgium). About 55 people attended the focus groups, including scientists, representatives of civil society organizations (e.g. NGO's), students and farmers, however, no farmers attended the last focus group. The structure of the three focus groups was similar: they started with a short introduction of the goal, were followed by a brainstorming session in smaller groups of 4 up to 6 people, and were concluded with a larger group discussion. In the first two focus groups, the brainstorming session was organized according to the '6-3-5 brainwriting' method (Heslin, 2009; Wodehouse and Ion, 2012). This method is an idea generation technique in which participants brainstorm in silence, i.e. participants get five minutes to write down three ideas in a concise way, after which pages are passed on to the next person in the group, who reacts to the idea, e.g. by giving recommendations, formulating requirements or giving examples. In the third focus group, participants discussed their ideas in the small groups to save time for the larger group discussion. After the brainstorming session, the small groups presented their top ideas to the rest of the group, which were arranged on the blackboard according to different themes. The focus groups concluded with a large group discussion on the (dis)advantages, feasibility and the impact of different categories of proposals. After the focus groups, the different mechanisms and arrangements were allocated to different categories of incentives, which were used to formulate policy recommendation to advance AF development in Flanders.

Results and discussion

Three categories of incentives were identified, which are 1) government schemes, 2) market schemes, (including sector-oriented schemes and consumer-oriented schemes) and 3) community-based schemes. They provide voluntary incentives for AF adoption by farmers (Segerson 2013), and their labels reflect their financing source as shown in Table 1.

Table 1: Output of brainstorm sessions, i.e. schemes/mechanisms that could provide economic incentives to farmers to adopt agroforestry.

	Government	Market		Community
		Sector-oriented	Consumer-oriented	
Type	Payment for Ecosystem Services/Agri-environment schemes e.g. AF investment subsidy e.g. AF maintenance subsidy Land incentives e.g. prioritizing public land for agroecology Greening measures e.g. ecological surface area Tax incentives	Payment for Ecosystem services/Emission trading schemes: e.g. carbon markets e.g. water quality trading e.g. biodiversity offsets Funds and trusts e.g. green seats of airline companies Insurance discounts e.g. smaller premiums for more resilient systems Interest-free loans e.g. for investing in AF	Standards and certification: e.g. carbon label e.g. animal welfare/quality label e.g. woodland eggs, e.g. pata negra ham Agritourism/ Direct marketing: e.g. farm shops e.g. farmers' markets e.g. vegetable/food boxes Niche and specialty markets e.g. buckthorn, e.g. nuts	Shared ownership with consumer: e.g. community supported agriculture e.g. Pomona cooperative AF business e.g. 'adopt a tree' Shared ownership with forester/investor e.g. annual compensation for maintenance of trees Local currency e.g. which can be used for local services
Financing source	Public	Private (companies, NGO's, banks, etc.)	Consumers	Community/ Cooperative
Participation incentives	Incentive payments (/regulatory threats)	Incentive payments	Consumer demand	Benefits from cooperation

Government schemes include all approaches that are financed by the government, i.e. with public money. The most traditional arrangement in this category is an AF subsidy program, by analogy with other agri-environment schemes. This idea was brought up in all focus groups, and was considered easy to set-up by the participants. In Flanders, such an AF subsidy program already exists since 2011, which is funded for 50% by the European Agricultural Fund for Rural Development (under Pillar II of the CAP), and covers up to 80% of the investment costs. Until 2017 54 plots were planted making use of the subsidy program, resulting in about 100 ha of AF. Besides the subsidy for AF systems, also support exists for the establishment of hedgerows. This support, granted by VLIF (the Flemish Agricultural Investment Fund) covers up to 100% of costs, and is complemented with a maintenance subsidy granted by VLM (the Flemish Land Agency). Another, more innovative idea is a land incentive program, in which publicly owned farming land is prioritized for sustainable farming systems. This idea is inspired by conservation easement programmes in the US (Duke and Lynch 2007). The lessor of the land, e.g. provinces, municipalities or church administrations, lowers the rent charged to the farmer on the condition that agroecological farming systems are used on the land. In Flanders, where the pressure on land is high and access to land is difficult, this measure could generate strong incentives for farmers to change their production methods. The government could also impose sustainability conditions on farmers' practices and management approaches in exchange for financial support. This concerns, amongst others, the greening measures on arable land in the context of the Common Agricultural Policy (CAP), resulting in farmers losing some of their basic payments in the case of non-compliance. Currently the greening measures still give a lot of freedom to the farmer who can chose to implement any of the suggested measures to achieve 5% of Ecological Focus Area. However, this freedom results in AF systems being pushed into the background to the benefit of easier and more straightforward measures that are often already implemented by farmers, e.g. catch crops, nitrogen fixing crops and fallow (Zinngrebe et al. 2017). Also the fact that AF on permanent grassland and AF plots that were not installed making use of the subsidy program (or were not officially registered as AF under the same stringent conditions), are not eligible as greening area, put AF as a greening measure at a disadvantage. Another government measure, which could increase the uptake of AF systems more directly, are tree density-based taxes. However, such a stringent measure that punishes farmers for having no trees on their farm could result in a lot of resistance from the agricultural sector. In this respect, voluntary approaches are considered by the respondents as more appropriate and effective.

Market schemes include inventive market mechanisms, or use new market channels to reward farmers for value creation through AF practices. Based on the financing source, they can be split up in sector- and consumer-oriented schemes. *Sector-oriented schemes* include all arrangements in which private actors like companies, organizations, banks and NGO's incentivize farmers to plant trees on their land. This includes ecosystem trading, an arrangement implying financial transfers between companies as causers, and farmers as mitigators of environmental pollution. Carbon markets, in particular, could provide incentives for AF systems because of the large potential of trees to store carbon and mitigate climate change. The government could oblige companies to participate in these markets by issuing compulsory tradable permits (Holderieath et al. 2012). However, respondents argued that, given the high negotiation and enforcement costs involved, in the short term, the establishment of voluntary funds and trusts for tree plantation on farmland might be more effective. An example of the latter are green surcharges of airline companies, through which they allow passengers to compensate for the generated carbon emissions. Respondents also thought that banks have a role to play by offering interest-free loans to farmers to invest in agroecological farming systems, whereas insurance companies could lower insurance premiums for robust and resilient farming systems. Indeed, many studies prove the resistance of agroecological systems against extreme climatic events (Altieri and Nicholls 2013), which is becoming increasingly important because of climate change. *Consumer-oriented schemes* are a group of marketing approaches that persuade the consumer to pay a correct price for an added-value product. In the case of AF systems this added value is the wide range of ecosystem services generated throughout the production process. Labels, which attract consumers' attention on a product's special attributes, belong to this group of approaches. In some EU countries these labels already exist, e.g. woodland eggs in the UK or 'pata negra' ham in Spain, reflecting especially animal welfare and quality aspects. Also direct marketing approaches that bridge the gap between producers and consumers are considered valuable, and a way to transfer the extra production costs directly from consumer to producer. In this respect, because of its landscape value, AF systems may be boosted especially by farm shops, which imply consumers passing by and stopping over at the farm. Finally, respondents emphasized the importance of the development of special markets for niche and specialty products, such as developing market outlets for e.g. buckthorn berries. The same is true for products which are not new, but for which no formal value chains exist yet in Flanders, as is the case for different kinds of nuts.

Community-based schemes bundle a range of initiatives that imply the formation of a cooperative structure that will finance or invest in AF systems. The ownership of the AF system is then shared between the different people involved in the cooperative. The best known example of such a structure, that considers also consumers as shareholders of the farm, is community-supported agriculture (CSA). Although often fruit trees are planted on a CSA farm, they are not assigned a central role. However, recently in Flanders a new CSA farm, Pomona vzw (Figure 1), was developed that will specialize in AF systems (Bauwens et al. 2018). The name of the cooperation refers to the Roman goddess of plenty, of fruit trees and orchards, which was chosen to draw attention to agroforestry as a regenerative and restorative farming system. Consumers commit themselves to purchase food products from the cooperation by becoming shareholders. In exchange the farmers of the cooperation commit themselves to the production of a broad range of food products through agroforestry or other forms of restoration agriculture, with respect for mankind, animals and the environment. Less binding agreements could also exist, in which families adopt a fruit tree and later on are allowed to harvest the fruits. A cooperative agreement can also be arranged between a farmer, and a forester or an investor, who takes care of tree management or annually compensates the farmer for the labor involved. To further stimulate local value generation, local currency systems could be thought out, in which the products of the AF can be traded off against local services. These ideas however are rather outside the box, and need careful planning before they can be implemented in practice.

Figure 1: Logo and banner of Pomona, an agroforestry cooperation that was recently established in Flanders

Conclusion

During the focus groups a wide range of financial incentive mechanisms were identified that could advance the uptake of AF systems by farmers. These arrangements can be clustered according to their main financing source, being (1) the government, (2) the market or (3) the community. Despite this wide range of ideas, currently only some government mechanisms, i.e. the subsidy program and greening measures, are put in place. The other mechanisms, although targeting different types of AF and representing great opportunities to involve different actors, are not yet (fully) exploited. However, different incentive mechanisms could co-exist and reinforce each other. Further development and tailoring of these different economic pathways can therefore help to turn AF into a more solid economic investment for farmers.

References

Altieri MA, Nicholls CI (2013) The adaptation and mitigation potential of traditional agriculture in a changing climate. Clim Change 1–13.

Bauwens L, De Roeck T, Temmermans M, Van Gasse B, Van Hoye A, Van Hoye I (2018) Pomona vzw [WWW Document]. URL http://www.pomonacoop.be/ (accessed 04/03/2018).

Borremans L, Reubens B, Van Gils B, Baeyens D, Vandevelde C, Wauters E (2016a) A Sociopsychological Analysis of Agroforestry Adoption in Flanders: Understanding the Discrepancy between Conceptual Opportunities and Actual Implementation. Agroecol Sustain Food Syst 40: 1008–1036.

Borremans L, Reubens B, Wauters E (2016b) Nurturing agroforestry systems in Flanders: an Agricultural Innovation System approach. 3rd European Agroforestry Conference, Montpellier, France.

Borremans L, Marchand F, Visser M, Wauters E (2018) Nurturing agroforestry systems in Flanders: Analysis from an agricultural innovation systems perspective. Agric Syst 162: 205–219.

Duke JM, Lynch L (2007) Gauging support for innovative farmland preservation techniques. Policy Sci 40: 123–155.

Heslin PA (2009) Better than brainstorming ? Potential contextual boundary conditions to brainwriting for idea generation in organizations. J Occup Organ Psychol 82: 129–145.

Holderieath J, Valdivia C, Godsey L, Barbieri C (2012) The potential for carbon offset trading to provide added incentive to adopt silvopasture and alley cropping in Missouri. Agrofor Syst 86: 345–353.

Palma J, Graves AR, Burgess PJ, van der Werf W, Herzog F (2007) Integrating environmental and economic performance to assess modern silvoarable agroforestry in Europe. Ecol Econ 63: 759–767.

Segerson K (2013) When Is Reliance on Voluntary Approaches in Agriculture Likely to Be Effective ? Appl Econ Perspect Policy 35: 565–592.

Smith J, Pearce BD, Wolfe MS (2012) Reconciling productivity with protection of the environment: Is temperate agroforestry the answer? Renew. Agric Food Syst 28: 1–13.

Van Vooren L, Reubens B, Broekx S, Pardon P, Reheul D, Van Winsen F, Verheyen K, Erwin W, Ludwig L (2016) Greening and producing: an economic assessment framework for integrating trees in cropping systems. Agric Syst 148: 44–57.

Wodehouse A, Ion W (2012) Augmenting the 6-3-5 method with design information. Res Eng Des 23: 5–15.

Zinngrebe Y, Pe’er G, Schueler S, Schmitt J, Schmidt J, Lakner S (2017) The EU’s ecological focus areas – How experts explain farmers' choices in Germany. Land Use Policy 65: 93–108.

INTRODUCING MODERN AGROFORESTRY TO STUDENTS AS THE NEXT GENERATION OF DECISION MAKERS IN ECOSYSTEM MANAGEMENT

Lamersdorf N[1*], Corre M[2], Gernandt P[3], Isselstein J[4]

Students of the Bachelor program on “Ecosystem Management” and “Molecular Ecosystem Sciences” at the University of Göttingen, Germany

(1) Soil Science of Temperate Ecosystems (2) Soil Science of Tropical and Subtropical Ecosystems (3) Department of Agricultural Soil Science, all Büsgenweg 2, 37077 Göttingen (4) Institute of Grassland Science, Von-Siebold-Str. 8, 37075 Göttingen

*Corresponding author: nlamers@gwdg.de

Abstract

Agroforestry (AF) in temperate climatic regions is often subject to ignorance or misunderstanding within the agricultural sector. The most obvious reason is a missing integration of temperate AF as a subject in the student’s curricula of related disciplines. Here, we present an example from the University of Göttingen, Germany, where more than 250 students have joined a specific and interdisciplinary course on AF since the last years. As we continuously received a very positive feedback, we allow us to present some selected results, gained from the student´s work on an extra installed field site, composed as an alley cropping system with poplar and willow short rotation coppices strips on cropland. Overall, we are convinced that our multidisciplinary approach, combining lab and field works as well as producing first relatively simple but clear results with respect to the agroforestry issue could help to promote the agroforestry approach in the long run.

Keywords: temperate agroforestry, student’s curricula, short rotation coppices, water budget, crop yields, mineral nitrogen

Introduction

Agroforestry (AF) in temperate climatic regions is often subject to ignorance or misunderstanding within administrative bodies and stakeholders of the agricultural sector. Here, AF is regularly linked to only the tropical- and sub-tropical scope or, for temperate areas, to only historical land use applications like e.g. “Streuobstwiesen”. However, already since decades knowledge of various modern scientific or practical approaches in temperate AF is available, like for instance for the USA or France. To our understanding, the most obvious reason for such an ignorance in most other countries is a missing integration of temperate AF as a subject in the student’s curricula of related disciplines like agriculture, forestry or geosciences.

Nevertheless, things might change: Since 2010, the University of Göttingen offers an interdisciplinary bachelor program on “Ecosystem Management” (www.uni-goettingen.de/en/84745.html). Three faculties contribute to this course, the faculty of agricultural sciences, the faculty of forest sciences and forest ecology and the faculty of geoscience and geography. Based on the insight into the essentials of agriculture, forestry and the geosciences, the key object of the degree course is to get to know the most important facts and concepts from ecology and economics and develop an understanding of the interaction of ecosystems. Within this study course, a specific module on agroforestry was incorporated (4 h present time per week, total work load of 180 h per semester, 6 study credit points). Furthermore, the module´s field experiments are also linked to the bachelor program “Molecular Ecosystem Sciences”, focusing on the impact different land use types on biogeochemical processes (www.uni-goettingen.de/en/203287.html). So far, our seminar is the first and still only explicit study module on temperate AF in Germany.

The focus of the study module lies on self-collected, preferably self-measured, as well as scientifically evaluated and presented field data. For that, we installed an extra field site in autumn 2010, composed as an alley cropping system. Tree strips of poplar and willow short rotation coppices (SRC) were combined in a block design with a common crop rotation in the alleys (Figure 1). Field data are collected and evaluated with respect to the impact of the given system on the thematic issues of water cycling, nutrient and C budgets, crop production, and biological diversity. Students are working in groups of 3 to 6 persons in each summer semester, dealing with specific questions of the given thematic fields. e.g:

- How is the soil structure and the infiltration capacity influenced by the tree component?
- Is there any significant impact on crop yields?
- Is there any indication for changes in the mineral nitrogen availability in the tree strips?
- What is the reduction of PAR within and next to the tree strips?
- How is the management of the tree component done, and what is it’s net benefit?
- How do earthworms react to the AF application?
- Do small mammals and the epigaeic fauna benefit from the integrated tree strips?

Until now, more than 250 students have joined the course, and as we continuously received a very positive feedback from our students, we allow us to present in the following some selected approaches and results, gained from the students’ work on our educational field plots in the given context.

Figure 1: Field site installed in autumn 2010, composed as an alley cropping system.

Results

I) Soil structure, infiltration capacity and the water budget

Applied methods

- Soil texture analysis
- Creating a water retention curve
- Determining the saturated water conductivity
- Estimating the infiltration rate
- Approximating a water budget under given climatic conditions for various crops

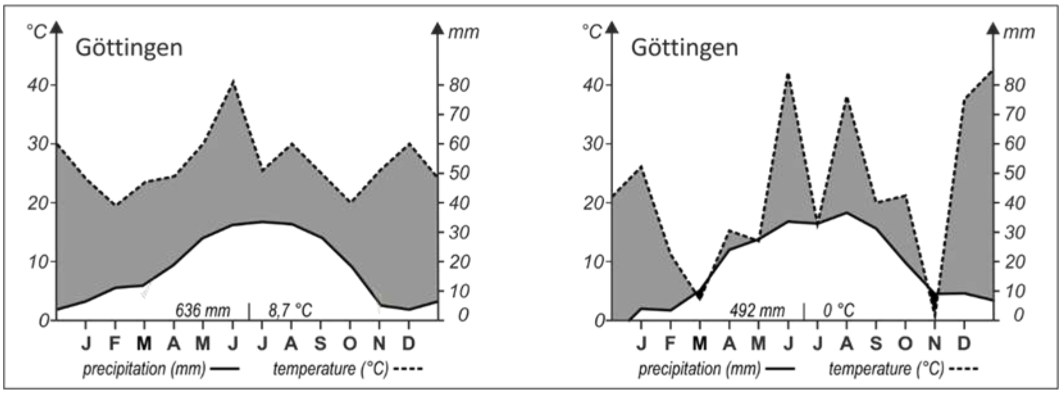


Figure 2: Long-term average (1961-1990) (left) and 2011 precipitation and temperature (right).

Selected results

- Due to the relative shallow soil layer, the study site is not suitable for every field crop. The water storage capacity is restricted for the cultivation of wheat, barley and sugar beet (Figure 3).

- On a long-term average, there is a positive water budged, i.e. a net seepage water output.

- In single years (here 2011) and certain critical growth periods (e.g. spring time) there is not enough plant-available water. Reduce growth or even drought stress might occur (Figure 2).

- Due to their intensive and deep-rooting, willow and poplar will i) gain water in such drought phases also from deeper soil layers but ii) might simultaneously reduce the seepage water output to zero then.

Conclusions on water issues

- When applying SRC within an agroforestry system, the water budged of the site has to be seriously considered.

- By deep-rooting, SRC as a tree component may help to gain water source from deeper soil layers. A hydraulic lift as well as the shadow of trees might help to protect the annual crops from drought stress.

Figure 3a: Liquid, gaseous and solid phases of the soil.

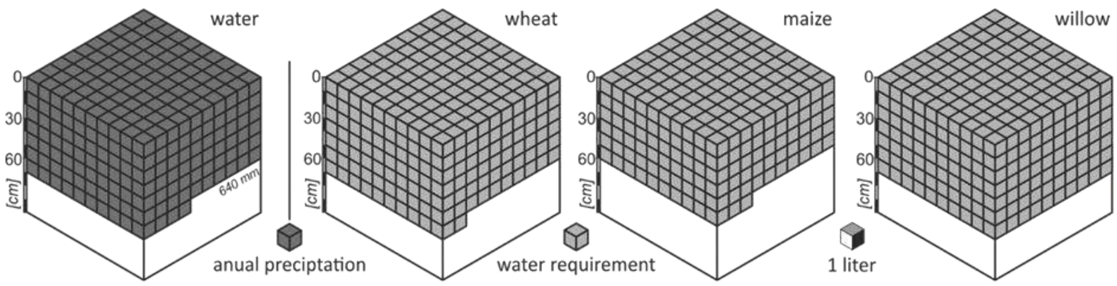


Figure 3b: Mean annual precipitation in Lower Saxony and crop-specific needs of water.

II) Crop yields

The aim of the research of the agronomy group of students is to assess the effect of alley cropping with short rotation coppice species on the yield formation of the annual agricultural crops. These crops change every year with winter wheat and canola as the main species in a crop rotation. The hypothesis is tested that the tree rows affect the growth conditions for the annual crops and therewith the morphology and biomass of the crop plants. A range of different measurements are performed in the crop in spring, at a time, when the crop species are flowering. It is assumed that at this stage the peak standing crop, i.e. the total above ground biomass is almost reached.

Applied methods

- Recording crop, weed and open soil covering by RGB imagery
- PAR measurements above the crop and at ground level
- LAI detection via calibrated spectrometry
- Identifying the tiller density, sward height, above ground biomass and leave/steam ratios (Figure 4)
- Soil water content
- ANOVA analysis via ‘R’, factors tree row (4 levels), slope/tree species (3 levels) and distance to the tree row (1.5 or 10 m).

Selected Results

- Over the years of measurements, the distance from the tree row has been proven to exert the strongest effect on the agricultural crop.
- Also the exposure showed some effects while the slope/tree species and the number of the tree row as well as the two- and threefold interactions were of minor importance.

Conclusions on crop yields

The Göttingen agroforestry experiment has been proven as a valuable resource for capacity building in the field of agronomy and crop growth in a sustainable production system.

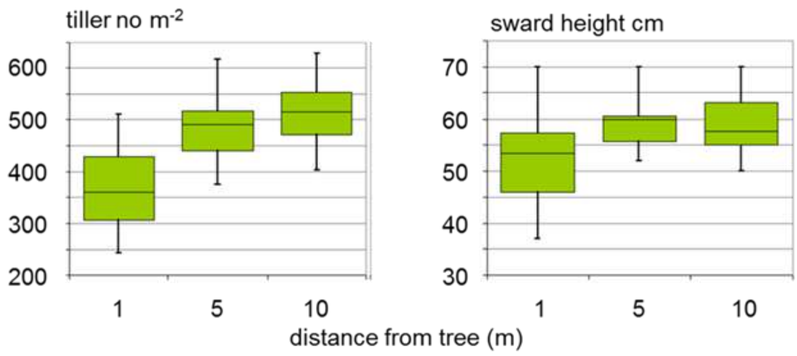


Figure 4: Tiller density (left) and sward height (right) of winter wheat at the flowering stage in relation to the distance from the tree row.

III) Mineral nitrogen availability and N_2O emissions

Applied methods

- Mineral N was detected after immediate *in situ* extraction with 0.5 M K_2SO_4 of samples from the upper 5 cm soil layer
- N_2O was measured in air samples of the headspace of gas chamber

Selected Results

- Results indicate significantly higher NO_3 but reduced NH_4 contents in the crop rows, compared to the trees rows
- N_2O emissions are significantly enhance in the crop rows while tree rows indicate a sink at the time of sampling (Figure 5)

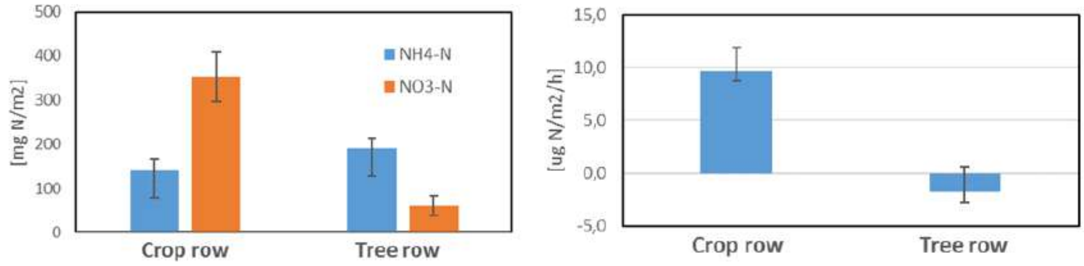


Figure 5: N_{min} (left; 0-5 cm soil depth) and N_2O emissions (right), n = 5 per plot, IX 2017.

Conclusions on nitrogen cycling

- Results indicate that tree rows of SRC on crop fields bear a significant potential to reduce NO_3 leaching as well to decrease N_2O emissions

IV) Educational implications

Overall, we are convinced that such a multidisciplinary seminar approach, combining lab and field works as well as producing first relatively simple but clear results with respect to the agroforestry issue could be a valuable example also for other universities and education units, which help to promote the agroforestry approach in the long run. It may thus be widening the students' perspective with regard to the issue "trees in agriculture", as well as improving their responsibility as the future generation of decision makers in landscape- and ecosystem management.

MODELLING AGROFORESTRY SYSTEMS WITH WEB-ECOYIELD-SAFE

Palma JHN[1*], Tomás A[1]

(1) Forest Research Centre, School of Agriculture, University of Lisbon

*Corresponding author: joaopalma@isa.ulisboa.pt

Abstract

Models may help improve understanding of agroforestry systems by being more cost and time-efficient than experiments. However it is lacking is the ability for stakeholders to directly use and understand models and a mechanism for the modelling experts to effectively communicate obtained results and interpretations with such stakeholders. The model EcoYield-SAFE, a development of the agroforestry process base model Yield-SAFE, is here presented as a web application allowing stakeholders to better understand and use the model. Any potentially interested person with an internet-connected device can make use of it, which in turn leads to more informed decision making and wider model acceptance, while providing feedback for improvements. An example is shown on how to use the online model comparing a) land use scenarios, i.e. arable, agroforestry and forestry and b) an agroforestry setup under different future climate scenarios.

Keywords: online platform; stakeholders; user-friendly; model; scenario comparison; climate change

Introduction

Agroforestry is a promising land use which delivers greater socio-economic and environmental externalities than conventional agricultural and forestry systems (Warner et al. 2016). Although there's an increased awareness of these externalities (i.e. ecosystem services), there's still much to be done to promote agroforestry worldwide, in a free, direct and simple way (Mosquera-Losada et al. 2009). In this sense, and considering also the lack of long-term data on the productivity of agroforestry systems, models may help improve understanding of these systems, by being more cost and time-efficient than experiments (Ford 1999). This was one of the motivations for the Yield-SAFE model (van der Werf et al. 2007) development. It is a parameter-sparse, process-based dynamic model that has been used to estimate long term productivity of agroforestry systems. However, it is currently lacking the ability for stakeholders to directly use and understand this model and a mechanism for the modelling experts to effectively communicate obtained results and interpretations with such stakeholders. For this reason, the model has recently been implemented as a web application, i.e. a web service together with an interface for ease of use. Any potentially interested person with an internet-connected device can make use of it, which in turn leads to more informed decision making and wider model acceptance (Walker and Chapra 2014). There are several advantages of naturally evolving models like this to web based versions, mainly: a) allowing an immediate access to the model without needing to download desktop software of browser plugins; b) simplifying maintenance in terms of fixing bugs and applying model updates, which can be done instantaneously with a single deployment to the server, being immediately available to all users; c) directly updating web page content from within the browser allows for improved user interfaces to access, visualize and analyse the results of the model; f) facilitating collaboration between multiple users (Byrne et al. 2010; Walker and Chapra 2014).

Web-EcoYield-SAFE aims to be a teaching instrument, an explorative environment for farm management and a versatile tool for further agroforestry research, while bringing stakeholders closer to modelling tools to support their management decisions.

Materials and methods

EcoYield-SAFE model

Yield-SAFE (van der Werf et al. 2007) was developed during the SAFE project (Dupraz et al. 2005). It is a parameter-sparse, process-based dynamic model that has been used to estimate long term productivity of agroforestry systems. Within the AGFORWARD project (Burgess et al. 2015) it has undergone a series of improvements (Palma et al. 2016a, b; Palma et al. 2017). EcoYield-SAFE now has an ecosystem approach, integrating livestock, soil carbon, microclimate effects, pasture productivity and non-timber forest products (fruit, cork) (Palma et al. in preparation).

Web implementation

The implementation of the model followed a hybrid architecture, with simulations performed on the server and visualizations generated in the browser. For the server-side, the model equations were implemented in Python, while fully integrated with Clipick (Palma et al. 2017) to retrieve current and future daily climate data, and is continuously being improved following the updates made to the model. Under python, the model provides a web service (Palma et al. 2016a), i.e. a server-side interface that accepts requests from clients with parameters instructing a model run simulation, returning a response with model output data. As a service, the model may be reached directly within the browser itself, or any software able to perform an HTTP GET request.

However, it is not visually attractive nor user friendly to perform http requests and therefore a user friendly web interface layer that provides simple usage of the model and interpretation of results was further developed. This web interface was implemented using HTML, CSS and Javascript (VueJS framework and helper libraries) that work in any of the modern web browsers.

Case studies

To demonstrate the usage of the model in the visual interface we set a case study focused on climate change assessment, by comparing a silvoarale poplar system with a density of 156 trees ha^{-1} with a rotation of natural grasslands as understorey in current and future climate scenarios, considering a rotation period of 80 years (Graves et al. 2010).

Results and discussion

Web implementation of the model

The interface (Figure 1) is composed by: the ‘Home’ (1) entry section; the ‘Docs’ (2) section where all documentation related to the model is available (model information, related articles and details about the arguments, parameters and outputs); and the ‘Dashboard’ section, where the arguments can be manipulated (3), the run order is given (4), and the outputs visualized (5). The user is able to create multiple scenarios (6) and make comparisons between them (7). Under each scenario tab, there are two main areas: on the left there are several tabs for each of the argument families (options, site and soil, tree, crop, livestock and soil carbon); on the right is where the graphics for the outputs will show up after the model is run. The outputs are displayed in the form of graphics (using the Google Charts tool), where some of the main output variables are shown by default, although the user may add new graphics (8) or edit (9) the existing ones. Also, it’s possible to download the generated data as a CSV file for later usage (10).

This structure enables the user to a) evaluate and compare the performance of different land uses; b) simulate different management alternatives combining trees, crops and livestock (or for each individually); c) evaluate different management intensities and options; d) compare different long term effects of climate; e) simulate pastures; f) evaluate the influence of the trees presence in crop/pasture development; g) analyse different database stored scenarios; and save, share or upload new scenarios.

Figure 1: Web-EcoYield-SAFE dashboard, can be accessed at www.isa.ulisboa.pt/proj/ecoyieldsafe

Case study - Future climate scenarios

EcoYield-SAFE runs over climate data retrieved from the tool CliPick, which provides datasets used by the International Panel On Climate Change (Palma 2017). By using this tool, the user may not only simulate the current climate but also for future climate changes. CliPick adopted two datasets, the Representative Concentrations Pathways (RCP): an optimistic scenario, the RCP 4.5, and a pessimistic scenario, the RCP 8.5.

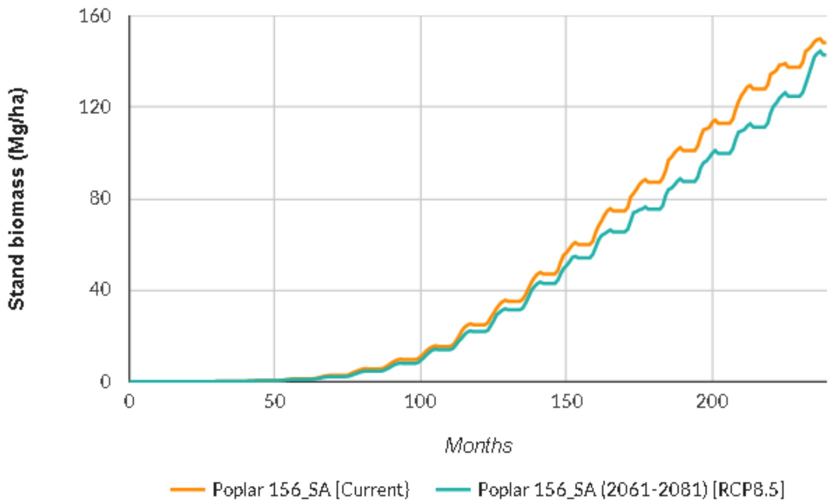


Figure 2: Poplar silvoarable systems in the UK simulated for different climatic scenarios (current climate and future RCP 8.5)

http://www.isa.ulisboa.pt/proj/ecoyieldsafe/#/dashboard?groupID=EURAF2018FutureClimate

Figure 2 shows the overlapping of the standing biomass series of each simulation. It is clear the effect of climate change over the growth of the stand, where the RCP 8.5 shows a slower development of the trees' biomass.

Future developments

Planned future developments include:

- Profiling of the interface towards different user groups: for farmers and farm advisors there's the need to downgrade the complexity of the interface so the users only had to deal with the components that are manageable by or otherwise of importance to them. This will imply having numerous parameters assumed as constant or as directly linked to other input variables.
- Making intelligent suggestions to users
- Including financial evaluations
- Allowing users to submit new calibrations and manipulate model parameters
- Adding a commenting and discussion system, enabling collaboration between researchers, students, farm advisors and farmers

There's an ongoing need to better understand what elements and design principles could improve the application ability to facilitate model understanding, including its accessibility to mobile devices (improve to a more responsive design).

Acknowledgements

We acknowledge support of the European Commission through the AGFORWARD FP7 research project (contract 613520) and INCREdible H2020 project (grant agreement 774632). This work was also partially supported by the Portuguese Science Foundation (FCT) under Project SOLAR (PTDC/GEOMET/7078/2014) and CEF PEst (UID/AGR/00239/2013).

References

Burgess PJ, Crous-Duran J, den Herder M, Dupraz C, Fagerholm N, Freese D, Garnett K, Graves AR, Hermansen JE, Liagre F, Mirck J, Moreno G, Mosquera-Losada MR, Palma JHN, Pantera A, Plieninger T, Upson M (2015). AGFORWARD Project Periodic Report: January to December 2014. Cranfield University, AGFORWARD.

Byrne J, Heavey C, Byrne PJ (2010) A review of Web-based simulation and supporting tools. Simul Model Pract Theory 18: 253–276.

Dupraz C, Burgess P, Gavaland A, Graves A, Herzog F, Incoll L, Jackson N, Keesman K, Lawson G, Lecomte I, Liagre F, Mantzanas K, Mayus M, Moreno G, Palma J, Papanastasis V, Paris P, Pilbeam D, Reisner Y, Vincent G, Werf Van der W (2005) Synthesis of the Silvoarable Agroforestry For Europe project. INRA-UMR System Editions, Montpellier, pp.254. https://www1.montpellier.inra.fr/safe/english/results/final-report/SAFE%20Final%20Synthesis%20Report.pdf (accessed 24/04/2018).

Ford A (1999) Modeling the Environment: An Introduction to System Dynamics Modeling of Environmental Systems. Andrew Ford Island Press, Washington DC.

Graves AR, Burgess PJ, Palma JHN, Keesman KJ, van der Werf W, Dupraz C, van Keulen H, Herzog F, Mays M (2010) Implementation and calibration of the parameter-sparse Yield-SAFE model to predict production and land equivalent ratio in mixed tree and crop systems under two contrasting production situations in Europe. Ecol Modell 221: 1744–1756.

Mosquera-Losada MR, McAdam J, Rigueiro-Rodríguez A (2009) Future Directions of Agroforestry in Europe. In: Rigueiro-Rodróguez A., McAdam J., Mosquera-Losada M.R. (eds) Agroforestry in Europe. Advances in Agroforestry, vol 6. Springer, Dordrecht, pp 435–438.

Palma JHN, Graves AR, Crous-Duran J, Garcia de Jalon S, Oliveira TS et al. (in preparation) EcoYield-SAFE: maintaining a parameter-sparse approach in modelling silvopastoral systems.

Palma, J.H.N., Graves, A.R., Crous-Duran J, Upson, M., Paulo, J.A., Oliveira, T.S., Silvestre Garcia de Jalón, S., Burgess, P.J. (2016a). Yield-SAFE Model Improvements. Milestone Report 29 (6.4) for EU FP7 Research Project: Project: AGFORWARD 613520. https://www.agforward.eu/index.php/es/yield-safe-model-improvements.html (accessed 24/04/2018).

Palma JHN, Graves AR, Crous-Duran J, Paulo JA, Oliveira TS, Garcia de Jalon S, Kay S, Burgess PJ, (2016b) Keeping a parameter sparse concept in agroforestry modeling while integrating new processes and dynamics: new developments in Yield-SAFE. 3rd European Agroforestry Conference, Montpellier, France.
Palma JHN (2017) CliPick – Climate change web picker. A tool bridging daily climate needs in process based modelling in forestry and agriculture. For Syst 26. Tool available @ http://www.isa.ulisboa.pt/proj/clipick/ (accessed 27/04/2018).
Palma JHN, Crous-Duran J, Graves AR, Garcia de Jalon G, Upson M, Oliveira TS, Paulo JA, Ferreiro-Domínguez N, Moreno G, Burgess PJ (2017) Integrating belowground carbon dynamics into Yield-SAFE, a parameter sparse agroforestry model, Agrofor Syst. https://doi.org/10.1007/s10457-017-0123-4.
van der Werf W, Keesman K, Burgess P, Graves A, Pilbeam D, Incoll LD, Metselaar K, Mayus M, Stappers R, van Keulen H, Palma J, Dupraz C (2007) Yield-SAFE: A parameter-sparse, process-based dynamic model for predicting resource capture, growth, and production in agroforestry systems. Ecol Eng 29: 419–433.
Walker JD, Chapra SC (2014) A client-side web application for interactive environmental simulation modeling. Environ Model Softw 55: 49–60
Warner DJ, Tzilivakis J, Green A, Lewis KA (2016) A guidance tool to support farmers with ecological focus areas - the benefits of agroforestry services and biodiversity. 3rd European Agroforestry Conference, Montpellier, France.

www.isa.ulisboa.pt/proj/ecoyieldsafe

Nijmegen

AGRO
FORESTRY
NEDERLAND

van Akker naar Bos

AFINET
AGROFORESTRY INNOVATION NETWORKS

USC
UNIVERSIDADE
DE SANTIAGO
DE COMPOSTELA

EURAF
EUROPEAN
AGROFORESTRY
FEDERATION