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A Methodological Framework for Quantification and Valuation of Ecosystem Services of Tree-Based Intercropping Systems

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Contribution of Tree-Based Intercropping Systems to the Adaptation of Agroecosystems to Climate Change in Québec

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Economics (UQAM)
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Modeling (CEF, UQAM)
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- Olivier Taugourdeau (postdoc)

Climate modeling (Ouranos)
- Marie-France Sottile

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OURANOS

Interdisciplinarity

Project Objectives

- **Growth and interactions**

Quantify the effects of agroforestry on trees and crops

- **Hydrology**

Study the dynamics of soil water in the agroforestry system

- **Biodiversity**

Measure the effects of agroforestry on soil microarthropods

- **Modeling**

Model the agroecosystems today in the future in a climate change context

- **Economics**

Quantify and monetize ecosystem services provided by agroforestry


Photo: Alain Olivier

Magritte


Photo: Alain Olivier

Photo: Alain Olivier


Magritte


NEUTRE EN CARBONE

majmajest.com

Des arbres, encore des arbres,
tel est le mot d'ordre.
L'arbre signifie l'eau, le fourrage, le bétail, les récoltes ;
l'arbre, c'est l'ombre, les loisirs, les chansons
– les poètes, les peintres, les législateurs, les visionnaires.

Henry Miller
Le Colosse de Maroussi
1941

Economics

Quantification and monetization of ecosystem services provided by agroforestry

1. What is the marginal value of ecosystem services provided by agroforestry systems?

2. Is agroforestry advantageous as a long term investment, when the "externalities" are internalized in an environmental cost-benefit analysis?

St-Paulin's Experimental Site (Québec)

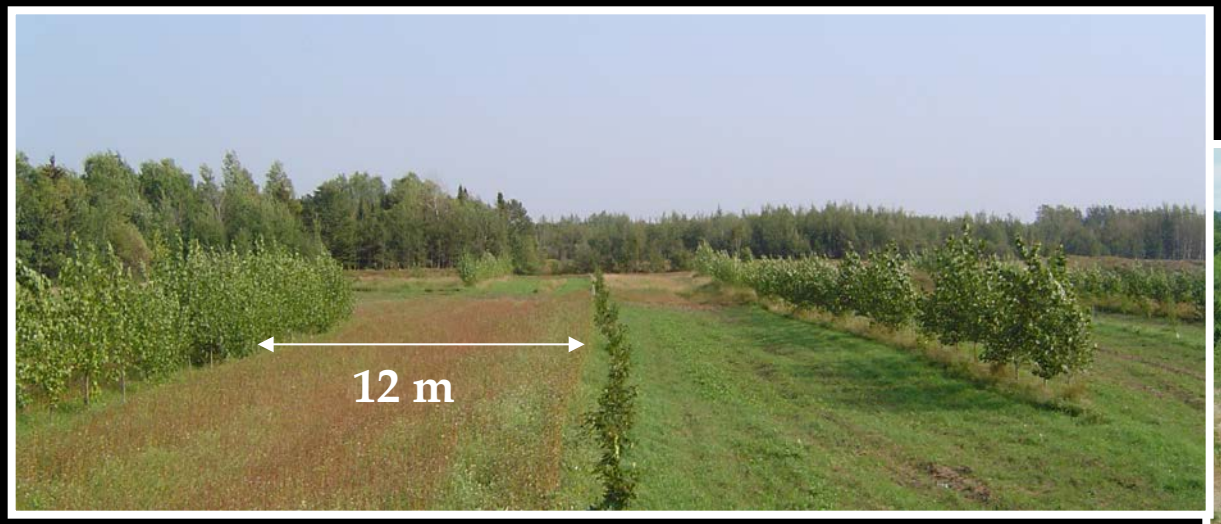
Tree planting: 2004

Intercropping: oats, buckwheat, canola, etc.

2 sp. of hardwood: red oak and black cherry

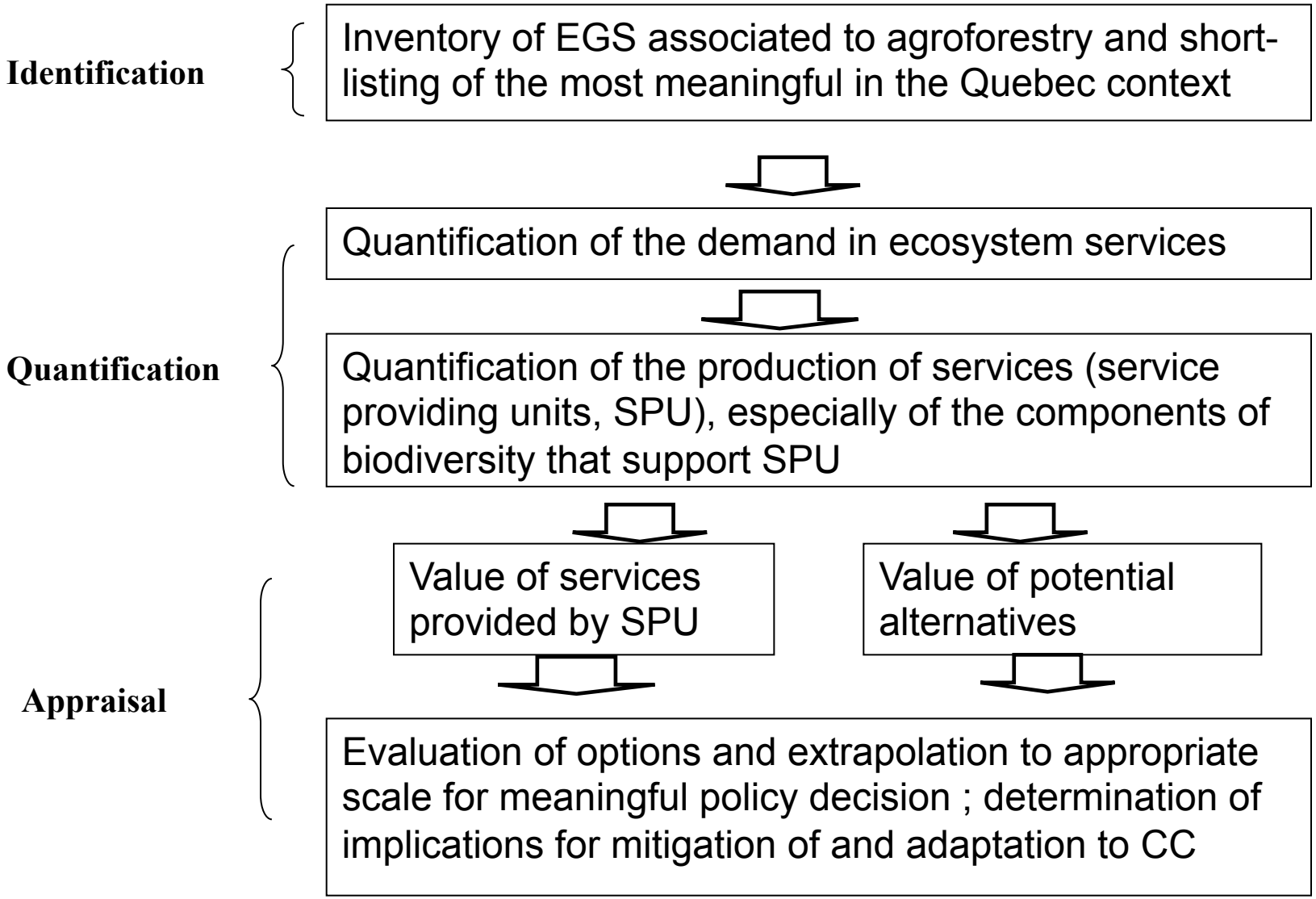
Two hybrid poplar clones: DN-3333 et DN-3570

D. Rivest



St-Paulin's Experimental Site (Québec)

Analytical Framework



Inventory and Selection of EGS Related to Agroforestry

Valuation Framework 1/2

Ecosystem Services	Assumptions/Data/Approach
Provision of timber and agricultural products	• Evaluated in terms of provision of agricultural products and provision of timber • Rotation on a 20 years period • Hybrid poplar, soybean, wheat
Air quality	Cost of pollution mitigation
Carbon sequestration and storage	• Net C-sequestration per ha per year • Total C sequestered = (Above ground) + (below ground) - Soil respiration – C leaching • Economic data: damage cost / social cost of carbon emission / carbon tax
Abatement of farm odor	Avoided cost of odour mitigation
Soil quality regulation	Evaluated in terms of soil formation, addition of SOM, erosion control, etc.

Valuation Framework 2/2

EGS	Assumptions/data/approach
Water quality	Cost of decontamination of pollutants
Biological pest control	Replacement cost approach
Pollination	Production Function Approach
Mineralization of nutrients	Input cost approach
Wind protection	Productivity approach
Socio-cultural services	1. Contingent valuation (Landscape aesthetics) 2. Travel cost (Education)

General Evaluation Model

$$ES_{TEV} = \sum ES_{n} = \sum ES_{\text{non-market}} + \sum ES_{\text{market}}$$

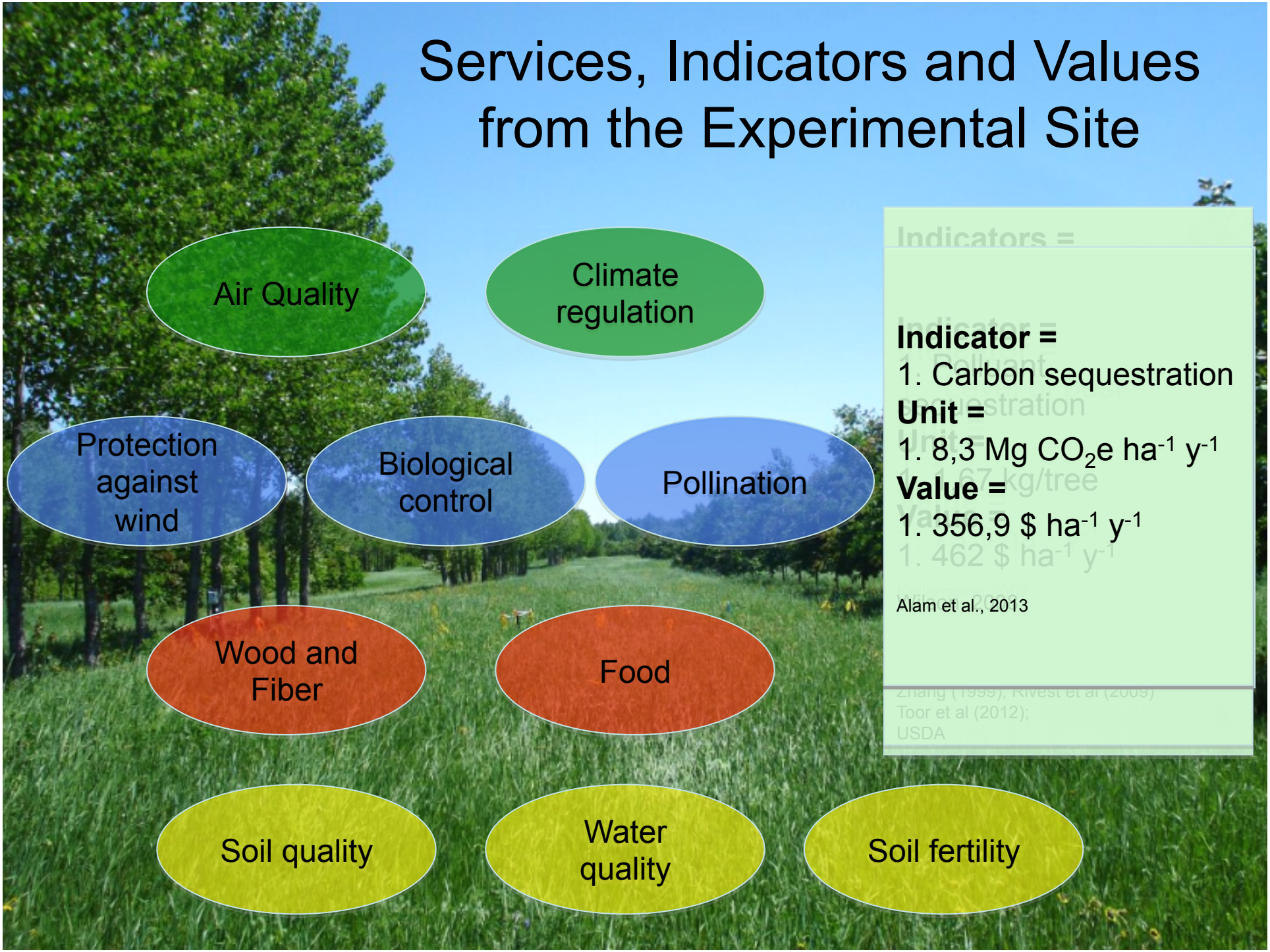
Where, n=1, 2, 3… 10

TEV= Total economic value

$\sum ES_{\text{non-market}} = \sum ES_{1\text{-}8}$ and

$\sum ES_{\text{market}} = \sum ES_{9\text{-}10}$

Services, Indicators and Values from the Experimental Site



Indicator =
1. Carbon sequestration

Unit =
1. 8,3 Mg CO_2e ha^{-1} y^{-1}

Value =
1. 356,9 \$ ha^{-1} y^{-1}

Alam et al., 2013

One example: Climate Regulation Service Provided by Agroforestry

Biophysical Assessment

$NCS = (B_t + B_r + B_l + CR + SOC) – (C_r + C_l) + C_{N2O}$

where, NCS, Net Carbon Sequestered; B_t, and B_r, Carbon stored in tree trunk biomass (including branches and leaves) and roots respectively; B_l, Carbon stored in litter fall; CR, Carbon stored in crop residues; SOC, Carbon pool in soil; C_r, Carbon returned back through soil respiration; C_l, Carbon lost through leaching into soil profiles; C_{N2O}, CO_2 equivalent avoided emission of N_2O.

Economic Valuation

$$VAD_{xtT} = \sum_{z=t}^{T-1} \frac{\Delta C_{x,z,z+1} CSC_{z+1}}{(1+r)^{z-1}}$$

Where, VAD_{xtT} is the present value of all damage avoided (or additional damage when negative), due to carbon sequestration on x land parcel from time t to T. In the right hand side $\Delta C_{x,z,z+1}$ is the carbon sequestered over the rotation period (between time z and z +1), SCC_{z+1} is the SCC in year z+1 and r is the discount rate.

Alam, M., A. Olivier, A. Paquette J. Dupras, J.-P. Revéret et C. Messier. 2014. A general framework for the quantification and valuation of ecosystem services of tree-based intercropping systems. Agroforestry Systems.

Sensitivity analysis of the value of the service of climate control according to the variation of the social cost of carbon and of the discount rate

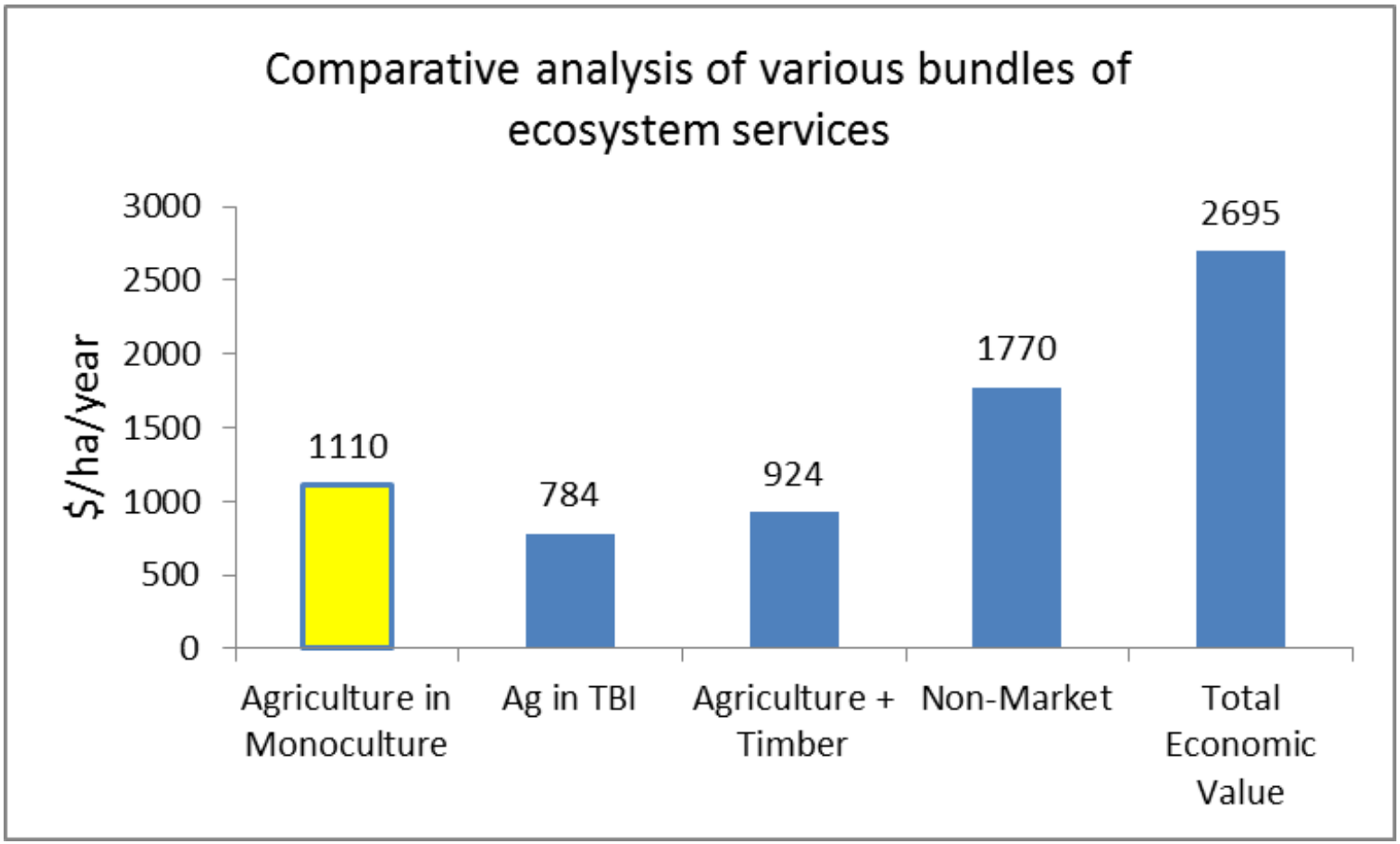
Sensitivity of VAD (Value of Avoided Damages) to various SCC rates (Social Cost of Carbon)

Social Cost of Carbon ($)	VAD ($/h)
10	5 670
350	198 473
106	60 107
SCC replaced by alternative technologies *	167 278

*$295, the minimum government subsidy for ethanol per ton of emissions of CO_2 equivalent (Samson et Stamler 2009)

Sensitivity of the VAD to different rates of variation of the Social Cost of Carbon (δ) and discount rate (r)

δ (%)	r (%)	VAD/ha ($)
2	1.4	16 037
2	3	11 868
4	1	26 710
4	3	17 329


Comparative analysis of various bundles of ecosystem services
$/ha/year
3000
2500
2000
1500
1000
500
0
1110
784
924
1770
2695
Agriculture in Monoculture
Ag in TBI
Agriculture + Timber
Non-Market
Total Economic Value

Conclusion 1/2

- Private benefits (supply of agricultural products) are slightly reduced in the studied agroforestry system
- However, the value of non-market ecosystem services by far exceeds the value of private benefits
- The importance of public benefits should encourage governments to adopt measures to compensate for private losses incurred by farmers when switching from conventional agriculture to agroforestry

Conclusion 2/2

- This is even more interesting considering that the results of our modeling indicate that in 2050, the presence of trees could help limit crop yield losses that are expected because of the anticipated climate change, but also ensure greater stability of yield, a very important element for the farmer

Acknowledgements

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Thank you !

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