

Data tree contribution to urban forest planning

Composition and Ecosystem services forecast, for Lisbon case studies

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- 2) “LX GARDENS - Jardins e Parques Históricos de Lisboa: estudo e inventário do património paisagístico”, (Projeto FCT, refª: PTDC/EAT-EAT/110826/2009).

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Abstract

The ecosystems services provide by street trees and other elements were already assessed in previous studies. However, gardens have a different structure and are managed according to different criteria, which in turn, may have repercussion in the capacity of the trees to provide Ecosystem Services (ES). However, as far as we know, no study has ever dealt with this topic, particularly for Lisboa, or in the Iberian Peninsula. As such this project has the objective of study the contribution of garden areas for urban ecology, promotion of diversity and other ecosystem services. The work was developed mainly to test one of tools readily available and in common use and to test its utility in scenario planning.

The study uses the iTree-eco software to analyse three gardens in Lisbon municipality (Jardim Guerra Junqueiro, Jardim Teófilo Braga, and Jardim França Borges) focusing on species abundance and diversity, and their contributions to the provision of ecosystem services. A comparison of tree characteristics and ES estimations was done for a sample of tree species common in both, gardens and street alignments. Future scenarios were explored using the i-Tree software's forecasting function, emphasizing the importance of data-driven decision-making in urban planning.

Of the three studied gardens, Jardim Guerra Junqueiro has the high species richness and diversity, whereas the Teófilo Braga has the lowers. The same patterns were studied regarding tree sizes (estimated by canopy and DBH).

The study results highlight the importance of species, such as *Taxodium huegelii*, *Ficus benghalensis*, *Celtis australis*, and *Platanus orientalis*, for their contributions to carbon accumulation, carbon absorption, stormwater management, and air pollutant removal, respectively. Economic quantification demonstrates the significant economic value generated by certain species, differenced by type of leaf phenology, tree and canopy dimension, emphasizing the importance of their representation in the urban landscape.

The study confirms the importance of data analysis in understanding urban vegetation's impact on ecosystem services. It reveals the contributions of an array of species to ecosystem benefits, providing valuable insights for urban planners and designers. Comparative analyses between street and garden vegetation highlight the influence of location, type of maintenance and location taking in considerations on plant growth and benefits.

This study depicts the value of integrating qualitative and dimensional (quantitative) data into urban forest planning, enabling informed decisions for positive results of urban interventions.

Ecosystem benefits; scenario planning; trees gardens comparison

Resumo

O estudo realizado foca-se sobre os serviços ecossistémicos proporcionados por áreas ajardinadas, especialmente em Lisboa. Os benefícios das árvores de arruamento na cidade já foram analisados em estudos anteriores recentes. Esta pesquisa pioneira concentrou-se nos jardins urbanos, reconhecendo sua estrutura e gestão distintas. Três jardins emblemáticos de Lisboa foram o foco: Jardim Guerra Junqueiro, Jardim Teófilo Braga e Jardim França Borges. A análise envolveu a avaliação da abundância, diversidade de espécies e, crucialmente, a contribuição dessas áreas verdes para os serviços ecossistémicos.

Utilizando o software iTree-eco, o estudo comparou árvores e estimativas de Serviços de Ecossistema (SE) em jardins e alinhamentos de ruas. Os resultados revelaram que o Jardim Guerra Junqueiro se destacava em termos de riqueza e diversidade arborea, enquanto o Teófilo Braga apresentava números mais modestos. As análises mostraram que certas espécies, como *Taxodium huegelii*, *Ficus benghalensis*, *Celtis australis* e *Platanus orientalis*, desempenham papéis cruciais na absorção de carbono, gestão de águas pluviais e remoção de poluentes atmosféricos.

Além disso, o estudo quantificou o valor económico dessas espécies, destacando sua importância em termos de fenologia foliar, tamanho da copa e outros parâmetros. Isso não apenas sublinhou a diversidade da paisagem urbana, mas também enfatizou a necessidade de considerar esses fatores no planeamento urbano. A análise comparativa entre vegetação de arruamento e jardins destacou a influência crucial da localização e manutenção na saúde das plantas, bem como nos benefícios que proporcionam ao meio ambiente.

Esse estudo demonstrou a importância de dados quantitativos e qualitativos no planeamento urbano. Ao integrar essas informações, os tomadores de decisão podem fazer escolhas mais informadas, promovendo intervenções urbanas mais eficazes e sustentáveis. A pesquisa não apenas preencheu uma lacuna de conhecimento, mas também ofereceu orientações valiosas para os gestores e projetistas urbanos, enfatizando a necessidade de valorizar e preservar as áreas verdes urbanas para garantir um ambiente urbano saudável e sustentável para as gerações futuras.

Resumo

A gestão adequada do arvoredo urbano desempenha um papel fundamental na melhoria da qualidade de vida nas cidades e na promoção da sustentabilidade ambiental, especialmente nos nossos tempos atuais, em que se regista um crescimento contínuo da população nos meios urbanos. Os serviços ecossistémicos prestados pelas árvores de arruamento e outras infraestruturas verdes já foram avaliados em estudos anteriores para Lisboa, outras cidades na Europa e no mundo. No entanto, os jardins têm uma estrutura diferente e são geridos de acordo com critérios diferentes, o que, por sua vez, pode ter repercussões na capacidade das árvores fornecerem Serviços de Ecossistema (SE). Contudo, tanto quanto sabemos, nenhum estudo se debruçou sobre as diferenças entre as árvores entre jardins e arruamentos; particularmente para Lisboa, ou na Península Ibérica. Assim, este projeto tem como objetivo estudar a contribuição das áreas ajardinadas para a ecologia urbana, a promoção da diversidade e outros serviços dos ecossistemas. O trabalho foi desenvolvido principalmente para testar a utilidade dos dados disponíveis sobre o arvoredo urbano, e várias ferramentas de recolha, armazenamento e análise de dados disponíveis, de uso comum e para testar a sua utilidade no planeamento de cenários de evolução do arvoredo.

Com base nos resultados obtidos, são discutidas as limitações, potencialidades e melhorias da abordagem adotada para que esta possa ser aplicada no planeamento projetos urbanísticos e contribuir para melhorias na gestão do arvoredo urbano.

Metodologia

O estudo analisa três jardins do concelho de Lisboa, o Jardim Guerra Junqueiro (Jardim da Estrela), o Jardim Teófilo Braga (Jardim da Parada) e o Jardim França Borges (Jardim do Príncipe Real), com enfoque na composição (abundância e diversidade de espécies de árvores), estrutura arbórea e na sua contribuição para a prestação de serviços ecossistémicos. A descrição da composição dos jardins foi obtida através da aplicação de índices ecológicos de riqueza, diversidade, uniformidade, dominância e similaridade.

A quantificação dos benefícios dos ecossistemas utilizou o software iTree-eco e baseou-se em dados de dimensão das árvores recolhidos no campo entre março e julho do ano 2023. A recolha de dados no terreno incluiu informação georreferenciada, visual, como o estado geral do exemplar e a percentagem de copa em falta; e informação dimensional, como o diâmetro à altura do peito (DAP), altura da árvore e a largura da copa. Os dados de base, as metodologias de campo e de análises subsequentes foram adaptadas de trabalhos anteriores com o arvoredo urbano, nomeadamente na área metropolitana de Lisboa, no âmbito de projetos Lx-Gardens e Lx-Tree (coordenados pelo CEABN no ISA).

O estudo utilizou o software iTree-eco (USDA 2023b) para estimar as características dimensionais de 892 árvores analisadas nos 3 jardins; especificamente, foram obtidos dados como a área foliar e a cobertura da copa de cada exemplar. Graças à estimativa destes dados dimensionais adicionais, também com o software iTree eco, foi possível estimar os serviços ecossistémicos prestados pelos espécimes estudados. Estes incluem o sequestro de carbono, a capacidade anual de remoção de carbono, a produção de oxigénio, o efeito hidrológico, a retenção

e remoção de poluentes e a produção de compostos orgânicos voláteis. A análise foi feita por espécie e por Jardim, os SE foram quantificados para a média dos exemplares de cada espécie, obtendo-se uma visão geral do comportamento das diferentes espécies nos jardins. Em seguida, foi atribuído um valor económico a cada SE, resultando na quantificação, em termos monetários, dos benefícios ecossistémicos (BE) proporcionados pela vegetação estudada, juntamente com a quantificação de um valor de substituição para esta última.

Foi efetuada uma comparação entre as características das árvores e as estimativas dos SE para as doze espécies arbóreas com mais representatividade e mais comuns nos jardins e nos alinhamentos das ruas. Esta análise foi depois aprofundada para as espécies *Celtis australis* e *Platanus x hispanica* através da comparação de exemplares pertencentes à mesma classe de diâmetro à altura do peito (DAP-DBH) e com bom estado fitossanitário.

Foram explorados cenários de evolução do povoamento arbóreo utilizando a função de previsão do software iTree, testando as potencialidades desta ferramenta e realçando a importância da tomada de decisões, baseada em dados quantitativos para o planeamento urbano. Foram assim concebidos quatro cenários para o Jardim Teófilo Braga, imaginando a sua evolução nos próximos trinta anos. No primeiro cenário, assumiu-se que o jardim não sofreria quaisquer alterações, mantendo assim a sua estrutura atual. No segundo cenário, estudou-se o efeito das obras de expansão do metro sobre o arboreto do jardim. No terceiro cenário, considerou-se a perda de um grande número de exemplares de *C. australis* devido a uma infeção causada pelo fungo *Inonotus rickii*. O quarto e último cenário aborda o desenvolvimento do jardim na ausência dos dois grandes exemplares monumentais de *Metrosideros excelsa*.

Numa primeira fase, foi quantificada a variação do valor de substituição das árvores pertencentes ao jardim após a intervenção. Posteriormente, foram analisadas as alterações na estrutura do jardim (com base no número de árvores, coberto arbóreo, crescimento médio do DAP e área foliar), os efeitos relacionados com o armazenamento e sequestro anual de carbono e as alterações nos efeitos hidrológicos das árvores (escoamento evitado, interceção de águas pluviais, evaporação, transpiração e evapotranspiração potencial) para cada cenário assumido.

Resultados

Para o conjunto dos 3 jardins foram identificadas 892 espécies, pertencente a 130 taxa, das quais 428 são caducifólias e 311 são autóctones.

Dos três jardins estudados, o Jardim Guerra Junqueiro é o que apresenta a maior riqueza e diversidade de espécies, enquanto o Jardim Teófilo Braga é o que apresenta uma composição menos rica e diversa. As espécies mais representativas entre os jardins estudados são *Celtis australis*, *Howea forsteriana* e *Corynocarpus laevigatus*, com uma forte dominância da primeira sobre as restantes. O Jardim Teófilo Braga, onde foram avaliados os quatro cenários, foi o que apresentou a maior densidade de árvores e a maior dominância de uma espécie, sendo esta uma das motivações que levou a selecionar o jardim como caso de estudo para futuros cenários.

Os resultados do estudo, para todas as árvores examinadas, evidenciam a importância de espécies como *Taxodium huegelii*, *Ficus benghalensis*, *Celtis australis* e *Platanus orientalis*, pelos seus contributos para a armazenamento e sequestro anual de carbono, gestão de águas pluviais e remoção de poluentes atmosféricos, respetivamente. A quantificação económica demonstra o valor significativo gerado por certas espécies, diferenciadas por área e tipo de tipo de fenologia foliar e dimensão da copa, sublinhando a importância da sua representação na paisagem urbana.

As análises comparativas entre as árvores de arruamento e as de jardim evidenciam a influência da localização, como das condições de plantação (não ser em caldeira) mas em áreas verdes que permite um melhor desenvolvimento radicular, do tipo de manutenção e da consideração do local no crescimento e nos benefícios das plantas. Das doze espécies estudadas, mais de metade apresentam maiores dimensões em termos de DAP, altura da árvore e largura da copa. No que diz respeito ao índice de área foliar (IAF-LAI), a diferença não foi tão acentuada, o que permite concluir que as árvores de rua continuam a caracterizar-se por uma boa relação entre a área foliar e o coberto vegetal. Entre as espécies analisadas, verificou-se que, em geral, as árvores pertencentes a jardins são de maiores dimensões do que as da mesma espécie na rua. Os dados relativos ao tamanho conduziram então a estimativas caracterizadas pelas mesmas tendências nos ES fornecidos.

Através da discussão dos resultados obtidos com a análise de cenários, foi demonstrado como várias intervenções no Jardim Teófilo Braga podem gerar respostas diferentes, evidenciando uma estreita relação causa-efeito ao longo dos 30 anos estudados. Foi possível quantificar como, dependendo do cenário aplicado, poderia ocorrer uma diminuição do coberto vegetal entre 57% e 71% da situação atual. Esta última análise permitiu testar a utilidade da ferramenta de previsão com os dados disponíveis para a cidade de Lisboa, demonstrando a sua eficácia e, ao mesmo tempo, evidenciando algumas limitações atuais da análise.

Conclusão

O estudo confirma a importância da análise de dados para compreender o impacto da vegetação urbana nos serviços ecossistémicos. Revela as contribuições de uma série de espécies arbóreas para os benefícios do ecossistema, nomeadamente dentro do contexto de jardim, fornecendo informações válidas para os a gestão do arvoredo e do planeamento urbano.

Este estudo mostra o valor da integração de dados qualitativos e dimensionais (quantitativos) no planeamento da floresta urbana, permitindo decisões informadas para intervenções urbanas assim como ferramenta importante para estudar cenários futuros e apoio no planeamento urbano.

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1 Introduction

1.1 Overview

At the beginning of this document a bibliographical review will be developed on the topics considered fundamental for current discussion of the urban forest (see chapter 2). Specifically, we will delve into the concept of urban ecology, dwelling on the dichotomy that this term encompasses (section 2.1) and then clarify the concepts of urban forest and green infrastructure (section 2.2). Topics covered in the literature review include the growing interest in the management of trees in cities (section 2.3) and an introduction to the ecosystem services they generate (section 2.4). In a world where frontiers are increasingly blurred and awareness of a common good is growing, an in-depth look at the UN's sustainable development goals and the role that the urban forest plays in this context (section 2.5) is included here, and then it turns local and introduces the innovations that Portugal has introduced in terms of urban tree management (section 2.6). Aware of the fact that urban forest management requires knowledge and farsighted planning, the topic of choosing the most appropriate species for the context (section 2.7) and the possibility of implementing planning by foreseeing future scenarios (section 2.8) are introduced here.

The area that this document will study is the city of Lisbon, as described in Chapter 3. Knowing our area of intervention, an overview was made of the vegetation present in the gardens (section 3.1) and street greenery (section 3.2). This initial panoramic view leads to the definition of specific objectives and a working methodology to achieve them, which will be illustrated in Chapter 4.

The methodology used to explore the urban forest in this study is outlined in Chapter 5. Specifically, we will elaborate on the process by which the information was processed (section 5.1) and how the specific study areas were selected (section 5.2). After having identified the spaces involved in this study, the systems by which the data were processed and analysed will be described in more detail (section 5.3).

Chapter 6 will show the results of the analyses. Information on the composition of the gardens and their component species can be found here (section 6.1), as well as an in-depth analysis of the arboretum structure of the areas studied (section 6.2). Next, the ecosystem benefits that the vegetation in the study areas can offer will be estimated (section 6.3) by comparing the data obtained within the gardens, with the analyses already carried out for the street trees, with particular emphasis on commonalities and discordances (section 6.4). The data collected and analysed made it possible to also look into the future, evaluating the different evolution of the arboretum within possible scenarios (chapter 7).

Finally, Chapter 8 contains the conclusions of this study. The combination of the results obtained during the multiple analyses carried out allowed us to develop final considerations on urban forest management (section 8.1), thus creating new questions that need future studies to be resolved (section 8.2).

The last pages of this document include Appendixes to further elaborate on some of the topics discussed during the previous chapters and the tree inventory conducted during the data collection phase.

2 Bibliographic Review

2.1 Urban ecosystem (the evolution)

Our cities, born as a pole of control over the surrounding area, are increasingly becoming the human environment par excellence (Chueca Goitia 1996). It is envisaged that by 2050 a large part of the world's population will live in urban areas (United Nations 2019). Already since 2007, the urban population has surpassed the rural population and at present, more than 4 billion people live in urban areas (Ritchie and Roser 2018).

Ecology was born as a branch of science, to study the quantity, distribution but above all the interactions between the living beings on our planet (Collins et al. 2000). That share two major types of landscape, the human-dominated and the non-human-dominated (Alberti et al. 2003). Urban centres are the apotheosis of human-dominated landscape systems and cover only between 1% and 6% of the earth's surface, generating a much wider and deeper impact within ecosystems (United Nations 2019). This reasoning makes us think that man, in his cities, is not an isolated element, much less an inert one, but has continuous connections with the landscape. This ecological and interconnected component can be read in two different ways: ecology in cities and ecology of cities (Grimm et al. 2000). The substantial difference is that the former, ecology in the cities, tends to study the dynamics that occur between living organisms, and the territory within the city; whereas ecology of cities treats cities as real ecosystems by studying their dynamics and functioning (Grimm et al. 2000).

By studying ecosystems, we have discovered how our urban environments are less diverse and consequently less resilient than ecosystems where humans are not dominant (Alberti et al. 2003). Taking a cue from these other ecosystems, we can deduce how city resilience depends entirely on its ability to maintain a balance between human and ecological activities within it (Alberti et al. 2003). This need for ecologically diverse environments to be more resilient, is supported by the controversial Biophilia hypothesis, according to which human beings have an innate affinity with the natural world, are therefore able to create relationships with other living beings and derive great benefit from them (Kellert and Wilson 1993). This theory has been increasingly confirmed in recent years by different studies and can become a driving force for interventions in our landscapes (e.g. Chang et al., 2020; Schiebel et al., 2022).

The application of ecology to urban planning could be an excellent way to improve the resilience and liveability of our ecosystems. Urban vegetation is the basis of natural processes, and thus urban ecology will benefit from the in deep knowledge of the vegetation characteristics and of the interactions with other components of the ecosystem (Magalhães 2001; Metta 2022). In fact, the topics of service and disservice provided from urban vegetation was focused in many research up to date (e.g. Cabral 1943; Loidi et al. 2010; McPhearson et al. 1997; Nowak 2003; Nowak and Dwyer 2000; Telles 2011).

2.2 The urban forest as a component of Green infrastructures

The flora component in the cities can be addressed in different ways. In this document, here after, we will refer to the vegetation in the city using the following definitions:

'Urban forests can be defined as networks or systems comprising all woodlands, groups of trees, and individual trees located in urban and peri-urban areas; they include, therefore, forests, street trees, trees in parks and gardens, and trees in derelict corners. Urban forests are the backbone of the green infrastructure, bridging rural and urban areas and ameliorating a city's environmental footprint' (FAO 2017).

'Green infrastructure in urban areas consist of vegetated green surfaces, such as parks, trees and small forests, grasslands, but also private gardens or cemeteries. These all contribute to supporting biodiversity, pollinators, carbon sequestration, flood protection and protection against excess heats events. This dashboard facilitates the understanding of the amount of urban green in Functional Urban Areas of the EU and EEA member states' (EEA 2018).

These definitions are among the most recent and as such have been used by a variety of publications in recent years (e.g. Owuor, Whitehead, and Vreese 2022). It is easy to relate the urban forest to green infrastructure; in fact, we can consider the former as the backbone of the latter. Urban forests are more than trees, however, tree specimens are in many cases among the characteristic elements of a mature phase of ecological succession, the climax, capable of providing benefits with continuity over time (Clark et al. 1997), thus make it the most perennial element of the forest.

With the exponential growth of cities experienced during the last century, we have experienced a steady and increasingly intense shift away from the dynamics that link the needs of our species with the ecological systems we inhabit (Burkhard et al. 2012). This detachment has been studied on a practical and philosophical level by many authors including Ribeiro Telles who sees the dichotomy between field and city in a concept of continuous and global landscape (Telles 2013). It is precisely by following this thought of continuity, spatial and temporal, that we can introduce the concept of green infrastructure within our man-made environments, as a tool that can offer multifaceted solutions (European Commission 2013). By reconnecting the surrounding landscape with dense urban fabric, green infrastructure performs great environmental and social functions, including recreating an awareness of what we consume and the limited availability of resources. (European Commission 2013). The tree component within the urban environment will be the main subject of this paper.

2.3 The trees in the cities

With the constant increase in population within cities and a sudden change in perspective given to us by the global pandemic experience in the year 2020, the benefits that a coexistence with vegetation can bring us are beginning to be common knowledge (e.g. Konijnendijk 2023). The relevant bibliography tends to classify the ecosystem benefits provided by vegetation into five main categories: health and social well-being, cognitive development and education, economy and resources, climate change mitigation and habitat, and finally, green infrastructure (Turner-Skoff and Cavender 2019). All these benefits fall, in many ways, within the global 2030 targets as will be explained in section 2.5 below.

Despite increased awareness for the importance of the city vegetation, we are still far from organising our cities by giving the plant component the importance and distribution it should have. Several studies report how, the knowledge developed on these topics is not adequately applied, aggravating risk of a lack of tree equity, namely the equal distribution of the urban forest and its benefits (Haaland and van den Bosch 2015). Alongside

the idea of tree equity, we can add the concept of environmental justice, which comes into play when we enter the world of territorial planning at the urban and social level (Grant et al. 2022). As such, there are now several guidelines on which land/urban management regulations have been developed in order to implement the distribution of vegetation (Konijnendijk 2021). First of all, we can refer to the 10-20-30 rule launched by Santamour Jr (2004). in the nineties of the last century. The rule, derived from empirical evidence from the field of applied ecology, aims to create a guideline for the distribution of plant species in urban areas, targeting a diverse and more resilient urban forest (Kendal, Dobbs, and Lohr 2014). To this end, it states that no more than 10% of the plants belonging to the same species, no more than 20% belonging to the same genus, and no more than 30% belonging to the same family should be found in the same urban system (Santamour Jr 2004). In the momentum of the 10-20-30 rule along with a request for specific guidelines for urban forest management and planning, and at national and international level, the 3-30-300 rules was born (Konijnendijk 2021). This new set of rules does not replace the first ones theorised by Santamour but complements them, dealing not only with taxonomic distribution but with spatial distribution. This rule states that it should be possible to see at least three trees of significant size from each building; each neighbourhood should possess at least 30% of its area of canopy cover; and each building should be at most 300 metres from a garden or park of at least one hectare in size (Nature Based Solutions Institute 2023). These guidelines, if applied, could help bring about an equitable distribution of vegetation within urban centres, thus spreading the ecosystem services associated with it.

2.4 Ecosystem Services (ES)

In the previous section 2.3, we mentioned the five categories of ecosystem services that urban vegetation can provide us with. Referring to these ecosystem services, there are many experts questioning how best incorporate research and the knowledge gained from it into decision-making processes for sustainable landscape management (e.g. Bennett et al. 2015). Ecosystem benefits are not point elements that can be considered in isolation, but are themselves the concretisation of the more complex relationships that exist between the biophysical context, ecological processes and human interventions (Mouchet et al. 2014). We must also emphasise the difference between the ecosystem services provided by vegetation and the benefits perceived by us. For example, the absorption of air pollutants through leaf deposition is something that happens normally wherever there is a plant, but it is the benefit we derive from it that can be wisely used in decision-making (Bodnaruk et al. 2017). There is a great difficulty in translating ecosystem services into benefits for our society (Bennett et al. 2015). Moreover, ecosystem benefits are not something simple to achieve but the result of complex interactions between multiple factors, belonging to different areas of interest, which makes their management complex (Fisher, Turner, and Morling 2009).

Many studies in different fields address the importance of ecosystem benefits in the city (Burkhard et al. 2012). The removal of pollutants and the consequent improvement of environmental quality is one of the most studied benefits from an urban ecology perspective (Nowak 2003). The urban forest has a great impact on urban water management as reported in the comparative study between the city of Lisbon and Singapore (Cui et al. 2021). For the city of Lisbon, which as we will see in the section 3 below, will be our study area, experimental

studies have already been carried out on the temperature mitigating capacity, carbon storage capacity of vegetation (Neto and Sarmiento 2019; Reis and Lopes 2019).

Not only is the effect of improving environmental quality interesting, but also the effect that vegetation has on our lifestyle, as it has been proven that proximity to a structured urban forest can decrease the risk of depression (Marselle et al. 2020). Along with these benefits, there is a first associated economic value since proper management of the urban forest can generate jobs (Pino et al. 2022).

2.5 United Nation - Sustainable Development Goals (SDGs)

Globally, it has been clear for decades how our impact, especially due to post-industrial production and consumption systems, has affected ecological processes (M.E.A. 2005). Despite this awareness, the need of our species to aim for exponential growth and thus to use more and more resources has meant that we leave an indelible mark on the functioning of our planet by entering what is called a new geological era, the Anthropocene, marked by strong conflicts of interest (Latour 2014).

To increase awareness, about the needs of promoting a sustainable development, the UN proposed the 2030 Agenda. Aiming to achieve 17 goals on broad themes, from social to ecological, fostering the implementation of solutions that are transforming our world (ONU 2015). Urban vegetation as a key element within the concept of green infrastructure. As we can observe in Table 1, urban forest falls in almost all of the seventeen goals proposed by the UN, each one from a different aspect of urban forest (e.g. Turner-Skoff and Cavender 2019).

The UN produced a more specific document, the United Nation's New Urban Agenda (NUA), which reports social, ecological and economic goals for our ever-widening urban areas (United Nations 2017). This document emphasises the need to consider that, even in urban environments, we are still talking about an ecosystem and, as such, one that is constantly evolving. Thus, the changes we are inducing are generating strong imbalances even within man-made environments, and the fundamental need to adapt our cities to these changes becomes apparent (Ordóñez Barona and Trammell 2022).

Many scientific papers, including research and outreach, emphasize the critically important role that green infrastructure plays within our cities (e.g. Turner-Skoff and Cavender 2019). Specifically, we can see green infrastructure as a solution to the problems of city-expansion, even more so after our experience with the Covid19 pandemic (Pino et al. 2022). The big stop that globally marked the first half of 2020 had generate needs in people that had been hiding behind their routines. At that moment, an awareness was born in many of us that we want to live in an environment where the chase for economic well-being does not undermine our mental and physical well-being. Following the goals of the United Nations, along with European development guidelines, Portugal is adapting its legislation on urban forestry.

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Table 1 - Example of connection between urban forest and Sustainable Development Goals (from ONU, 2015)

Goal 1 - <i>End poverty in all its forms everywhere.</i>	There are several evidences of how urban vegetation can be an important resource from an economic point of view, such as in the 'Working for Water' project active in South Africa (Binns, Illgner, and Nel 2001)
Goal 2 - <i>End hunger, achieve food security and improved nutrition, and promote sustainable agriculture</i>	Among the various services offered by the urban forest, the opportunity of non-timber forest products (NTFPs) should not be overlooked, as the Incredible Edible project has been able to apply in a variety of situations (Morley, Farrier, and Dooris 2017)
Goal 3 - <i>Ensure healthy lives and promote wellbeing for all at all ages.</i>	The physical and mental well-being generated by living in an environment that includes a high proportion of plants is often used in policy decision-making (Donovan 2017);
Goal 4 - <i>Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.</i>	Exposure to an environment that includes a vegetation component proves to be beneficial for educational purposes and assists learning (Kuo et al. 2019).
Goal 6 - <i>Ensure availability and sustainable management of water and sanitation for all.</i>	A good tree component, if properly maintained, can help with management of fast floods in an urban environment (Berland et al. 2017).
Goal 7 - <i>Ensure access to affordable, reliable, sustainable, and modern energy for all.</i>	Urban greenery can also improve climate amenity to saving energy, not only for its ability to mitigate temperature but, as FAO argues, it is possible to use its 'waste' for sustainable energy production (Salbitano et al. 2016).
Goal 9 - <i>Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation and foster innovation.</i>	Green infrastructure unlike grey infrastructure is alive and part of a land continuity system capable of distributing countless ecosystem benefits (EEA 2018)
Goal 10 - <i>Reduce inequality within and among countries.</i>	The urban forest is a tool that can improve the quality of life in the environments in which it is consciously used; at the same time, the creation of better living environments may have controversial effects to gentrification and inequity (Grant et al. 2022).
Goal 11 - <i>Make cities and human settlements inclusive, safe, resilient, and sustainable.</i>	The social impact of the urban forest is by no means minor, in this regard it has been studied how a disease and subsequent reduction in ash tree led to an increase in crime in the city of Cincinnati, Ohio (Kondo et al. 2017).
Goal 12 - <i>Ensure sustainable consumption and production pattern.</i>	Proper management and exploitation of the urban forest is capable of generating a significant benefit within a local circular economy (Poe et al. 2013).
Goal 13 - <i>Take urgent action to combat climate change and its impacts.</i>	Rethinking our living environments by better integrating the urban forest and benefiting from the ecosystem services it provides can help combat climate change (Owuor et al. 2022).
Goal 14 - <i>Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.</i>	Urban vegetation, including trees, can be used for their phyto-purification capacity, thus treating polluted water before it reaches watercourses (Schwab 2009).
Goal 15 - <i>Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.</i>	Understanding the value of vegetation and valuing the existing specimens is one of the keys to counteracting the loss of biodiversity (Alvey 2006).
Goal 16 - <i>Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable, and inclusive institutions at all levels.</i>	The well-being of the individual is inked within a functional society; we need to feel good to create healthy relations and live in harmony. To this merit, multiple studies address the topic, showing that there is a very close relationship between the feeling of personal well-being, social well-being, and the relationship we have with the natural elements around us (e.g. Bennett et al. 2015; Carrus et al. 2015; Ingold, n.d.; M.E.A. 2005)

2.6 Law 59 of August 18, 2021 - Portugal

The publication of Law 59/2021 is profoundly changing the approach of municipalities toward public green management (Assembleia da República 2021). This law complements the Law on the Classification of Arboretum of Public Interest (Diário da República 2012), which in turn replaced the Law on the Maintenance of Vegetation in the Proximity of Architectural heritage, dating back to 1938 (Diário da República 1938). As for the city of Lisbon, even before Law 59/2021 came into effect, the municipal arboretum regulation was in vigour (MUNICÍPIO DE LISBOA 2017). Indeed, the new law brings innovations from the management point of view in multiple facets of urban green, for example:

- Article 5 defines different principles to which tree heritage must refer by dwelling on the ecological, economic, and social function it has and for which it must be identified and protected.

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- Article 8 requires municipalities to develop within a year, a management regulation for the arboretum to establish a plan for it.
- Article 9 defines what is to be included in the regulation named in Article 8 to standardize the composition of management plans.
- Article 11 mandates the creation of an inventory of the urban arboretum by clearly articulating the data to be collected and included within the document.
- Article 12 mandates the dissemination through an online platform of the management regulations and inventory of the arboretum to generate an informed and participatory management of one of the largest community resources.
- Article 17 reports compensation operations in cases where the arboretum, and consequently its ecosystem services, is damaged or must be for other reasons altered.

One of the expected that from the application of this law is to gain a thorough understanding of urban vegetation. With a deeper knowledge on that component of the urban ecosystem, it is possible to make solid support decisions, better choices in the long term, such as the inclusion of appropriate plant species to every specific context and management objectives.

2.7 The importance of make a good selection.

The importance and role of plants within the urban system is something closely linked to the interactions that are created within the ecological system (Telles 1957). With the objective of planning resilient and ecologically complex landscapes, whether they are urban or not, it is essential to know the vegetation component.

In the specific case of the urban forest, a constant motoring of what we have is necessary in order to be able to understand the dynamics influencing its evolution (van Doorn et al. 2020). As we presented in the section 2.4, we receive multiple ecosystem benefits from our coexistence with the vegetation component. We must, however, dwell on the fact that there are also ecosystem disservices. Amongst these we can find the economic costs of management, possible damage to property or persons, the visibility limitations that vegetation generates, especially in the road environment, and the production of Volatile Organic Compounds (Escobedo, Kroeger, and Wagner 2011). However, these disservices can be limited by a correct taxonomic selection of the species to be planted (Turner-Skoff and Cavender 2019). Being able to find and integrate the use of real and correct data into decision-making processes becomes indispensable for the reduction of ecosystem disservices and the costs they generate (European Commission 2013).

In addition to the ecological dynamics that we need to be aware of and take into account for proper urban forest planning, it will be necessary to consider the effects of climate change on urban ecosystems and adapt varietal selection to what may be future realities (Pino et al. 2022). More and more studies are highlighting the need to adapt our urban forest to the already well-known climate change (Ordóñez Barona and Trammell 2022). In recent years, various tools have been emerging, with the aim of disseminating knowledge and the possibilities to make a correct taxonomic selection, which can provide guidelines for a forward-looking choice of vegetation (e.g. Nowak 2008; The Morton Arboretum 2023). These tools can help us develop a planning system for scenarios.

2.8 Scenario planning

We must, however, consider that scenario planning in the field of land management, especially on an economic level, has already been known and studied for several years, and this is where the idea comes from:

The central idea of scenario planning is to consider a variety of possible futures that include many of the important uncertainties in the system rather than to focus on the accurate prediction of a single outcome.

(Peterson, Cumming, and Carpenter 2003)

Planning by scenario analysis of the urban forest, capable of generating ecosystem services which can then be perceived as beneficial by positively influencing our urban ecosystems has been increasingly in use (Amini Parsa, Salehi, and Yavari 2020).

There are methodologies, such as 'The Urban Forest Effect' (UFORE), that can quantify the structure and functions offered by the urban forest (Nowak and Crane 2000). Within the framework of planning by scenarios, a number of studies have already been developed, with the aim of creating a methodology capable of integrating the ecosystem services envisaged within the project choices (e.g. Amini Parsa et al. 2019; Amini Parsa, Salehi, and Yavari 2020; Barron et al. 2023; Hilde and Paterson 2014).

The idea of scenario planning is to apply these quantifications to hypothetical urban forest development scenarios to quantify the ecosystem benefits and their value. The iTree software, developed by the USDA (United States Department of Agriculture), which can estimate the ecosystem benefits provided by vegetation, in its latest version, offers the possibility of evaluating possible future scenarios.

A great deal of information on the urban forest is emerging for the city of Lisbon, which allows us to think about the application of scenario planning to the Portuguese capital.

3 Lisbon characterization

Our area of interest is the city of Lisbon, capital of Portugal, one of the westernmost territories on the European continent. The city is strategically located at the right margin of the Tagus River estuary, which radically influences its territory, geomorphologically and, consequently, its climate. Given this location, over the centuries, multiple populations landed on its shores, thus leaving their mark (Telles 1997).

Lisbon has a Mediterranean climate, characterized by hot summers and cold winters, with a strong Atlantic influence that mitigates temperature extremes during the seasons thus leading to a mean maximum temperature in June of 27.4°C and a minimum in January of 8.2°C (Alcoforado et al. 2005). Rainfall is concentrated in the winter months, typically between October and April, a period during which several extreme weather events have occurred during recent decades causing flooding and subsequent disruption in the urban area (CML / Departamento da Estrutura Verde e Departamento de Planeamento 2017; Dias 2022).

The Tagus River together with the Sado River, located to the south, carved out over the ages one of the three largest depressions on the Iberian Peninsula, thus creating one of the most fertile territories on the Iberian Peninsula, an essential element for the settlement of a population (Telles 1992, 1997). The strong presence of water as a land sculpting element creates extremely dynamic, biodiverse environments, but at the same time they require forward-looking and ecologically sustainable planning to build a coexistence between exploitation for our purposes and conservation of these territories (Sijmons et al. 2017).

As early as 1997, Professor Gonçalo Ribeiro Telles promoted, within the Lisbon Green Plan, the creation of an ecological structure of metropolitan dimension and with landscape continuity, necessary within an urban development strategy (Telles, 1997). The ideas applied by Professor Telles during the implementation of the green plan, were already the domain of the school of landscape architecture since its founding by Professor Caldeira Cabral (Cabral 2003).

We can guess, therefore, how important it is to know what the urban forest of a heavily urbanized area, such as Lisbon, is composed of so that we can fully understand the usefulness of these 'natural' elements that have been part of the Lusitanian landscape even before human settlement. According to Nowak (2008), the management of an urban arboretum, thus the management of a green plan as complex as that of a metropolis, must be done from climate data and the adaptability that species have to these conditions. With the ability to know the past of our study area and consequently be able to predict possible future scenarios, we can make conscious and forward-looking choices.

Information regarding Lisbon's urban forest has been collected and analysed in several studies since last century (Andresen 1982). A depth economic evaluation was already done, in order to focus people's attention on the real value of the urban forest, by Professor A. L. Soares (Soares 2006). To obtain a true estimate of what the value of Lisbon's urban forest might be, STRATUM software, part of the i-Tree software suite, was used, having the capacity to quantify the ecosystem services provided by street trees. From a set of 36.265, a sample of 3.033 tree specimens were surveyed in 2003 and 2004, to quantify the value of the entire urban forest. The

results of this study revealed that, each year, the capital's street trees provide \$8,432,779 in ecosystem benefits, considering the expenditure of \$1.9 million for arboretum management one can observe a net benefit of \$6.5 million (Soares et al. 2011).

Several projects were born after this first appraisal of the ES in Portugal (e.g. Graça et al. 2018). In the metropolitan area of Lisbon, we mention two projects carried out by CEABN (ISA) with the municipalities of Cascais and Almada where the iTree-Eco tool was used, for the quantification of ecosystem benefits (USDA 2023a). A much larger project was also developed for the municipality of Lisbon, with the aim of assess the composition, structure and ES provided by street trees. Considering the most recent data collected, the Lisbon street arboretum has 109,879 recognised specimens of 469 different taxa (Cunha et al. 2022).

Lisbon urban forest is more than street trees and recently a was concluded the characterization of historical gardens that identified 27,610 individuals of 799 taxa (Soares 2021).

These data sets have in common variety of species that are managed in different context and with different purposes, thus allowing to evaluate the effect of these factors for species provision of ES.

3.1 Lx-Gardens

The Lx-Gardens project financed by FCT (Fundação para a Ciência e a Tecnologia) stems from the need to protect, develop and promote the landscape heritage. With this objective, was implemented a study of 64 historical parks and gardens in the city of Lisbon, created between the 18th and 20th centuries, which included a landscape inventory, historical, artistic and botanical analysis (Soares 2021).

The study was developed in accordance with the International Cultural Tourism Charter (ICOMOS 1999), revisited by the International Charter for Cultural Heritage Tourism (ICOMOS 2022) maintaining its consistency with what are the goals of cultural heritage management. Specifically, we can refer to the sixth principle of the charter, which advocates:

Increase the resilience of communities and cultural heritage through capacity development, risk assessment, strategic planning and adaptive management.

(ICOMOS 2022)

Thus, it is the focus in resilient management that includes strategic planning in view of the radical changes we are experiencing in our historical period that makes the study carried out by Professor A. Soares and her team during the last few years, a fundamental document for understanding Lisbon's urban forest.

During the tree census of the 64 gardens, 27,610 trees belonging to 799 different species were inventoried, which denotes high level of plant richness within Lisbon's gardens, albeit considering that three of them are considered botanical gardens and, as such, inherently contain a varied botanical collection (for more details, see Vasconcelos et al., 2021.). The data on tree spatial location and identification were available for further studies.

3.2 Lx-Tree

The Lx-Tree project resulted from a protocol between The School of Agronomy (CEABN) and the Municipality of Lisbon, with the goal of completing the tree inventory of Lisbon's city streets and quantifying the ecosystem services provided by the urban forest (CEABN 2021). The first part of the study focuses on 48000 specimens, of which a sample were studied and surveyed in the field, while the remainder analysed through remote sensing systems (Soares et al. 2022). A sample of 6928 was used for ecosystem services estimates (Figure 2).

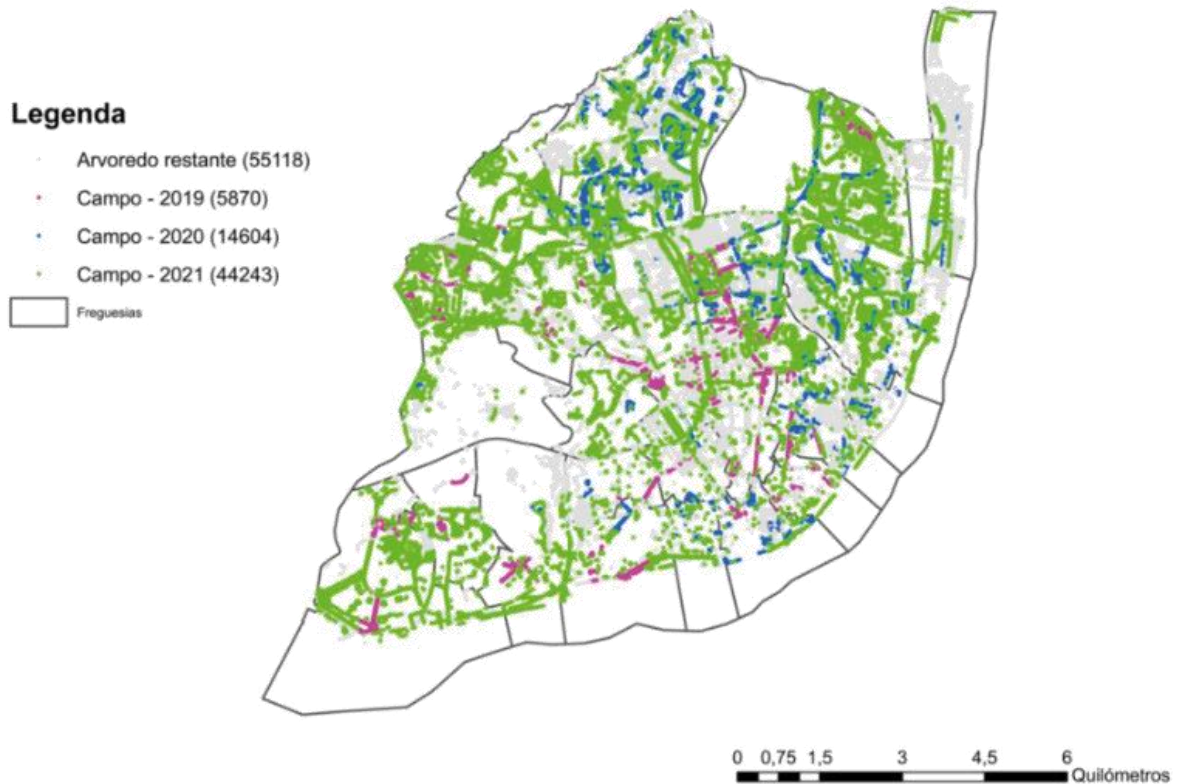


Figure 1 - Lisbon surveyed tree map for the complete Lx-Tree data set, 2019-2021 (S. Dias et al. 2022)

During the project, street trees were identified and studied based on the concept that, for a tree to be classified as a street tree, it must be inserted in an urban space, associated with the circulation of cars, on the edge of roads, so belonging to the public space and in relation to the surrounding buildings (Dias et al. 2022).

The result of this work brought to light useful information and critical issues related to the composition of Lisbon's street arboretum. Unlike the nearly eight hundred species identified in Soares (2021) within the gardens of Lisbon, street trees are characterized by 469 taxonomically diverse species, among which there are four specific species that account for about one-third of the total number of specimens (Soares et al. 2022).

According to the results of this study, the annual ecosystem benefits provided by a sample of 6,928 trees was estimated, through the iTree-Eco software (Figure 2) in nearly €62,000. The extrapolation of these this

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values for the total street trees (from the iTree-Canopy software) resulted in an estimated value of 447,100€ per year of ecosystem benefits provided by street trees within the municipality of Lisbon (Soares et al. 2022).

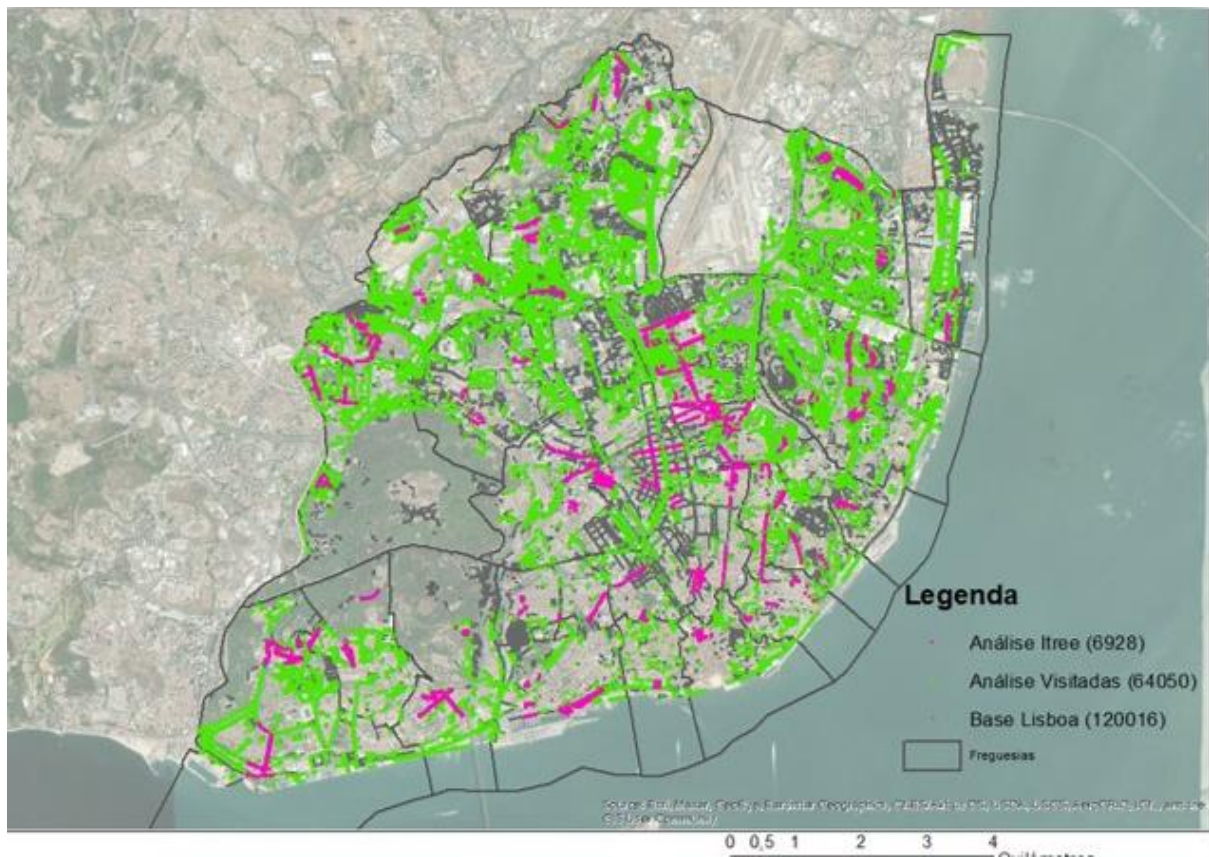


Figure 2 - Lisbon surveyed tree - iTree analysed specimens in pink - surveyed trees in green - Lisbon trees database in grey (Dias, Soares, Nunes, Duarte, et al. 2022)

In addition to the values above, it appears from the study conducted that greater ecosystem benefits come from larger sized trees or trees with a greater leaf area. Furthermore, depending on the inherent species characteristics (leaf type and size, phenology etc..), they may provide different benefits. This information, if properly used, can become critical in thinking about future urban arboretum management, using vegetation as a pivotal tool for achieving urban-level outcomes (Dias et al. 2022).

4 The Question

Forest structural data encompass a range of vital attributes including, but not limited to, tree quantity, species composition, dimensional characteristics of trees, their vitality, as well as precise geospatial coordinates. These multifaceted data collectively underpin pivotal estimations to aggregate leaf area, tree and foliage biomass, thereby facilitating a comprehensive quantification of diverse trees functionalities, synonymous with ecosystem services (Nowak et al. 2008).

Given that the selection of tree species, their size when planted and the way it is managed is dependent of the human intervention in the cities, it is important to understand how different options can provide different results and to test the actual and available tools that could help us to make strong based options.

Our main objective will therefore be to understand and test how these data can generate interesting information that can be used within a forward-looking design and management of the urban forest. To achieve this goal, five sub-objectives have been identified to subdivide the project phases (see Figure 3).

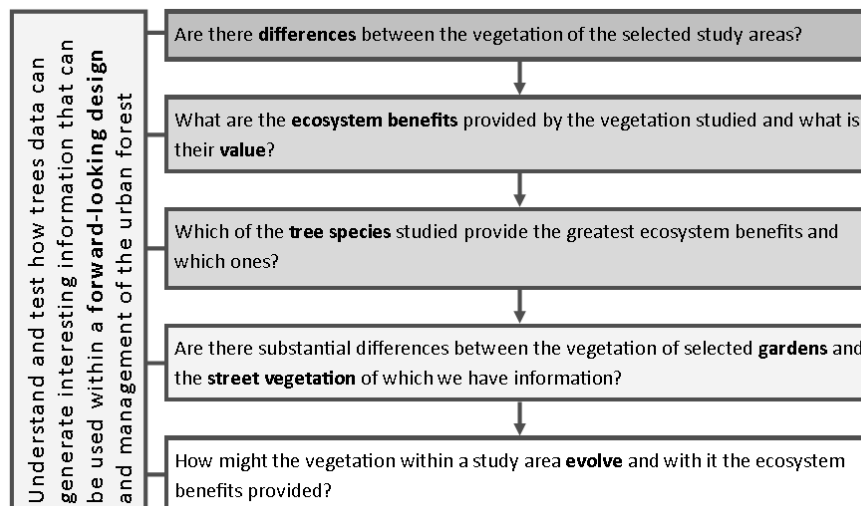


Figure 3 - Dissertation objectives

To answer the previous questions, a workflow was developed (see Figure 4). After an initial phase of bibliographic review and collection of the knowledge essential to be able to carry out work of this kind (section 1.1), we moved on to the collection and evaluation of the information available to date (section 5.2). To the data that had been obtained, the missing information was added (section 5.3), after a fieldwork phase, to have a database necessary for carrying out comparative analyses (sections 6.1, 6.3, 6.4). Then, the information collected and processed was used to identify possible future scenarios and estimate the changes associated with them (section 7). At the end, conclusions are given (section 8.1), relating the different analyses carried out to the objectives proposed in Figure 3.

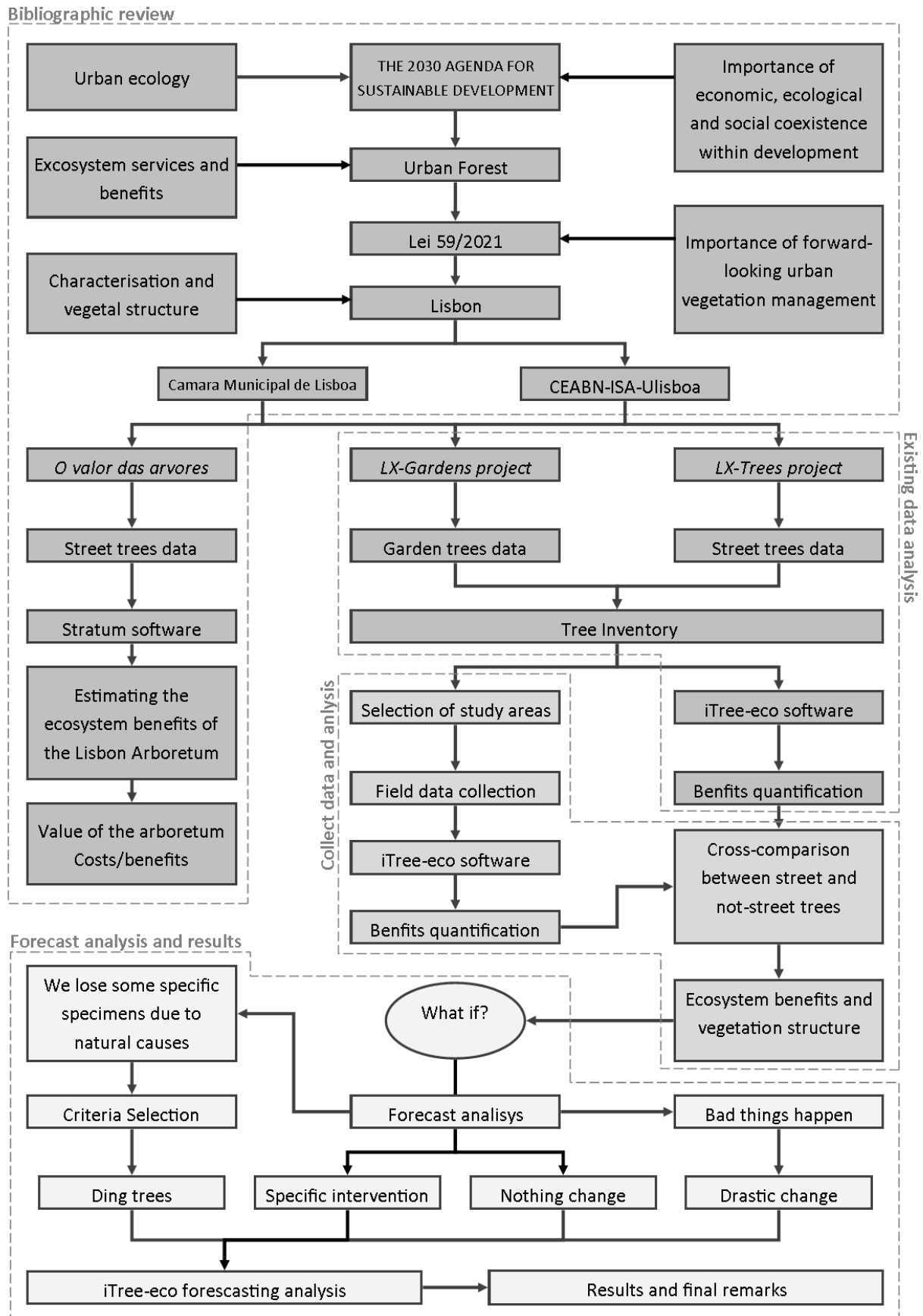


Figure 4 - Workflow

Detailed descriptions of the methodology applied in the various phases of the study are available as Appendixes at the end of the document. It is possible to consult the methodology used for data collection (Appendix No.01 - Field data collection); the corrections and data processing done after collection (Appendix No.02 - Post collection corrections and additions); the procedure used for data entry within the iTree-eco software (Appendix No.03 - iTree project submission), the indices applied within the analyses and the formulas used (Appendix No.04 - Calculations and applied indices); and the methodology used to obtain a random selection of specimens (Appendix No.05 - Random selection of trees).

5 Material and Methods

5.1 Applied process

Our study begins by developing a thorough understanding of what is the urban forest in Lisbon. To date different studies have been carried out on the latter, in particular, regarding the arboretum of gardens, we can refer to the section 3.1 Lx-Garden (Soares 2021). While speaking of the street arboretum, the recent Lx-Trees project helps us understand how this is structured (Soares et al. 2022). The two studies have different analysis characteristics from each other, since: Lx-Gardens focuses on gathering information on the species occurrence and their spatial distribution of the Lisbon gardens arboretum, while the Lx-Tree project, analyses quantitative and qualitative data (through iTree-Eco software) to estimate the ecosystem benefits provided by the street arboretum.

The approach used in Lx-Tree project to estimate ES can be replicated in other type of vegetation components, namely in gardens, where the composition can have shared elements, but with different characteristics, in terms of management, implantation and structure. These complementary approaches could then be used to comparing street trees with garden trees in terms of their contribution to ES. The same approach and software can in turn be used to discuss possible scenarios and their outcomes (Figure 4). Building on the projects developed to date, we will go on to replicate the quantitative analysis used during the Lx-Tree project to selected elements within the Lisbon gardens. This will require in-depth data collection in the field, to obtain a sufficiently characteristic library of information that can be analysed through the iTree-Eco software (Figure 5).

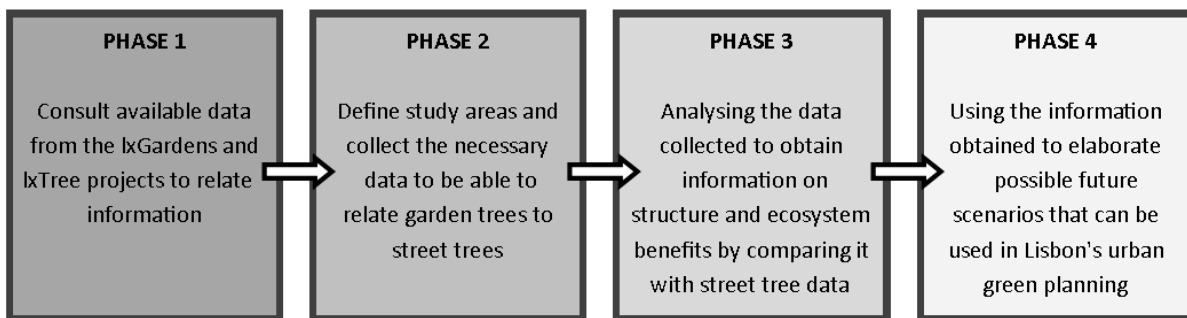


Figure 5 – Synthetic methodologic workflow

5.2 The study areas

5.2.1 The garden selection

The three gardens selected, within the Lisbon municipality are inserted in consolidated neighbourhoods from the old city : Jardim Guerra Junqueiro, from the Estrela parish; Jardim Teófilo Braga, from the Campo de Ourique parish; and Jardim França Borges, located in Príncipe Real, from the Misericórdia parish (Figure 6). For more details about the process of the data collection in the studied area process see Appendix No.01 - Field data collection.

The three gardens selected for this thesis, were selected from the 64 already surveyed, with the aim of deepening their knowledge from an ecosystem perspective. Starting from the data available from the technical documents belonging to the Lx-Gardens project (Vasconcelos et al. 2021), it was possible to rebuild a georeferenced map of the vegetation within the area of interest, thus using georeferencing and specimen-specific recognition as a starting point. The data obtained in this way, were then confirmed in the field and complemented with the necessary information (namely tree dendrometry, condition and location), to proceed to a quantification of the ecosystem benefits provided by the case studies.

It was therefore possible to complement vegetation information with measurements made in the field. In the act of verification, small changes were found within the composition of the gardens, as to be expected since our data verification took place ten years after the collection made by A.L. Soares' team (Vasconcelos et al. 2021).

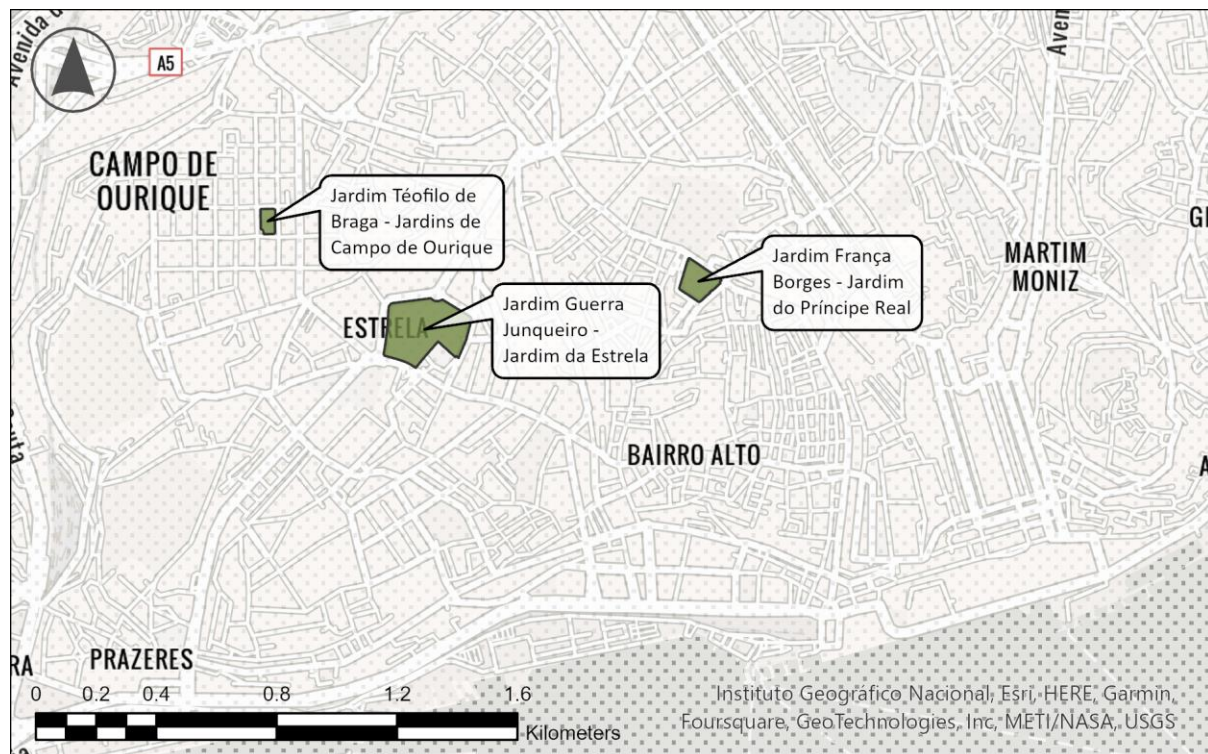


Figure 6 - Location of the selected gardens: Jardim Teófilo Braga (Campo de Ourique), Jardim Guerra Junqueiro (Estrela) and Jardim França Borges (Misericórdia)

5.2.2 Jardim Guerra Junqueiro (Jardim de Estrela)

One of the oldest gardens in Lisbon, dating back to 1852; certainly, the second public garden in the city (the first public garden was Passeio Publico, now Avenida da Liberdade), created following the English landscape style. Its peculiarity, which strongly links it to the aforementioned style, is its sinuous layout, the creation of several floors, and the great biodiversity that characterizes the botanical choices made (Soares 2021). Precisely because of the presence of a wide variety of plant species, this garden was selected as an element within our analysis.

Featuring an area of about 4.5ha, the Lx-Gardens document reports 562 tree specimens of 120 species identified as living and placed within a public space (Soares 2021).

5.2.3 Jardim Teófilo Braga (Jardim da Parada)

The Jardim da Parada, also called Jardim Teofilo Braga, is in the parish of Campo de Ourique and represents one of the few green spots in this densely populated neighbourhood of Lisbon. The Jardim Teofilo Braga is the smallest of the three study gardens, in terms of size, it is the same size as the characteristic block of Campo de Ourique, roughly 0.5 hectares, thus fitting into the regular grid that characterizes the urbanization of the neighbourhood. The area of half a hectare covered by the garden is the indispensable minimum according to Konijnendijk, in the theory of 3-30-300 (Konijnendijk 2021). The garden in question was chosen within this analysis for two reasons: first, it is a garden with historical value that has four classified monumental tree specimens within it; second, the great controversy that has arisen around the extension of the red line of the Lisbon subway (Metropolitano de Lisboa 2022b), has drawn our attention, making it necessary to understand the ecological value of the specimens belonging to this garden.

The Jardim da Parada dates back to the mid-19th century, as do other green spots within Lisbon's historic centre (Soares 2021). Among the various species in the garden, we can recognize four specimens classified for the Portuguese Institute of Nature Conservation and Forestry: these are two *Metrosideros excelsa*, one *Taxodium huegelii*, and one *Sequoia sempervirens* (Saraiva and Almeida 2016). The presence of these four specimens of public interest, represents a singularity of this neighbourhood garden of the size of only half a hectare. The inhabitants of Campo de Ourique, in fact, find cool shelter on summer days almost exclusively in this place within the neighbourhood. The remaining urban grid outside this block is characterized by the repetition of housing modules with a very little presence of greenery.

5.2.4 Jardim França Borges (Jardim de Príncipe do Real)

The third study garden is the Jardim França Borges, located in the Príncipe Real neighbourhood in the heart of Lisbon. This garden, also dating back to the mid-19th century, bears several specimens classified as public interest, including three *Ficus macrophylla*, one *Ceiba speciosa*, one *Araucaria columnaris*, and one *Cupressus lusitanica*, with singular bearing (Saraiva and Almeida 2016). This cypress is perhaps one of the most recognizable trees in the city of Lisbon, with a very strong historical and cultural presence (Dias, Soares, Nunes, Gaião, et al. 2022).

Inside the Jarim do Principe Real is an architecturally significant work of art, a water reservoir cistern dating back to 1856 (Soares 2021). This garden has a size of about 1.2 hectares and, like the previous Jardim da Parada is bordered by roads, which makes the trees within it border between street green and garden.

5.3 Data processing and analysis

5.3.1 Preparing global data set

The field data done during May and July 2023, for a total of 175 hours of fieldwork, comprised a total of 997 georeferenced elements in the three gardens, for which the information described above was collected. The data, initially on the Google Drive platform through the use of Google Sheets software (Google 2023b), were then transferred and processed through the use of Excel software from the Microsoft platform (Microsoft 2023). Additions and corrections that have been made to the data collected in the field can be found in Appendix No.02 - Post collection corrections and additions.

The data containing georeferenced information was entered into the ArcGIS Pro software in order to be visualised (Esri 2023), analysed and to be able to characterise the study areas.

5.3.2 Taxonomic composition

The composition of the studied gardens was evaluated according to several attributes (similarly to the work done for the roadside arboretum (Dias, Soares, Nunes, Gaião, et al. 2022). Data on the family, genus and species was used to determine species (or Taxa) richness. Relative abundance of each species for each garden was also computed. These values were then used to obtain indices regarding of species diversity, dominance and similarity of the tree community. The indices used for the characterisation of the study areas are shown in the Table 2 below. More information on the application of these can be found in Calculations and applied indices.

Table 2 - List of the indices used to characterise the tree community composition of the three studied gardens.

Richness (S)	To calculate specific richness
Shannon-Wiener index (H')	To calculate species diversity
Pielou's index (E)	To calculate its taxonomic evenness
Dominance index	To calculate a possible taxonomic dominance
Sørensen Similarity index	To identify the gardens similarity

5.3.3 iTree-Eco functionality

The iTree-Eco software was used to analyse the data belonging to the surveyed vegetation. This software is capable of estimating the ecosystem benefits provided by one or more specimens, based on information collected in the field (Bodnaruk et al. 2017). Specifically, the data collected using standard procedures on vegetation are sent to USDA (submitted online) and cross-referenced with the vast library of information available on the different species at their disposal, so as to obtain an estimate of the ecosystem values we seek (McPherson 2010). In addition to the collected vegetation data, we provided to the software local data regarding population density, climate and air pollution, which will be explored in section 5.3.4. As shown in the official software operation diagram (

Figure 7), thanks to the data collected in the field, it will be possible obtain information about the analysed urban forest and then proceed with predictive models on future developments.

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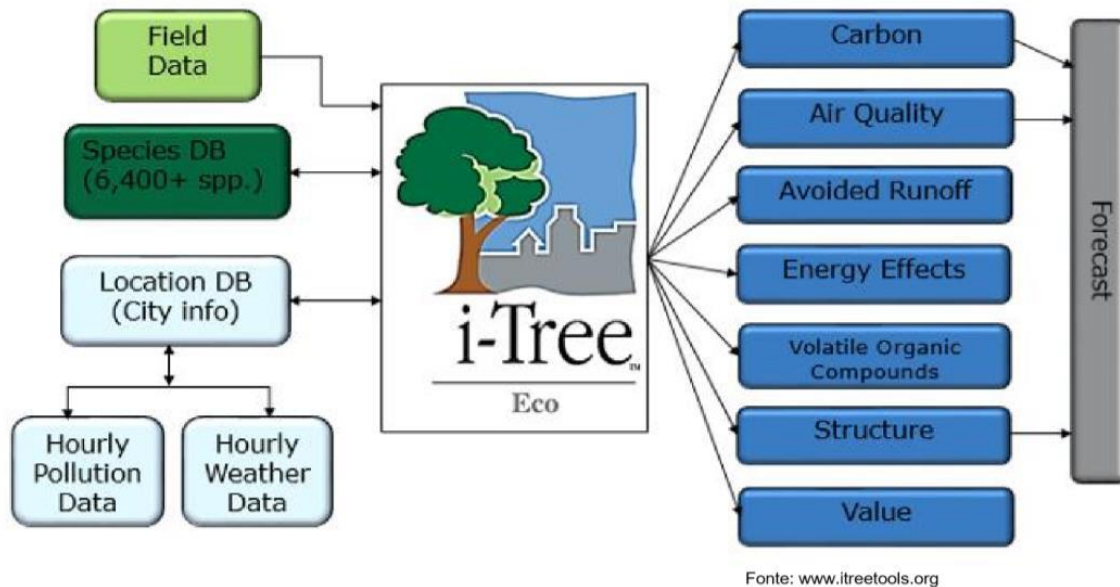


Figure 7 - Operating diagram of iTree-Eco (USDA 2023b)

The outputs from the I-Tree process, for the three gardens analysed individually and, subsequently, for each specimen are:

- Structure and composition of each garden arboretum.
- Carbon storage.
- Annual carbon sequestration.
- Ability to reduce surface water runoff.
- Oxygen production.
- Ability to remove air pollutants.
- Emission of volatile organic compounds (VOCs).
- Economic value of the benefits provided by the arboretum.

It is precisely the last, economic value, that is the key element in the view of using collected data for decision-making purposes (Bodnaruk et al. 2017). The ultimate goal of this analysis, in fact, is not only to know the composition and benefits that vegetation can provide us but to test the use these data as a decision-making tool for future intervention (Pino et al. 2022).

5.3.4 iTree-Eco project parameter

To continue with the analysis through the iTree-Eco software and to subsequently be able to compare the results obtained with the corresponding results from the Lx-Tree project, the following parameters were set within the software. The project was classified as a complete inventory, as within the study areas all tree components were analysed, located at the studied gardens, consequently the basic settings entered are:

- Nation: Portugal
- State: Continente
- Country: Área Metropolitana de Lisboa
- Place: Lisboa
- Is the study area urban? Yes

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- Population: 504.718
- Population per km²: 5825

The reference meteorological station, coded as LISBOA/GEOF (085350-99999) was used, with data referring to 2017 since it included hourly meteorological data (temperature, precipitation and wind speed and direction) and urban pollution information.

The dollar to euro currency exchange rate entered is for the date on which the project was created on the iTree-Eco software and corresponds to € 0.89845.

Since the project refers to garden trees, the distance of these from buildings was not considered, so the software was not asked to evaluate the benefits related to energy savings. However, it was necessary to establish a value in euros for the ton of carbon, set at € 111.00; and likewise, a value per cubic meter of water corresponding to € 9.27. These two values are needed as conversion coefficients to attribute, through the iTree-Eco software, an economic value to the different ecosystem services estimated for the trees. The specific procedure used for data entry in the iTree-eco software can be found in Appendix No.03 - iTree project submission)

5.3.5 Data crossing between garden and street trees

To be able to cross-analyse the collected data with those available from the Lx-Tree project, it was necessary to filter them. Indeed, only 66 of the 130 species identified, within the three studied gardens, match the species list studied during the Lx-Tree project. With the aim of assessing the ecosystem efficiency of the different species, within the two studied environments of the 66 species identified as a match, only those with 1% or more representativeness among the specimens viewed during this study were considered. This value we assigned, as we can observe in Table 3, corresponds to a minimum of 9 specimens per species out of the 892 used for the ecosystem benefit analysis in this study. This skimming is necessary to base future assessments on enough data to be able to identify a mean and representative value for the species. A value obtained by taking a small number of specimens as a reference may not represent the behaviour of the species in question (i.e., has less statistical meaning, and thus the inferences are less meaningful).

As a result of this selection process, 17 tree species present a match between the gardens' data set and those available from the Lx-Tree study. To maintain a consistency of representativeness of the analysed species, having defined a value of >1% representation, a further selection of species was made by eliminating those that, among the available data on street trees, do not reach the value of nine census individuals. Given these considerations, it is necessary to remove the following from the list of analysed species: *Corynocarpus laevigatus* (4 specimens), *Ceratonia siliqua* (3 specimens), *Pittosporum undulatum* (3 specimens), *Magnolia grandiflora* (7 specimens), *Ficus macrophylla* (3 specimens).

We thus obtain a selection of twelve tree species, whose presence was verified both within the three gardens studied and in the street vegetation. Of these species we confirmed a minimum representativeness to justify a comparative analysis of their ecosystem benefits.

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A further screening was carried out to cross analysing the data, organising the trees by DBH class. In this case, only those specimens were taken into consideration which reported a value equal to 'EXCELLENT', 'GOOD' or 'FAIR' in the 'Tree Condition' field, the result of data processing by iTree-eco.

Table 3 - Selected species list, with total number of individuals and relative abundance (in %). Highlighted in red are the discarded species.

	Selected species from 892 trees identified in the studied gardens		Corresponding trees from selected species in 6928 trees surveyed in Lx-Trees project
	Number	%	Number
<i>Celtis australis</i>	179	20.1%	1156
<i>Corynocarpus laevigatus</i>	46	5.2%	4
<i>Ceratonia siliqua</i>	31	3.5%	3
<i>Jacaranda mimosifolia</i>	30	3.4%	531
<i>Ligustrum lucidum</i>	29	3.3%	65
<i>Pittosporum undulatum</i>	27	3.0%	3
<i>Olea europaea</i>	25	2.8%	38
<i>Tilia platyphyllos</i>	20	2.2%	135
<i>Magnolia grandiflora</i>	18	2.0%	7
<i>Aesculus hippocastanum</i>	17	1.9%	38
<i>Fraxinus angustifolia</i>	15	1.7%	295
<i>Platanus x hispanica</i>	14	1.6%	303
<i>Tilia tomentosa</i>	13	1.5%	209
<i>Ginkgo biloba</i>	10	1.1%	99
<i>Cercis siliquastrum</i>	9	1.0%	182
<i>Ficus macrophylla</i>	9	1.0%	3
<i>Pinus pinea</i>	9	1.0%	121

The application of this additional selection was necessary to limit the analysis to specimens with a good phytosanitary condition, thus excluding specimens with anomalies in their development. This further selection of phytosanitary status, and subdivision by DBH classes, led to a strong limitation of comparable specimens. To compensate for this factor, although the analyses were carried out on all twelve of the above-mentioned species (Table 3), only the results obtained for the species *C. australis* and *P. hispanica* will be shown in the section 6.4.2, as it is the only one with a sufficient number of specimens to be able to derive appreciable results. Comparative analysis use means and standard error or 95% confidence interval as a measure of dispersion ($\alpha < 0.05$), more information in Appendix No.04 - Calculations and applied indices.

5.4 Forecasting

5.4.1 Scenario processing

The forecasting functionality, offered by the iTree-Eco software, allows us to idealise future development scenarios for our urban forest (U.S. Forest Service 2021), from the data collected during phase 2 (Figure 5). The data collected correspond to the totality of the tree component present in the three gardens studied.

The data obtained from the 'FORECAST' function, offered by the iTree-eco software, were exported and organised in dynamic tables on Microsoft Excel software. Given the 'STRATUM' organisation of the iTree project, as explained in the section 5.3.1, it was possible to extract the results of the analysis relating to the reference

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Jardim Teófilo Braga (Jardim da Parada). This garden was chosen because of its media prominence due to the construction of the Lisbon metro service (Metropolitano de Lisboa 2022a). In addition, as we will see in section 6.1.1, it is the garden with the lowest taxa richness and diversity, which makes it a less resilient environment (Alberti et al. 2003). It was then possible to obtain data on the future developments of:

Table 4 - Obtained data from 30 years forecast analysis.

Garden structure	Carbon effect	Hydrologic effect
<ul style="list-style-type: none"> • Number of trees • Tree cover (ha) • Mean DBH growth (cm) • Leaf area (ha) 	<ul style="list-style-type: none"> • Carbon storage (ton) • Annual Carbon sequestration (kg) 	<ul style="list-style-type: none"> • Avoided Runoff (m³) • Interception (m³) • Evaporation (m³) • Transpiration (m³) • Potential Evapotranspiration (m³)

The information extracted refers to 30 years period. In the case of Gross Carbon Sequestration and Mean DBH Growth, the metabolic activity of the specimens was estimated from time zero, resulting in a value from year one. Taking this element into consideration, we included the value obtained in the first year also in year zero, if the same result occurred in the previous year.

To compare the different scenarios over the thirty years, thirty-two time units were identified to obtain the results presented in subsequent chapter 7: (1) The zero moment, referring to the current situation; (2) the post-scenario moment, where we will see the first differences from the current state of things; (30 years) and the following thirty years, in which the development of the garden will be visible.

5.4.2 General forecast

The first analysis done through the Forecast function used the default setting offered by the platform. An initial global analysis was applied to test the potential of this recently included tool within the iTree-eco software. In this case, for the 892 trees surveyed within the gardens, a forecast will be made over the next 30 years. The data that the iTree-eco software proposes to use as default settings, in our case, were:

- Number of the years forecasted: 30.
- Days per year without frost: 168
- Base annual mortality rate for healthy trees: 3.0%
 - a tree is considered healthy between 0-49 dieback.
- Base annual mortality rate for sick trees: 13.1%
 - a tree is considered sick between 50-74 dieback.
- Base annual mortality rate for dying trees: 50.0%
 - a tree is considered dying between 75-99 dieback.

5.4.3 Specific forecast on Teofilo Braga garden

With the aim of focusing on possible future scenarios, it was necessary to concentrate on a specific and delimited area to imagine possible scenarios consistent with the surroundings. In this case, the Teofilo Braga garden, in the neighbourhood of Campo de Ourique, was selected for its urbanistic importance. In the case of the chosen garden, four possible scenarios of 30 years evolution were identified.

1. If the garden remained as it is, what would be its trend over the next 30 years, applying settings suggested by software.

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2. In accordance with the Lisbon City Council's statement, how would the structure of the garden change if six perimetral arranged specimens of *C. australis* were removed.
3. If, as observed in various areas of Lisbon, the specimens of *C. australis* in the garden were infected with a disease that would increase their mortality rate and undermine public safety.
4. If the two large specimens of *Metrosideros excelsa* in the garden, to which the citizens who use the garden show a great cultural connection, were to be lost for greater causes.

After carrying out the analysis through the application of the pre-established settings and identifying limitations in the construction of the scenarios within the settings offered by the software, a working methodology was developed to be applied to the four scenarios (Figure 8). This step was necessary because the current version of the software does not allow the control of specimens inserted or removed specifically, it will therefore be necessary to make changes to the initial data concerning the census specimens, making the necessary modifications to simulate the imagined scenarios.

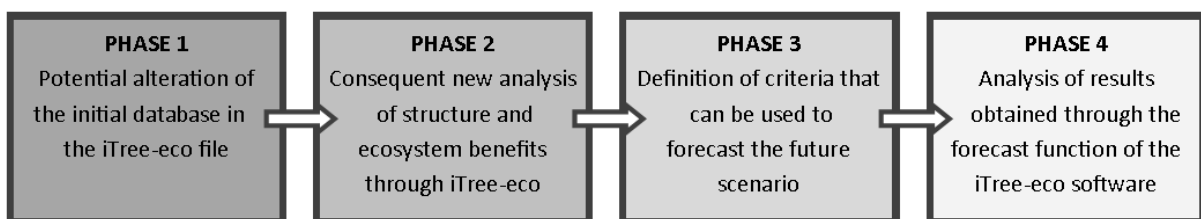


Figure 8 - Scenario workflow model

5.4.3.1 First scenario

To realise the first scenario, it was sufficient to apply the 'Forecast' tool from the iTree eco software using the basic settings explained in the previous section; it corresponds to business as usual scenario (BAU). In addition, an annual number of trees was found to be placed in the garden to maintain the benefits provided by the garden.

5.4.3.2 Second scenario

Regarding the second scenario, it was necessary to make changes to the tree inventory data input, in accordance with the interventions proposed by the company Metropolitano de Lisboa in collaboration with the municipality (Metropolitano de Lisboa 2022c). The authorities concerned have in fact stated that, due to construction work on the new metro station, only six specimens of *Celtis australis* will be removed from the Jardim Teófilo Braga, four of which will be relocated later. From the Figure 9, provided by Metropolitano de Lisboa (2022a), it is possible to identify which two specimens will be removed and which four replaced. This indication was sufficient to be able to identify the specimens in question in the inventory and to proceed with their status change. The specimens of *C. australis* that we identified as: id_TEO_N002, id_TEO_N003, id_TEO_N045, id_TEO_N046, id_TEO_N050, id_TEO_N051; which we can see identified in the Appendix No.08 - Trees inventory of Jardim Teófilo Braga.

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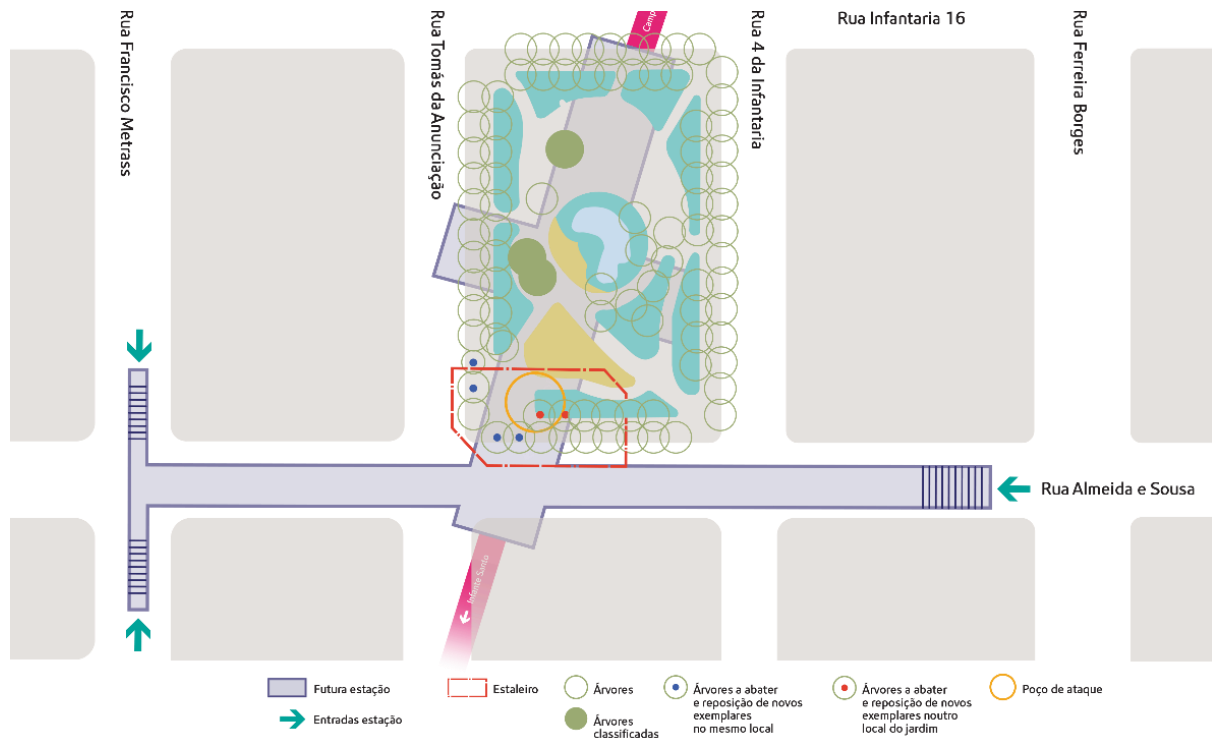


Figure 9 - Project map of jardim da Parada (Metropolitano de Lisboa 2022a) with the identification (dots in red) of the elements to be eliminated and (in blue) the trees to be replaced

In addition to the specimens subject to removal or replacement, indicated by the Metropolitano de Lisboa (2022c), there are two specimens of *C. australis* found in the proximity of the sanitary facility that are scheduled to be removed. The explicative map of the intervention, shown in the Figure 9 above, does not show the presence of these two specimens. Of the photorealistic images, provided by the Metropolitano de Lisboa, in which the result of the intervention is illustrated, one of the two specimens are in good phytosanitary condition (Figure 10).



Figure 10 - Metro station access in Jardim França Borges (Metropolitano de Lisboa, 2022b)

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In the scope of this study, was considered that these two specimens of *C. australis*, identified in the Figure 11, with the code id_TEO_N047, id_TEO_N048, will be damaged, if not entirely removed, during the construction work on the metro infrastructure and its access lift (Appendix No.08 - Trees inventory of Jardim Teófilo Braga). Therefore, to imagine probable future scenarios, we will consider the removal of these two additional specimens.



Figure 11 – Scenario 2 trees affected by construction work. In red removed tree; in yellow tree in danger; in green replaced tree; in light green existing tree (scale 1:1500).

In total we will consider the removal of the eight specimens mentioned above and the insertion of four young trees belonging to the same species and having the following characteristics:

- DBH: 5 cm
- DBH height: 1.30 m
- Crown condition: 80-85%
- Total high: 3.00 m
- Crown Top Height: 3.00 m
- Crown Base Height: 1.50 m
- Crown Width N/S: 1.20 m
- Crown Width E/W: 1.20 m
- Crown missing: 10-15%
- Crown Light Exposure: 1 Side

By doing so, we obtained a modified garden structure, be able to evaluate the ecosystem benefits offered by the insertion of young trees and estimate its evolution over the next thirty years through the application of the Forecast function.

5.4.3.3 Third scenario

The third scenario considered the spread of fungus infection of *Inonotus rickii*. Based on the studies on *C. australis* in Lisbon (Ramos et al. 2017), specimens with a DBH greater than 40cm were isolated, where it was

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proven that the fungus has a higher incidence. Among the isolated specimens, 92% of specimens were causally selected using the 'Random' function available on the Excel software, assuming the presence of symptoms or fruit bodies. From these selected specimens, the 'Random' function was repeated to identify a 45.7% of specimens that could be attributed a risk rating value greater than (Ramos et al. 2017). The selected specimens shown in the Figure 12, were removed from the iTree database to assess the state of the Jardim França Borges in the presence of a high incidence of the *I. rickii* fungus. In the application of the 'Forecast' function for the next 30 years, an additional variable was included to indicate a further 3% annual mortality of the remaining *C. australis* to simulate a spread of the infection among the remaining trees. The methodology used to obtain a random selection of specimens can be found in Appendix No.05 - Random selection of trees)



Figure 12 – Scenario 3 random selected trees (23). In red selected trees; in green existing trees (scale 1:1500).

5.4.3.4 Fourth scenario

The implementation of the fourth scenario, consider the occurrence of a disaster with the two *Metrosideros excelsa* specimens of monumental importance within the garden, identified with the codes id_TEO_N087, id_TEO_N088 (see Appendix No.08 - Trees inventory of Jardim Teófilo Braga). The specimens were selected because of their fundamental landscape importance within the garden, to quantify how much, if any, their absence might affect the current and future state of the garden in terms of ecosystem benefits and value. As already emphasised, the analysis carried out does not consider the social and ornamental value of the specimens analysed but attempts to estimate their economic value based on the quantifiable ecosystem services they provide.



Figure 13 - Scenario 4 removed tree. In red the two removed tree; in green the existing tree (scale 1:1500).

The two above mentioned specimens, identified within the Figure 13, were then removed from the database entered in iTree-eco, so the structure and ecosystem benefits provided by the garden and their evolution over the next thirty years were again quantified.

6 Results and discussion

6.1 Tree abundance and composition in the studied gardens

Analysis of the data, referring to the 892 trees characterised in the three gardens, led to a meticulous description of the composition of the arboretum in question and the ecosystem benefits it provides.

Within the three gardens, 130 taxa were recognized of which 47 with in a single specimen. The twenty-two most representative tree species for all data set are presented the Figure 14. The three dominant species are: *Celtis australis* (179 specimens), *Howea forsteriana* (50 specimens), *Corynocarpus laevigatus* (46 specimens).

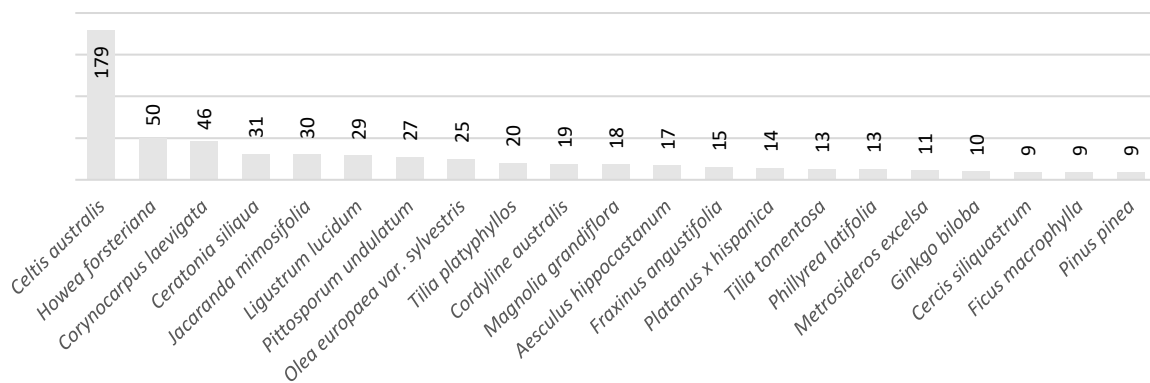


Figure 14 - Number of trees for twenty two most representative species for the complete data set representing of the three studied gardens.

The abundance of specimens varies between gardens, their uneven occurrence and abundance is mainly a reflection of gardens with different sizes. Figure 15 depicted how most specimens are concentrated in the Jardim Guerra Junqueiro, Jardim da Estrela, the largest quantity of the three.

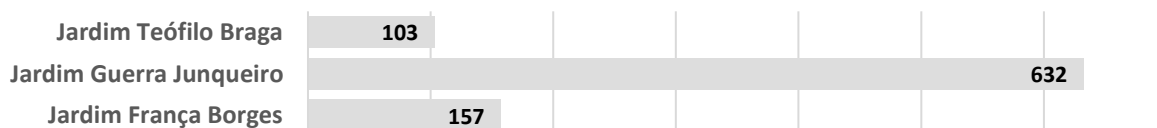


Figure 15 - Number of trees in each studied garden

Although the number of specimens is higher in the Jardim Guerra Junqueiro, tree density (35arv/ha) is lower than the other studied gardens, which could be explained by the vastness and complexity of a romantic garden such as the Jardim Guerra Junqueiro, where trees are found in consociation with a large herbaceous and shrub understorey (Soares 2021). On the other hand, the Jardim Teófilo Braga is composed almost solely of trees, characterized by a strong vertical development (Figure 16). The origin of this development is easily connected in the first place to the light limitation generated by the proximity to the surrounding buildings and, subsequently, to the strong competition that the trees face among themselves for sunlight (Muscas et al. 2023). The mean tree density among the three gardens is 144 (143.9) trees per hectare.

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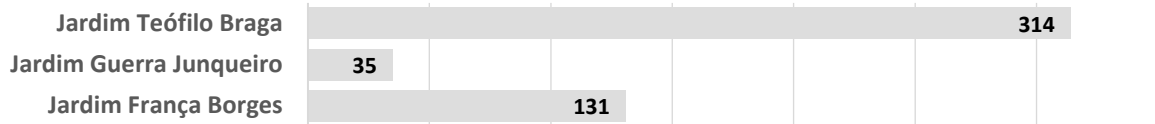


Figure 16 – Density of trees in each garden (trees/ha)

In the Jardim Guerra Junqueiro, *Howea forsteriana* is the most representative species (Figure 17). This is a small-sized palm species that occurring in many of the garden beds. In second place we find *Celtis australis*, as well as the species most present in the three gardens studied; finally, in third place *Corynocarpus laevigatus*, an Australian species widely used in Lisbon gardens for ornamental purposes (Vasconcelos et al. 2017).

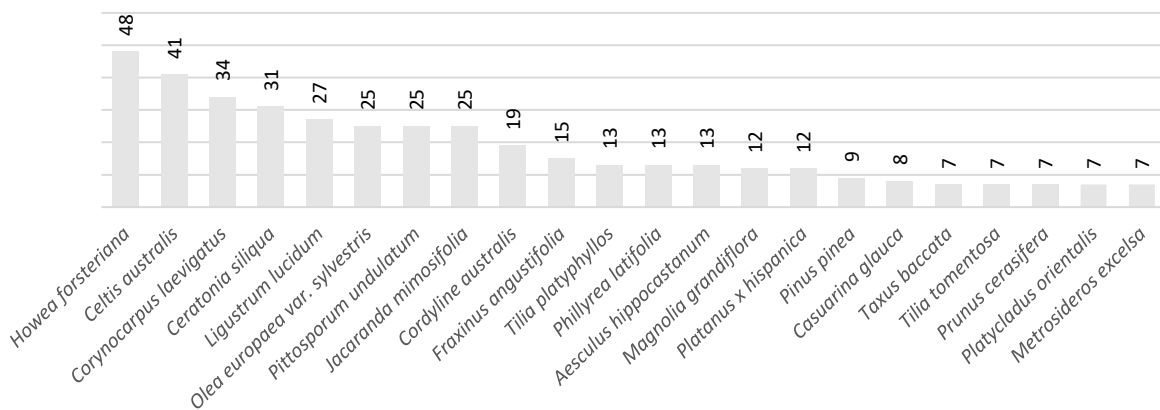


Figure 17 - Population summary in Jardim Guerra Junqueiro - first 22 species (trees number)

As for the other two gardens (Figure 18, Figure 19), *Celtis australis* is by far the predominant species and distributed mainly in the periphery to act as the boundary with the roads and acting as a structuring species of the two gardens. In fact, *C. australis* is the predominant species within the street arboretum of the city of Lisbon (Soares et al. 2011). The second most representative species in both cases is, *Corynocarpus laevigatus*, while in third place is *Ginkgo biloba* for the Jardim Teófilo Braga and *Nerium oleander* in the Jardim França Borges.

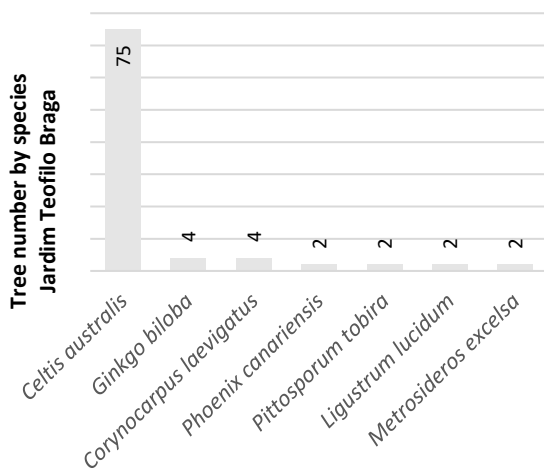


Figure 18 - Population summary Jardim in Teofilo Braga - the most abundant 7 tree species

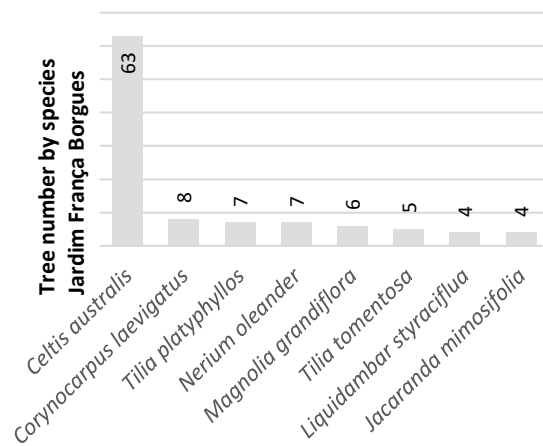


Figure 19 - Population summary in Jardim França Borges - most abundant 8 tree species

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Regarding the richness of the three gardens studied (Figure 20), it is evident that the Jardim Guerra Junqueiro is the one in which the highest number of species is concentrated (117 species) followed by the Jardim França Borges and in last, the Jardim Teófilo Braga, due to its small size and dominance of *Celtis australis*. The variability of species within the garden is generally an important factor in assessing its ecosystem benefits provided over the various seasons and years (Mace, Norris, and Fitter 2012). Regarding specifically of biodiversity, it would also be important to consider the shrub and herbaceous component, which, in this study, due to lack of data, will not be considered within the assessments.

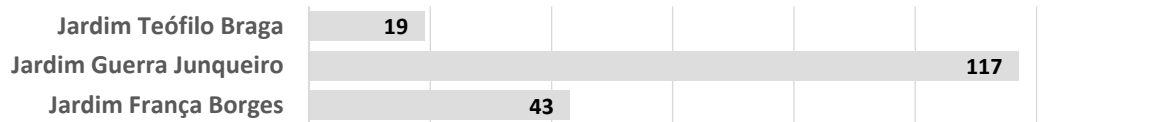


Figure 20 - Tree species Richness (S) in each of the studied gardens

As indicated in the section on data processing (5.3.2), the diversity of taxa in the three different gardens was quantified with the Shannon index (H') and the evenness index (E). Higher values of tree diversity were found in Jardim Guerra Junqueiro (Figure 21), which is probably related to the high number of *C. australis* present in the Jardim França Borges and Jardim Teofilo Braga, that dominate their tree community.



Figure 21 - Tree species diversity estimated with the - Shannon index (H')

In fact, values of evenness index presented in Figure 22, are higher and close to 1 in show Jardim Guerra Junqueiro (0.86). This shows how, compared to the remaining study areas, it is characterised by a more uniform distribution of species abundance, but still with a prevalence of some species over others, as we can see from the Figure 17. Similarly, the value of 0.45 referred to the Jardim Teófilo Braga indicates that the suitability of species abundance is far from the maximum potential, describing a study area characterised by the clear predominance of one species over the rest; specifically, this is *C. australis*, which is present in double lines on the entire perimeter of the garden.

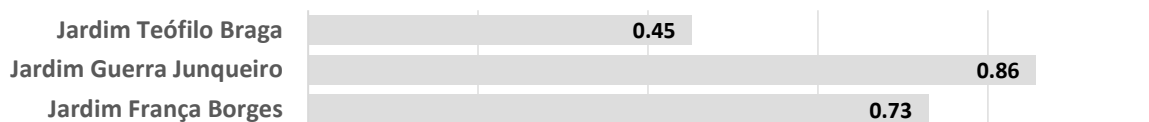


Figure 22 - Evenness index (E) regarding tree species in the studied gardens

Finally, from the analysis of the dominance index depicted in the Figure 23, in which it is evident that the Jardim Teofilo Braga is the one in which the two most abundant species assume higher importance, almost 77%. On the other hand, the Jardim Guerra Junqueiro is the one showing a more evenly distribution of species abundance,

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with the two dominant species covering only 14.1% of the tree community. Between the two is the Jardim França Borges with 54% of the specimens belonging to the two predominant species.



Figure 23 - Dominance index (%) regarding the tree communities in the studied gardens

Comparing the three gardens, we can see in Figure 24, how there are considerable differences between them. In fact, the higher similarity is reached with 40% of species in common between the Jardim França Borges and Jardim Guerra Junqueiro. The Jardim Teofilo Braga, due to the low variability of species within it and the smaller number of specimens, is the one that differs the most from the remaining two, sharing only 24% of species with the Jardim Guerra Junqueiro and 32% with the Jardim França Borges.

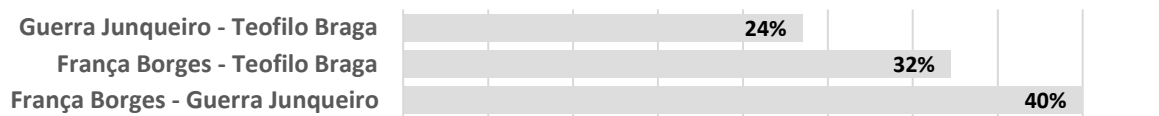


Figure 24 - Values of Sørensen similarity index (in %) between the three studied gardens.

An interesting result obtained through iTree-Eco is the importance that each species has within our case study. This is a dimensionless value that helps us to understand the composition of study sites and the importance of plants in the canopy. The value is obtained by summing the percentage of population representation for each species with the respective percentage of leaf area. This index confirms the consideration of *Celtis australis* as a structuring species, followed by *Platanus x hispanica* and *Ficus macrophylla*, of which the few specimens are characterised by very large crowns. The gap between the first species and the others, in terms of importance is particularly pronounced, which could generate problems at the ecosystem level in the event of a disease affecting *Celtis australis* (Ramos et al. 2017).

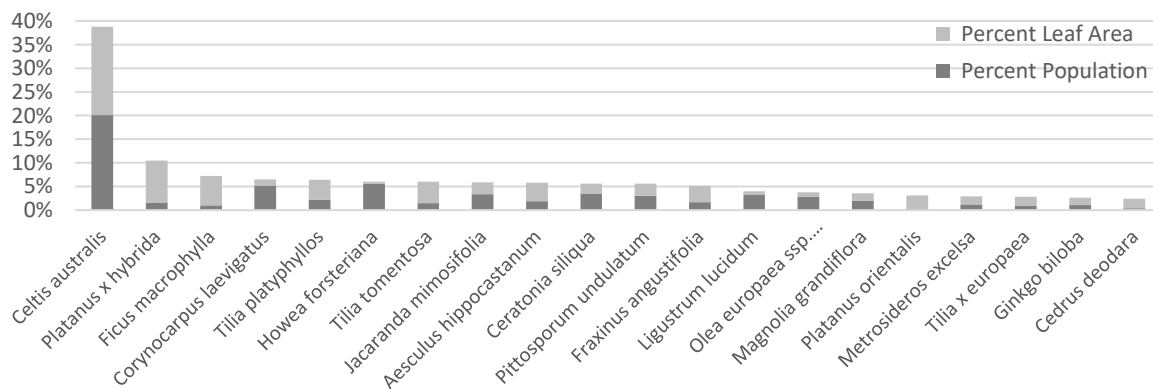


Figure 25 - Importance Value (%)r estimated with iTree-eco

6.2 Arboretum structure

The structure of the arboretum in the studied gardens was characterised using data on the canopy, foliar area (effected by the dimension and type of leaf) and size of the specimens (mainly related with tree eight, crown size and diameter at breast height, DBH). Subsequently, this information, together with physiological characteristics of the species analysed will feed iTree estimations of ES (U.S. Forest Service 2021).

Specifically, by reporting not only the observed species but also: canopy height, DBH, any canopy damage rates, and failures, iTree-Eco is able to estimate for each specimen its leaf area.

For the three gardens studied (Figure 26), *Celtis australis*, the most abundant species have higher contribution to the total leaf area (+ 26%). The second higher contribution to the foliar area is from *Platanus x hispanica* with only 14 specimens. Even more surprising in third place is *Ficus macrophylla*, of which only nine specimens were surveyed.

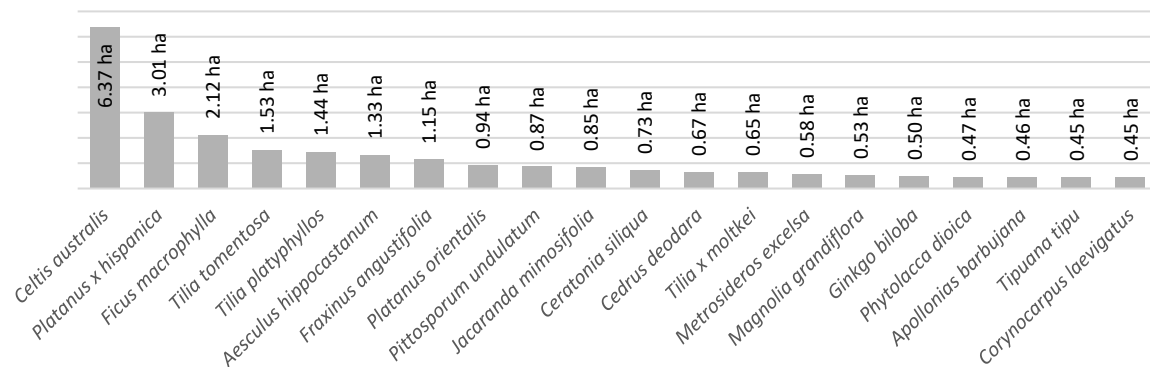


Figure 26 - Total leaf area by tree species (ha) in the three studied gardens.

In the Figure 27 we can observe the mean leaf area for individuals of the same species. In fact, *Celtis australis* which up to this point were considered the undisputed dominator of tree component, is not included in the top 20 tree. The dominant species in this case is *Platanus orientalis* of which only three specimens were surveyed but each with considerable size. In second place, is *Ficus benghalensis*, of which only one specimen was surveyed at the Jardim Guerra Junqueiro. In third position, is *Ficus macrophylla*, the species with the most visually important specimens, some of them classified as monumental, and with data-level importance and great landscape value; in fact, their presence is often a central element within the three gardens studied. It is so clear from the data collected how the genetic and architectural diversity of each species affects its growth and how the software takes this into account when estimating the leaf area (Barthélémy and Caraglio 2007).

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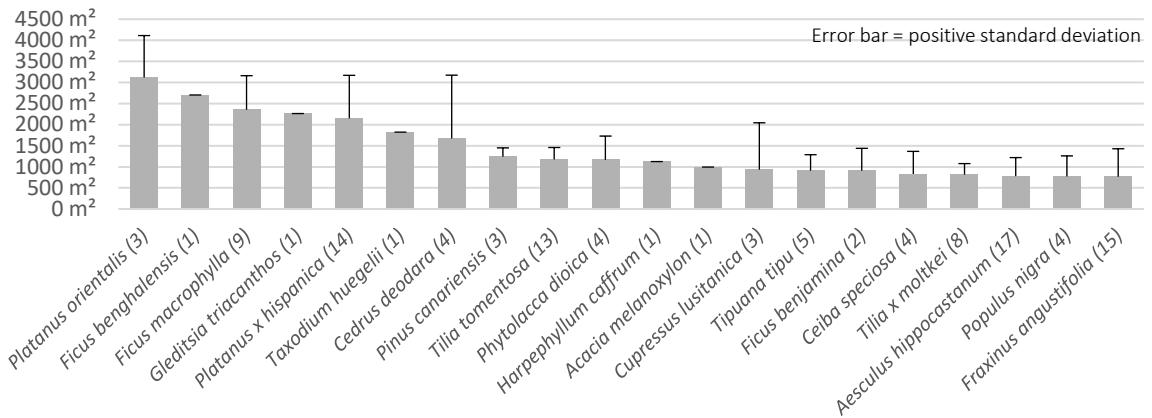


Figure 27 – Mean (+ standard deviation) leaf area by tree (m²) for the 20 species with higher mean values . Number of each specimen analysed for each species in brackets.

The distribution of the estimated foliar area varies between gardens. In fact, although the Jardim Guerra Junqueiro is the most arboreally populated, we find the highest density of foliage area, in the Jardim Teófilo Braga (Figure 28). When comparing the tree density with the tree leaf density it is possible to assume that the density of trees affects the total foliage area more than the biodiversity of these, at least in these case studies.

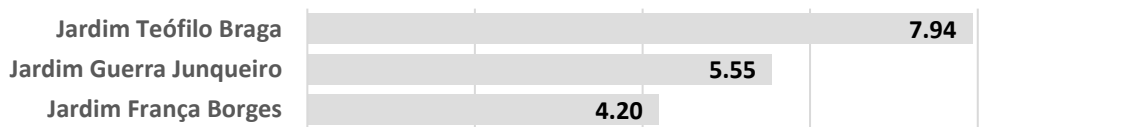


Figure 28 - Density of Leaf area (ha/ha) for each of the studied gardens

In addition to the foliar area, the iTree software refers to the diameter class at breast height (DBH) for the estimation of ecosystem benefits. From Figure 29 below, referring to the ten most representative tree species among gardens, most specimens are between 15 and 30 cm in diameter. Exceptions are for *Celtis australis* and *Tilia platyphyllos*, which show a more uniform distribution with a peak of individuals having between 45 and 60 cm in diameter. This finding is generated primarily by the large use of those species in urban environments, their physiological and architectural characteristics of the two species, and the landscape role they play within city of Lisbon (Soares et al. 2011).

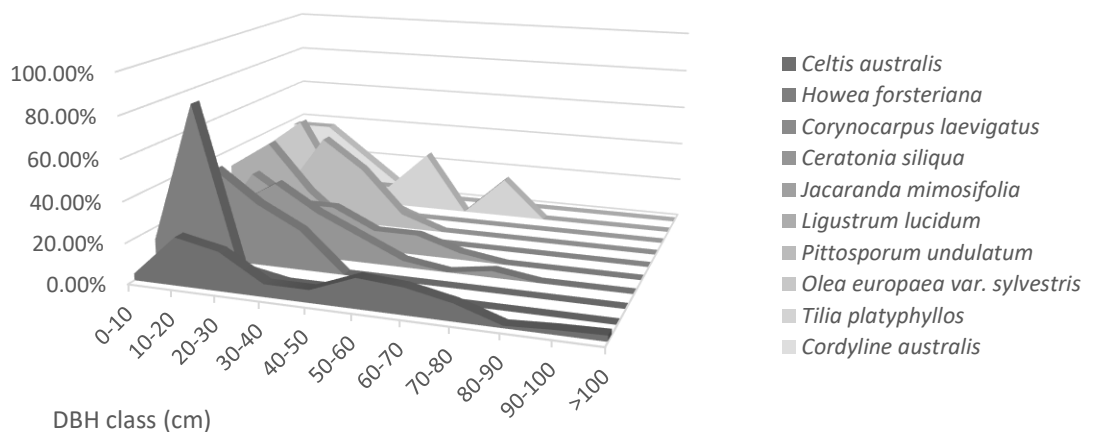


Figure 29 - DBH class distribution by species

6.2.1 Jardim Guerra Junqueiro (jardim de Estrela)

During our field data collection, we were able to recognize 723 tree or shrub specimens with an arboreal habit. Of these, 632 were classified as living in public space, the remainder were in fact dead specimens, removed or placed in private areas with prohibited access (Figure 30). These belong to 45 different families, distributed in 85 genera, for a total of 117 different species. At the west entrance to the garden, there was a large area whose data had not, previously, been collected during the Lx-Gardens project. The specimens were then classified and geolocated to complete the previous tree inventory of the garden.



Figure 30 – Jardim Guerra Junqueiro surveyed trees (scale 1:3000).

Regarding the tree origin, 25% of the specimens belong to native species to the geographical area in which they are found, when the majority, 72%, are allochthonous (Figure 31). Around 3% of the analysed specimens are artificial hybrids to which it would be incorrect to attribute a certain geographical origin. Regarding the type of leaf and the permanence of these on the vegetation (phenology), that 62% of the specimens are evergreen, 36% a deciduous leaf and only 2% are marcescent (Figure 32).

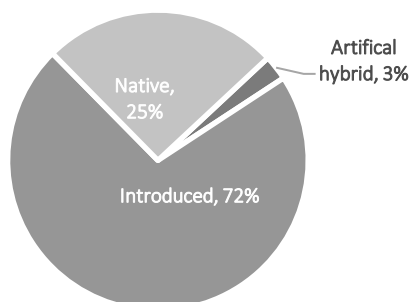


Figure 31 - Geographical distribution of species

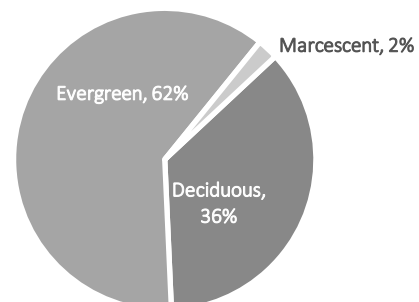


Figure 32 - Phenology distribution of the tree species

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We can observe from the graph Figure 33 that most of the individuals present a height of between 5 and 15 metres and a diameter at breast height (DBH) of between 10 and 20 centimetres (Figure 34), if they are characterised by a single stem architecture. Observing the distribution of the specimens in the two graphs, we can see that only two specimens present a height of more than 34m, at the same time as many as 19 specimens are characterised by a DBH of more than 100 cm. From a reading of these borderline cases, we can deduce how, in the Jardim Guerra Junqueiro, the trees tend to have a greater growth in width than in height.

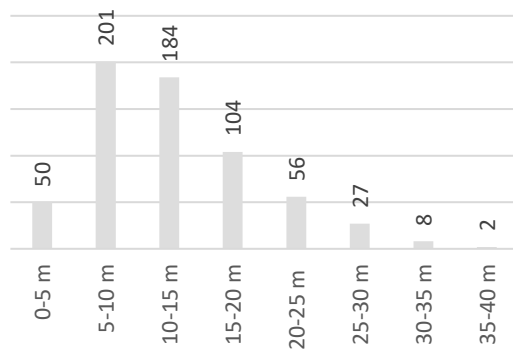


Figure 33 - Tree distribution by total height

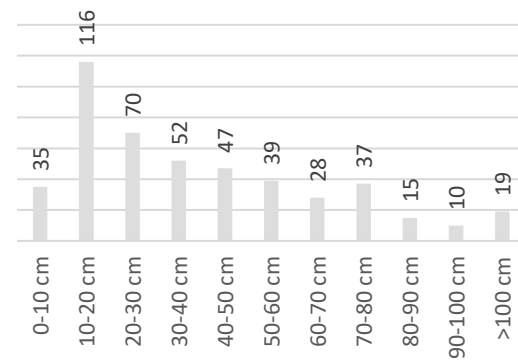


Figure 34 - Tree distribution by DBH

Within the Jardim Guerra Junqueiro, there are no specimens currently classified as monumental, although big trees are easily identifiable. Among them are three specimens of *Ficus macrophylla* (with the identification code of Id_EST_N146, Id_EST_N488, Id_EST_N215), which have a DBH above three metres. These are trees characterised by a very large canopy, which, is of great value in terms of the provision of ecosystem services. In addition, they play a fundamental landscaping role, acting as a landmark within the garden. The complete list of recognised species and their location can be seen in the Appendix No.06 - Trees inventory of Jardim Guerra Junqueiro and Appendix No.07 - Trees index of Jardim Guerra Junqueiro.

6.2.2 Jardim Teófilo Braga (jardim da Parada)

The Jardim Teófilo Braga in Campo de Ourique is the garden studied with the smallest number of tree specimens surveyed and the smallest area of development. A total of 103 specimens were identified, as we can see in Figure 35, belonging to 15 different families, and distributed over 17 genera. The 103 specimens surveyed within the Jardim Teófilo Braga are two less than the 105 identified during the Lx-Gardens project (Soares 2021).

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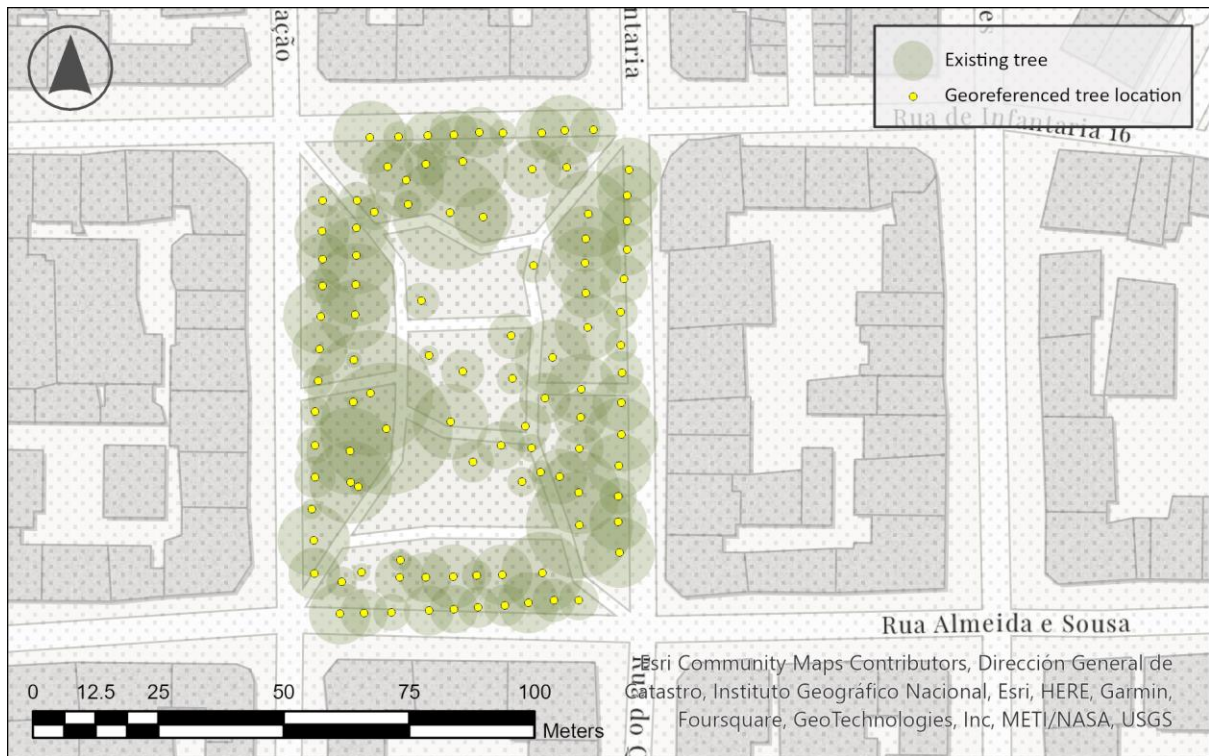


Figure 35 – Jardim Teófilo Braga surveyed trees (scale 1:1500).

Of these, in contrast to the Jardim Guerra Junqueiro, the majority (73%) belong to species classified as autochthonous in this geographical reference area (Figure 36). Only 27% of the individuals surveyed belong to species considered allochthonous. Similarly, around 83% of the specimens have a deciduous phenology, only 17% are characterised by a perennial foliage (Figure 37). These data are strongly influenced by the large number of *C. australis* present in the study area, which, as mentioned in the section on species diversity (section 6.1), in this case strongly dominates over the others, creating a strong landscape seasonality in the study area.

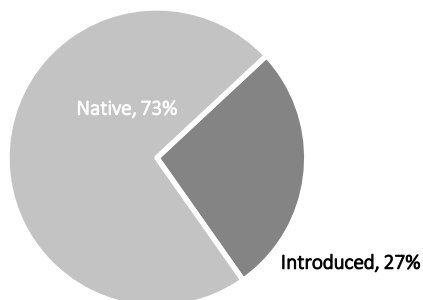


Figure 36 - Geographical distribution of species

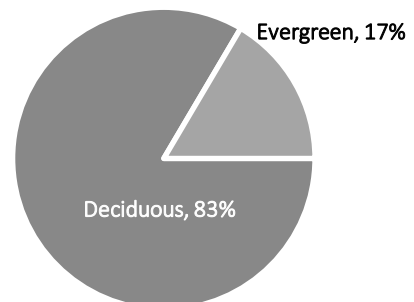


Figure 37 - Phenology distribution of tree species

Regarding the distribution of the characteristic dimensions of the studied specimens, most of the trees are concentrated in the class between 15 and 20 metres in height (Figure 38), while the single stem specimens are characterised by most specimens with a DBH between 50 and 60 centimetres (Figure 39). These distributions show us how the proximity to buildings and the close connection with the surrounding streets influenced a greater growth in height of the vegetation, compared to the data observed at the Jardim Guerra Junqueiro

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(Muscas et al. 2023). While the concentration of a greater number of plants within the DBH class between 50 and 60 centimetres depicted how the species used are characterised by a genetically larger size and/or greater (Rigo et al. 2016).

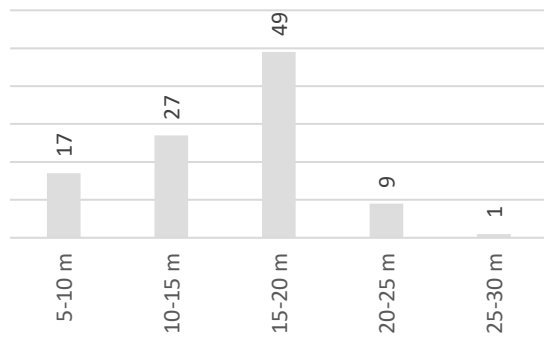


Figure 38 - Tree distribution by Height class (m)

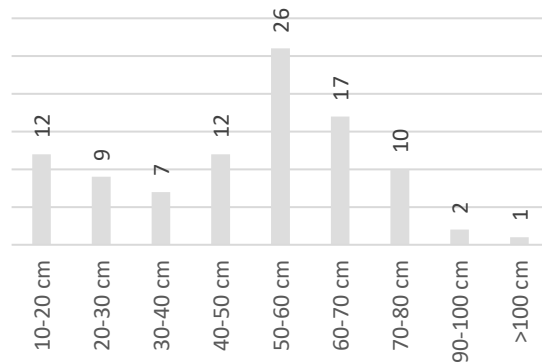


Figure 39 - Tree distribution by DBH class (cm)

The role played by the four trees classified as monumental cannot be overlooked when studying the composition of the Jardim Teófilo Braga. First among them is a singular specimen of *Taxodium huegeii* (code id_TEO_N090), one of the few gymnosperm genera with deciduous foliage habit. Next to it, a *Sequoia sempervirens* (code id_TEO_N092), a species found in only 9 gardens in Lisbon with a total of 24 specimens (Soares 2021). But the population's greatest appreciation goes to the two big specimens of *Metrosideros excelsa*, which, with their foliage of more than 350m², shade the heart of this green space. The two specimens have been identified by the codes: id_TEO_N087, id_TEO_N088; and with their imposing preponderance they certainly play a central landscape role within the garden. The list of recognised species in the Jardim Teófilo Braga and their location can be seen in the Appendix No.08 - Trees inventory of Jardim Teófilo Braga and Appendix No.09 - Trees index of Jardim Teófilo Braga.

6.2.3 Jardim França Borges (jardim do Príncipe do Real)

In the Jardim França Borges, located in the Príncipe Real district, 157 specimens (Figure 40) belonging to 43 different species have been counted. Within the garden tree specimens were recognized 4 less than 161, previously surveyed during the Lx-Gardens project (Soares 2021). In particular, the absence of a specimen of *Phoenix reclinata*, at the time classified as a tree of public interest, can be noted.

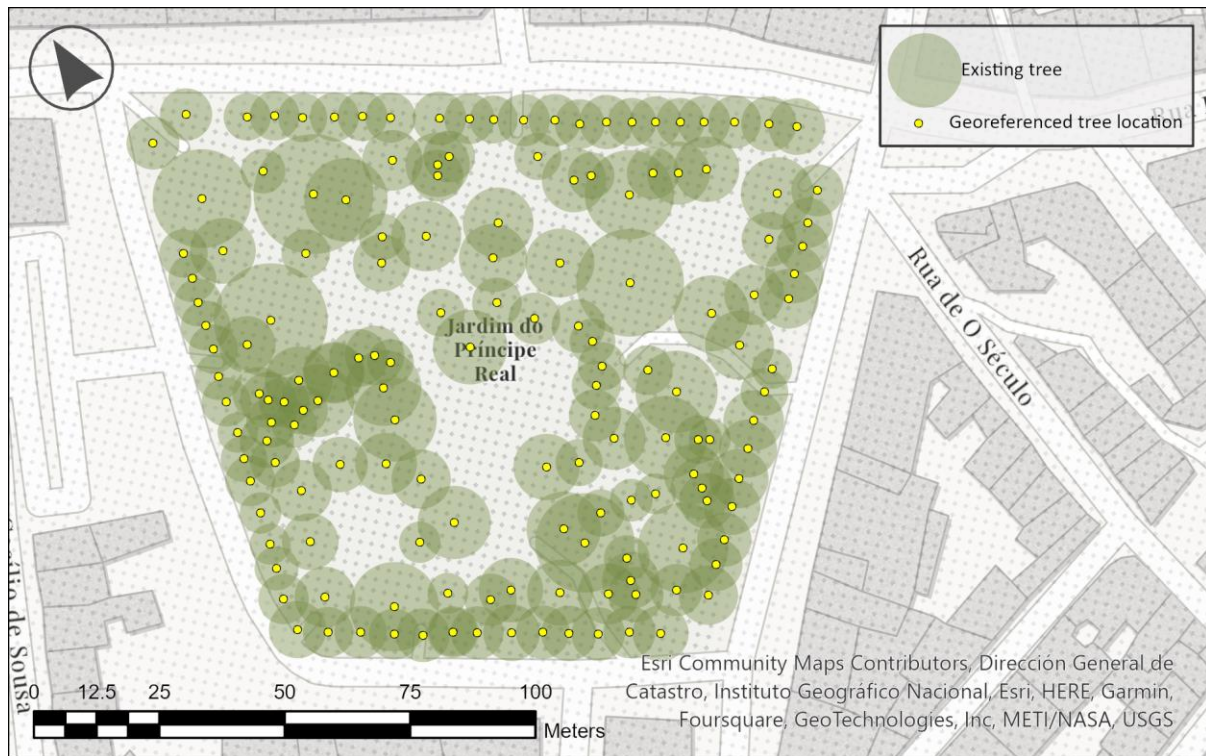


Figure 40- Jardim França Borges surveyed trees (scale 1:1500).

These 157 specimens are grouped into 35 genera belonging to 29 taxa. In the Jardim Teófilo Braga, most specimens show a deciduous phenology (71%), when only 29% have perennial foliage (Figure 42). As for the distribution in relation to the geographical origin of the specimens observed, 48% of them are native, while 49% are allochthonous species (Figure 41). As in the case of Campo de Ourique (Jardim Teófilo Braga), data are greatly influenced by the predominance of *Celtis australis*.

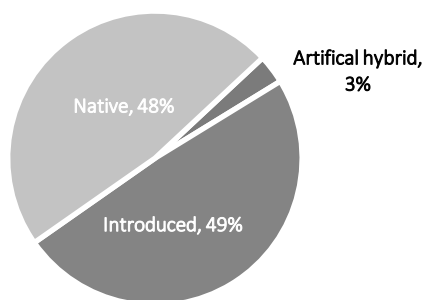


Figure 41- Geographical distribution of tree species

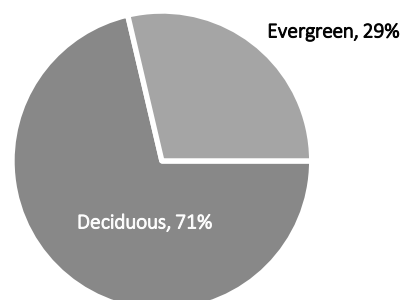


Figure 42 - Phenology distribution of tree species

Most of the trees in the garden are between 5 and 10 metres in height (Figure 43). The DBH of the single stem specimens, is mainly concentrated between 10 and 30 centimetres in diameter (Figure 44). According to the data, unlike what was observed in the Jardim Teófilo Braga, trees in the in the Jardim França Borges we are smaller both in height and in diameter. This is comparable to the situation observed in the Jardim Guerra Junqueiro, where the influence of the surrounding buildings may be minor, given their remoteness, and this generates a smaller increase in height. Considering that also in this garden *C. australis* plays a fundamental role

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but, unlike in the Jardim Teófilo Braga, has less growth in terms of trunk diameter (DBH), we can deduce that the average age of the vegetation is lower than in the Jardim da Parada. As we can observe in the Figure 43, most of the trees in the garden are between 5 and 10 metres in height. This datum is followed by the analysis of the DBH of the single stem specimens, which sees most of the individuals concentrated between 10 and 30 centimetres in diameter (Figure 44). The data show us that, unlike what we observed in the Jardim Teófilo Braga, we are in the presence of smaller specimens, both in height and in diameter. This is comparable to the situation observed in the Jardim Guerra Junqueiro, where the influence of the surrounding buildings may be minor, given their remoteness, and this generates a smaller increase in height. Considering that we are in a garden in which *C. australis* plays a fundamental role but, unlike in the Jardim Teófilo Braga, has less growth in terms of trunk diameter, we can deduce that the average age of the vegetation is lower than in the Jardim Teófilo Braga.

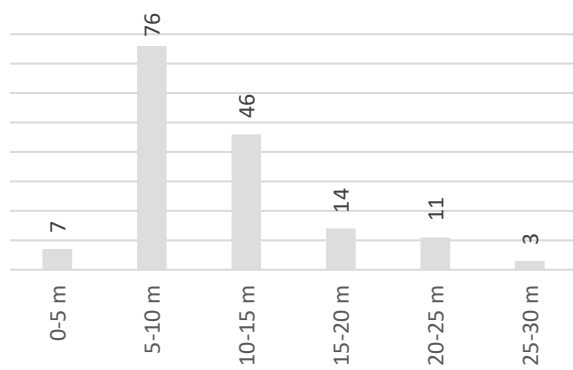


Figure 43 - Tree distribution by Height class (m)

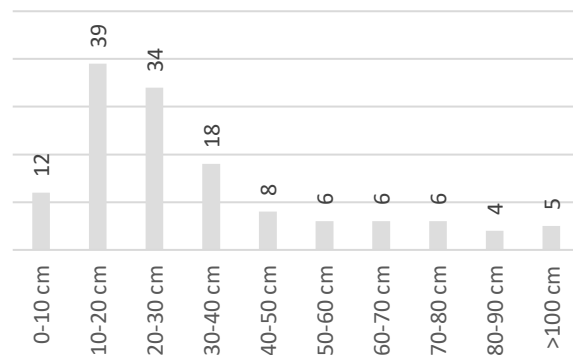


Figure 44 - Tree distribution by DBH class (cm)

Within the Jardim França Borges there are six trees that stand out from the rest of the garden's structure and have been assigned the title of classified specimens (Diário da República 2012). These are three *Ficus macrophylla* characterised by a DBH greater than 1.5m (with the identification codes id_PDR_N093, id_PDR_N096, id_PDR_N069). In addition to these three, a specimen of *Araucaria columnaris* and a *Ceiba speciosa* (code id_PDR_N092 and id_PDR_N148 respectively), stand out over the remaining trees. But the undisputed star of the scene that makes up this magnificent garden, can only be the majestic *Cupressus lusitanica* with an estimated canopy cover of 600m², directed horizontally on an art-nouveau supporting structure. The cypress in question (identified by the code id_PDR_N085) is of virtually unquestionable aesthetic landscape value to the Jardim Príncipe Real. The list of recognised species in the Jardim França Borges and their location can be seen in the Appendix No10 - Trees inventory of Jardim França Borges and Appendix No.11 - Trees index of Jardim França Borges.

6.3 Ecosystem benefits

6.3.1 General overview

With the data collected and the parameters estimated by the software and described in the previous sections, it was possible to calculate various ecosystem benefits provided by the total arboretum analysed, by species and by case study garden. The vegetation in question stored almost 500 metric tons (499.3 ton) of carbon

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and can sequester almost 7.5 metric tons (7,408) each year. On the other hand, the removal of air pollutants (CO, O₃, NO₂, SO₂, PM_{2.5}, PM₁₀) reach 517kg per year, accompanied by an oxygen production of about 20 tons (19.6) annually. Another extremely interesting data is related to the capacity of these trees to decrease the surface runoff of rainwater, a volume of about 533.8 cubic meters of water, each year, whose runoff is intercepted and prevented flash floods by the plant structures. In the next sections some of the ES are described for the total sample.

6.3.2 Carbon storage

Carbon storage is directly related to the characteristics of individual species and their degree of growth. According to the Figure 45, the greatest amount of carbon does not refer to the most representative species such as *Celtis australis*, which ranks fourth, but rather to the species that include the largest specimens. In this case, the species that have accumulated the most carbon are the same ones, considered as monumental and with a considerable size: *Ficus macrophylla* and *Metrosideros excelsa*, which, together with *Platanus x hispanica*, hold the top three positions in stored carbon.

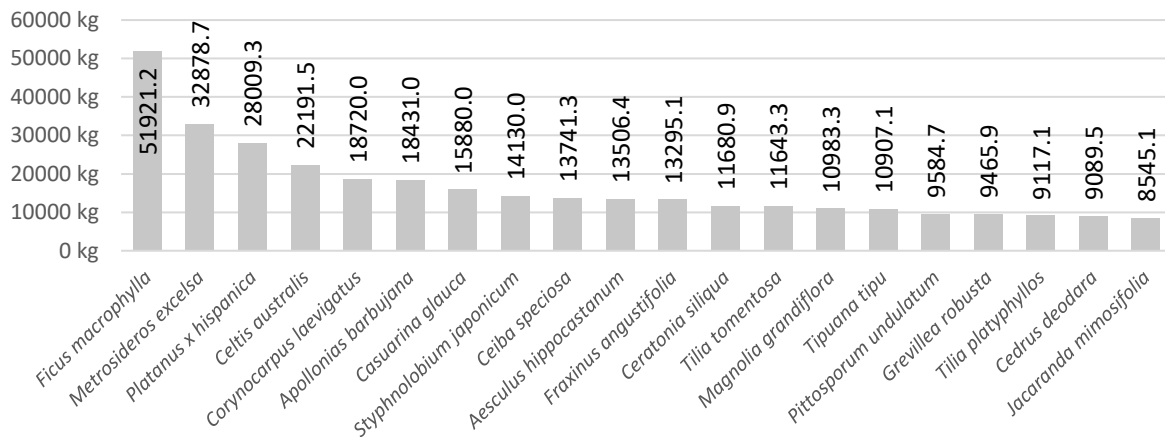


Figure 45 - Carbon storage value by species (kg)

In addition to knowing which species, can store highest amounts of carbon, it is also possible to analyse individually. It will be sufficient to divide the amount of carbon stored for each species by the number of individuals belonging to that species and thus obtain the mean amount of carbon stored for each exemplar (Figure 46). This analysis shows that the *Taxodium huegeij*, classified as monumental, from the Jardim Teofilo Braga is the specimen that contributes the most to carbon storage. *Ficus macrophylla* and *Metrosideros excelsa* now hold a second and fourth place, interspersed with *Ceiba expeciosa*, an ornamental tree of Brazilian origin with four specimens among the three gardens studied, one of them classified as monumental.

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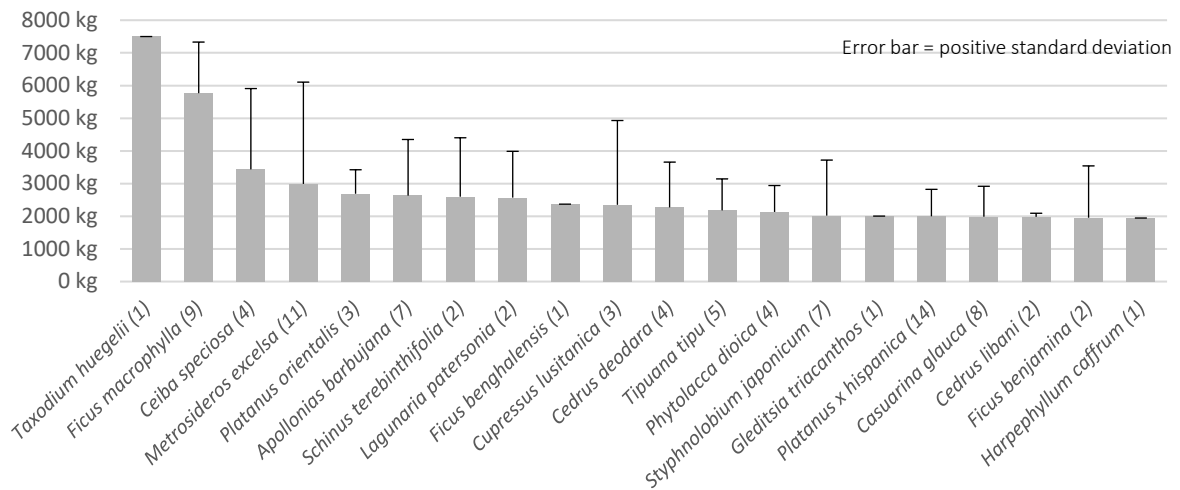


Figure 46 - Mean (+ standard deviation) carbon storage by tree species (kg)

6.3.3 Annual carbon sequestration

Combined with the amount of carbon stored by vegetation as it grows, it is possible estimate the amount of carbon absorbed each year. This is essential information for assessing the benefits obtained from the ecosystem services that the analysed gardens provide. In this case (Figure 47), the result is strongly related to the number of specimens in the garden. In fact, the Jardim Guerra Junqueiro is, among the three analysed, the one that absorbs the most carbon each year with a value of more than 5000 kg, significantly higher than the remaining two gardens.

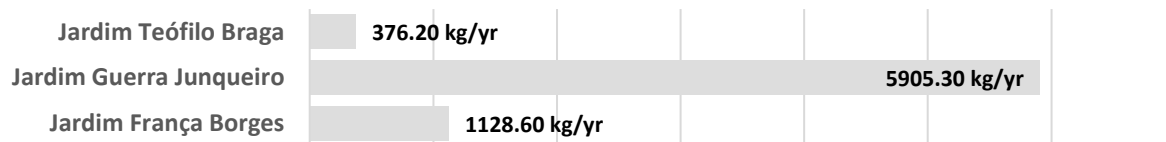


Figure 47 - Annual carbon sequestration by garden (kg/yr)

Depending on its physiological characteristics, each species contributes more or less in carbon absorption. As we can observe in Figure 48, the species *Corynocarpus laevigatus* is responsible to sequester the most carbon through the process of photosynthesis. Interestingly, the same species, regarding carbon storage capacity, is ranked in fifth place (Figure 45), leaving room for species characterized by much larger individuals. For example, *Metrosideros excelsa*, with two majestic individuals classified as monumental; and *Platanus x hispanica*, which, as an annual capacity to sequester carbon, occupy the second and third places. *Celtis australis*, despite its strong presence in terms of numbers, holds only the sixth place in order of importance, signifying that, in the case studies, it is not among the main species capable of providing this ecosystem service.

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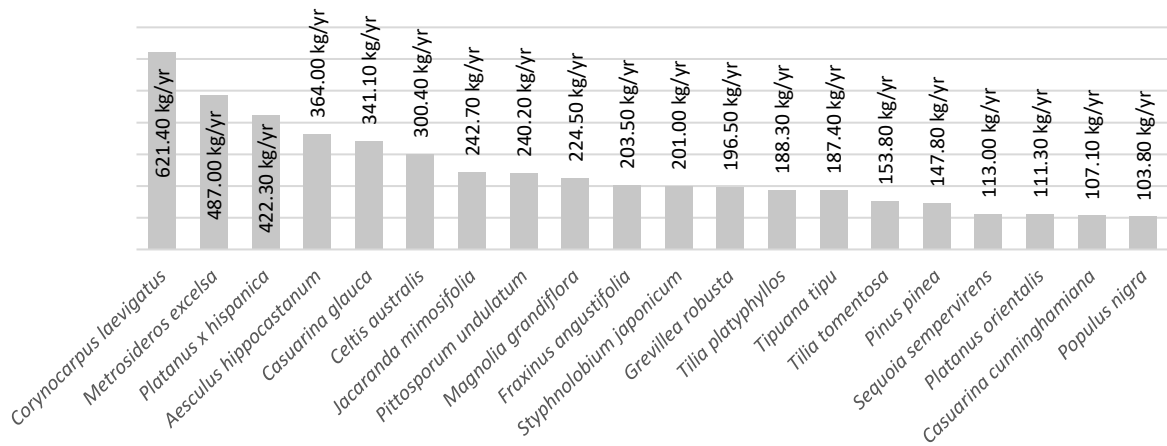


Figure 48 - Annal carbon sequestration by species (kg/yr)

To confirm the importance, in terms of annual carbon sequestration, of different species, it is possible to estimate what the carbon sequestration of individual specimens might be considered (Figure 49). In fact, from the analysis above, the number of specimens present for each species is not considered, and this could strongly influence the real sequestration capacity. By thus dividing the results obtained by the number of individuals of each species, we can trace an estimate distributed over the different specimens. It is immediately evident how the number of individuals influenced the previous assessments, in fact, *Corynocarpus laevigatus* that held the first place. Similarly, *Celtis australis*, with a whopping 179 specimens is also outside the first 20 species, further underscoring how it is not the most suitable species for CO₂ sequestration. In contrast, *Metrosideros excelsa*, with its 11 specimens, ranks third in order of importance, further confirming the good ability this species has to absorb carbon dioxide. Only *Ficus benghalensis* and *Gleditsia triacanthos*, of which only one individual was surveyed per species, hold greater importance.

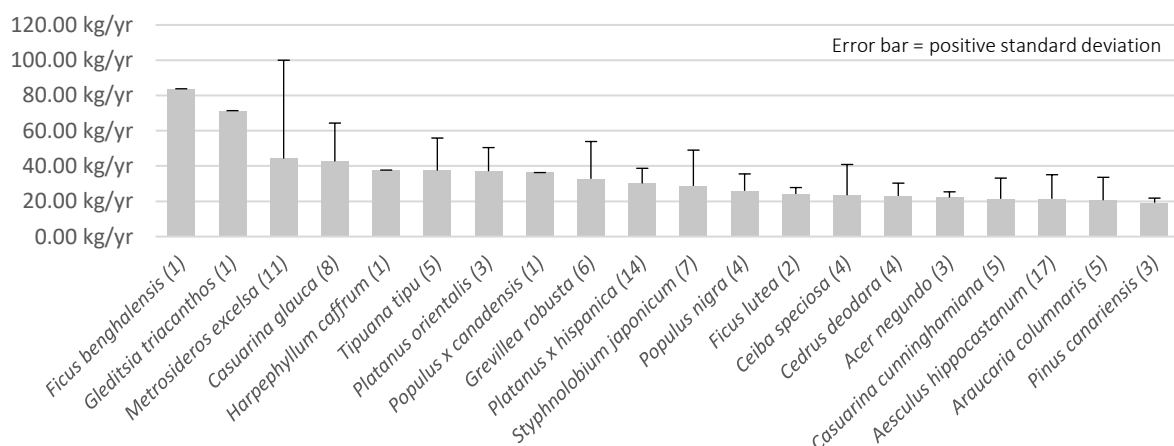


Figure 49 - Mean (+ standard deviation) annual carbon sequestration by tree (kg/yr)

6.3.4 Hydrology effect

Among the various ecosystem benefits are the ones related to land hydrology. Vegetation can intercept stormwater and prevent surface runoff of water, which, in the urban environment, is generating enormous management problems. The amount of vegetation, the complexity with which it is structured on different spatial

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levels and the intrinsic characteristics of each species profoundly influence these ecosystem functions (Ossola, Hahs, and Livesley 2015). Although the Jardim Teófilo Braga is the one with the highest leaf density as a function of surface area, it is also the smallest garden, with the least amount of vegetation, thus makes it the least effective in terms of limiting surface water runoff. On the other hand, avoided runoff is severely limited by the Jardim da Estrela, with an estimated nearly 400 cubic meters of water per year intercepted and retained by the trees (Figure 50).

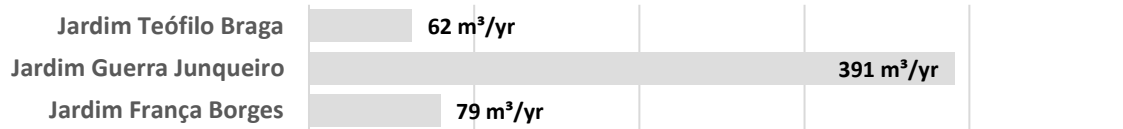


Figure 50 - Avoided runoff by garden (m³/yr)

As indicated earlier, it is the physiology of a plant species or even the particular plant that greatly influences its ability to intercept and retain rainwater (Dowtin et al. 2023). *Celtis australis*, as the dominant species from the quantitative point of view, also proves to be the most effective from the hydrogeological point of view, retarding or avoiding surface runoff (Figure 51). *Platanus x hispanica* and *Ficus macrophylla*, not so much because of their abundance within the gardens studied but because of their high canopy volume are, capable of intercepting large volumes of stormwater.

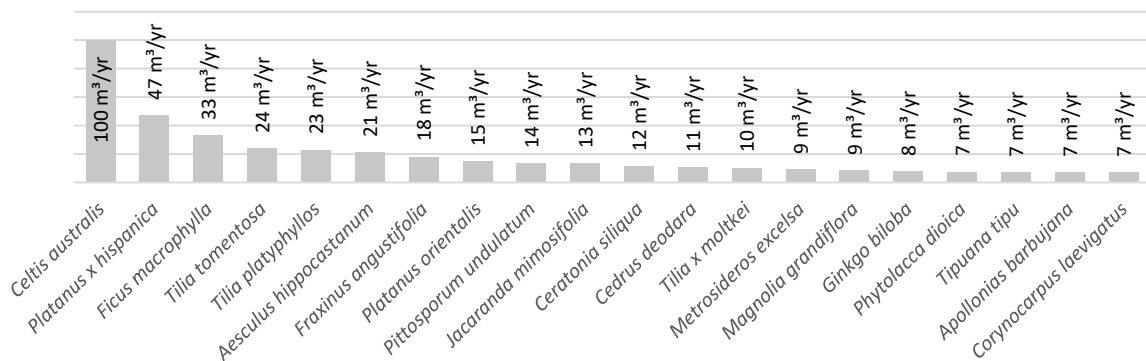


Figure 51 - Avoided runoff by species (m³/yr)

Regarding the species mean values to avoid surface water run-off, *Celtis australis*, as on other occasions, no longer plays such a key role. The species whose importance from the point of view of reducing surface runoff stands out the most is certainly *Platanus orientalis*, followed closely by two different species of *Ficus*. Care must be taken in reading these data because, while for *Platanus orientalis* and *Ficus macrophylla* there are several specimens in the three gardens studied and thus have a minimum of variability among individuals, this is not the case for *Ficus benghalensis* of which only one large specimen was surveyed. In this way, the *F. benghalensis* in question turns out to be a very good plant given its huge canopy, which could, however, be a singular case compared to the norm (Figure 52). To have more accuracy in the data one would need to possess more information, especially for those species of which only one individual has been identified.

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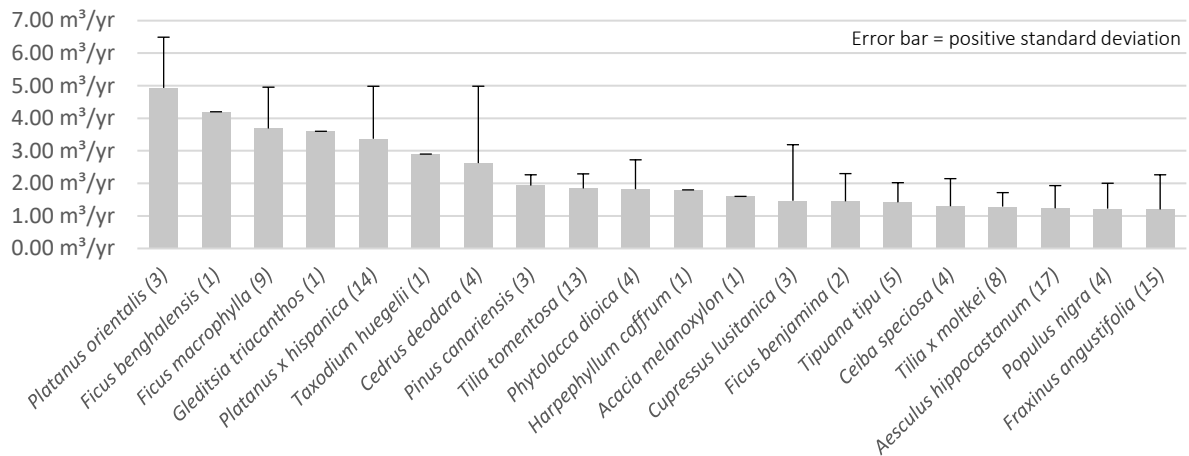


Figure 52 - Mean (+ standard deviation) avoided runoff by tree (m³/yr)

6.3.5 Oxygen production

Water and carbon dioxide are two key elements for photosynthesis within chloroplasts, subcellular organs in which most of the metabolic processes of plant structures take place. “Waste” from the photosynthetic process is the production of oxygen. As we can see in the Figure 53, the production of the latter is intimately related to the number of specimens present; thus, the Jardim Guerra Junqueiro once again emerges as the most active in providing ecosystem services.



Figure 53 - Oxygen production by garden (kg/yr)

When comparing the annual oxygen production per hectare with the total production (Figure 54), it is clear how, although the Jardim da Estrela retains first place, the difference between the various gardens is incredibly small. In this case, the type of species presents in the three studied gardens, the phytosanitary status of the canopies and the density of the vegetation are the elements that most influence the data.

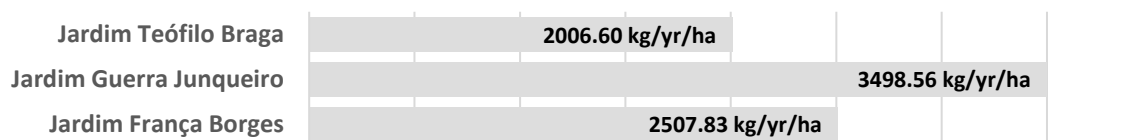


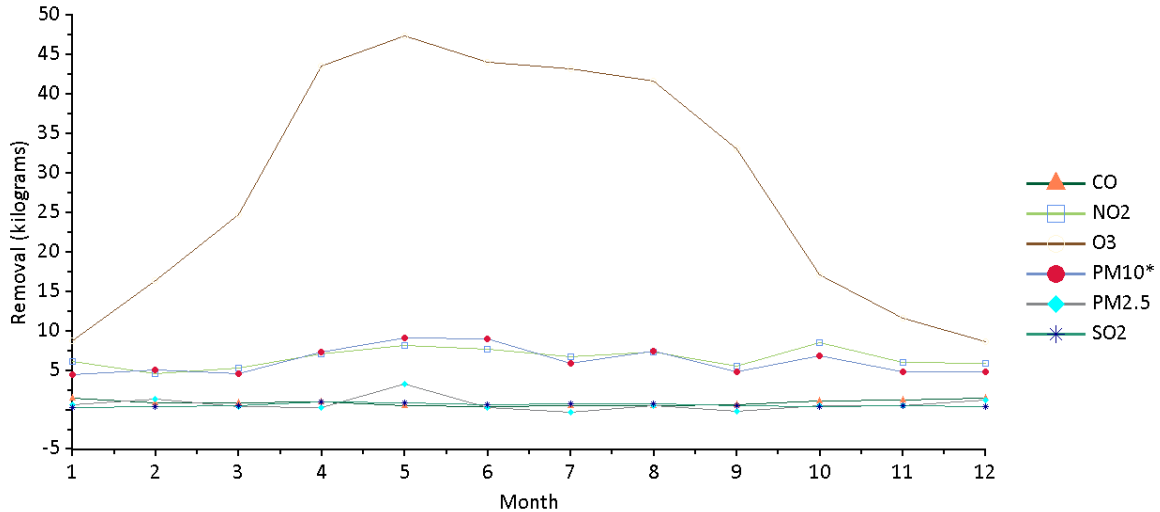
Figure 54 - Oxygen production by unit area (kg/yr/ha)

6.3.6 Atmospheric pollution effect

Within the ecosystem benefits it is also included the removal of air pollutants such as carbon monoxide, ozone, nitrogen dioxide and many others that make up the famous photochemical smog (Rani et al. 2011). These pollutants are retained by plant surfaces such as leaf pages or bark. Depending on the time of year, as the seasons change, the capacity for air pollutants sequestration of the studied gardens changes dramatically. According to the Figure 55 below, obtained through estimates made with iTree-Eco software, Ozone is the

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pollutant whose uptake undergoes the most intense fluctuation throughout the year. Along with it, the uptake of the other pollutants also undergoes fluctuations, although much smaller. These variations are largely due to the vegetative phase of the trees studied. In fact, a percentage of these pollutants are retained by the leaf pages and therefore during the months of vegetative rest and absence of leaves, this effect will be limited.



PM10* is particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is particulate matter less than 2.5 microns. If PM2.5 is not monitored, PM10* represents particulate matter less than 10 microns.

Figure 55 - Air pollution removal during a year (image generate with iTree-eco)

Celtis australis as the most abundant species in the three case studies also appears to be the most effective in removing air pollutants. The values in this case are much lower than the uptake of other pollutants such as CO₂, a key element in the metabolic process of photosynthesis. *Platanus x hispanica* and *Ficus macrophylla*, of which there are far fewer specimens, hold the second and third places, respectively, as important for the removal of air pollutants (Figure 56). This is probably due to their large size, extensive leaf area, and their distribution within gardens since, unlike other species such as *Platanus orientalis* that have more leaf area but are found singly or in few specimens, they are recurrent species in more than one garden.

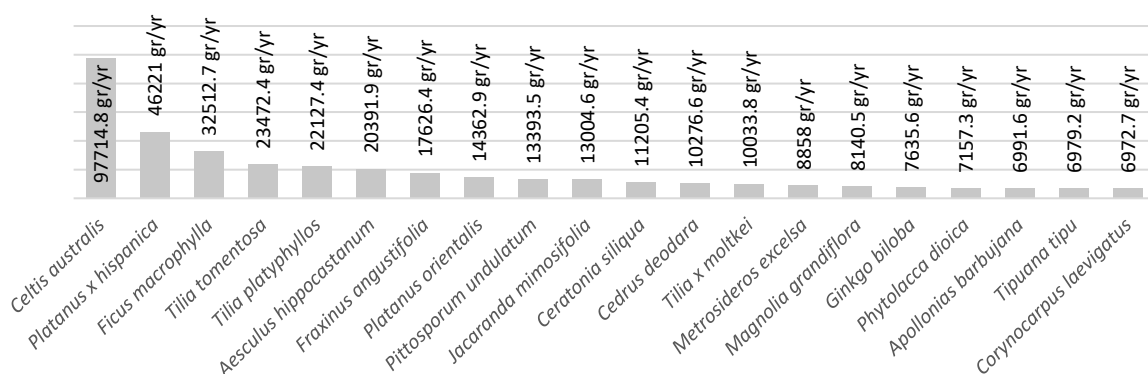


Figure 56 - Pollution removal by species (g/yr)

Looking at the amount of air pollutants removed by each specimen on mean (Figure 57), *Celtis australis* moves over to 20th place in order of importance. The most important species in this case is confirmed to be

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Platanus orientalis, probably due to its peculiar leaf area (see Figure 27, section 6.2). *Pinus canariensis* and *Cedrus deodara* are, in this case, a clear example of how the physiognomy of the plant, specifically the leaves, affects the deposition of air pollutants. Needle trees have a larger and more articulated leaf surface than broadleaf trees, which makes them more prone to sequester this type of pollutant (Steinparzer et al. 2023).

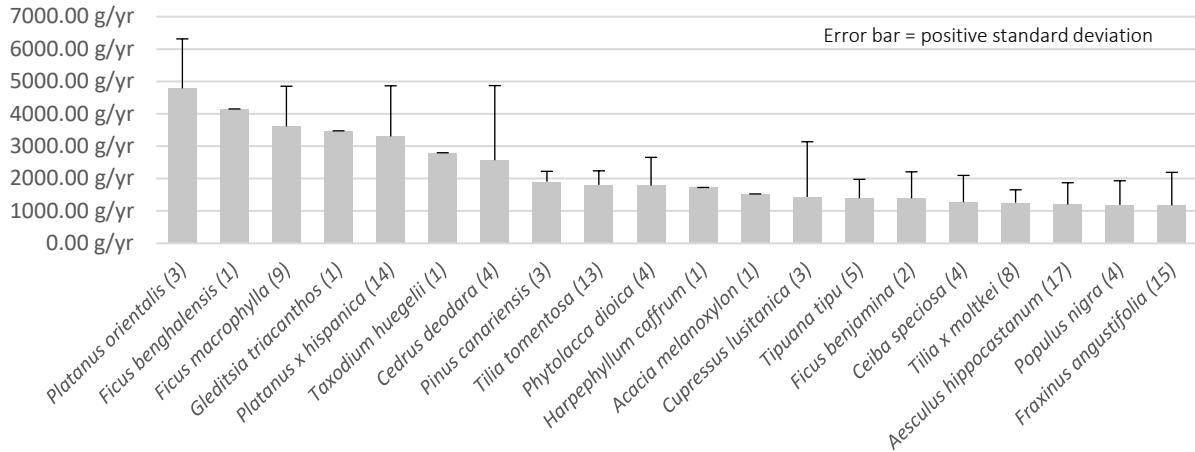


Figure 57- Mean (+ standard deviation) pollution removal by tree (g/yr)

In addition to the ability to retain air pollutants, vegetation, as living things, requires metabolic processes that can generate the emission of volatile organic compounds (VOCs) (Lerdau, Guenther, and Monson 1997). The iTree-Eco software can estimate the amount of monoterpene and isoprene emitted by the individual specimens analysed. Regarding the total organic compounds emitted by the various species, in Figure 58, *Platanus x hispanica* is the most influential species. *Celtis australis*, despite its abundance, ranks seventeenth in order of importance for this ES, making it an unimportant species in the process of photochemical smog formation (Rani et al. 2011).

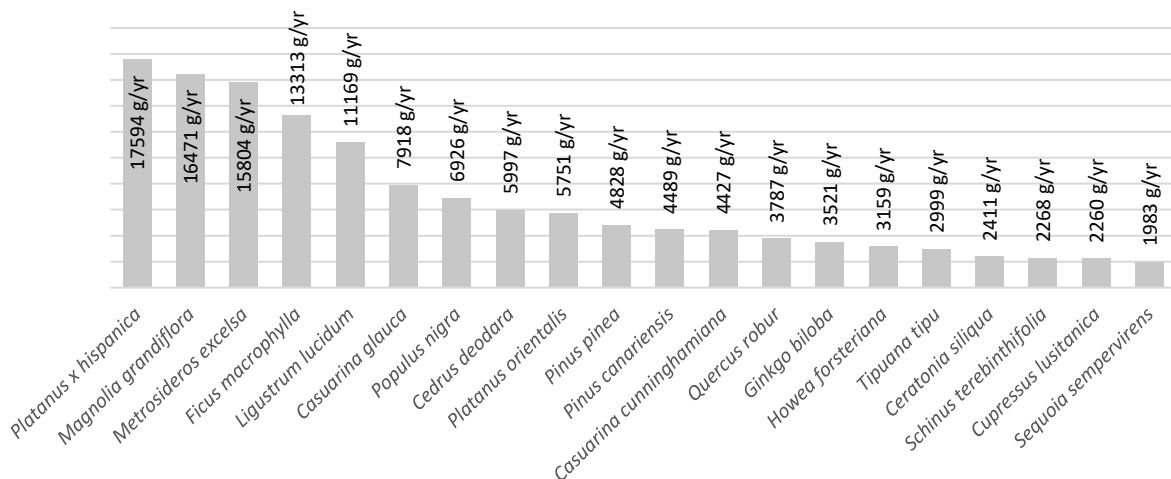


Figure 58 - Total VOCs emission by species (g/yr)

Once again, despite the difference that may exist between one species and another, the mere presence of greater tree population significantly increases emissions of volatile organic compounds (Figure 59). In addition,

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we must consider that *Celtis australis* plant which has little influence in this respect, is proportionally slightly less present within the Jardim Guerra Junqueiro than in the other two smaller gardens, since it is outclassed by *Howea forsteriana*, which is able to emit more volatile organic compounds according to the Figure 58 above.

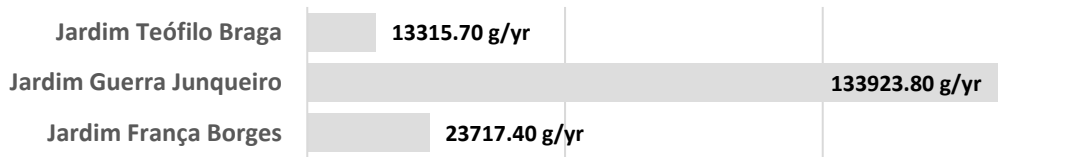


Figure 59 - Total VOCs emission by garden (g/yr)

6.3.7 Economic value

The values given in the previous sections in weight or volumetric units are difficult to understand, especially in an urban environment and even more so if we want to make sense of them at the decision-making level. Therefore, it is necessary to quantify in economic terms the values observed so far, so that we can be able to combine the ecosystem services provided by the vegetation studied with a quantifiable socio-economic benefit.

The analysis of the Figure 60, indicate that, the over 50 tons of carbon stored by *Ficus macrophylla* can be converted to 5763€ monetary value (given the conversion value of €1053.03 per ton of carbon used by the iTree-Eco software). The total value of stored carbon, from the tree specimens, in the three gardens is estimated 55422.48€. Regarding carbon storage, it is interesting to note that the greatest value is closely related to the size of the trees, specifically the *Ficus* sp. and *Metrosideros excelsa*, which are often considered monumental specimens, characterized by an age and growth significantly above the standard of the three gardens analysed.

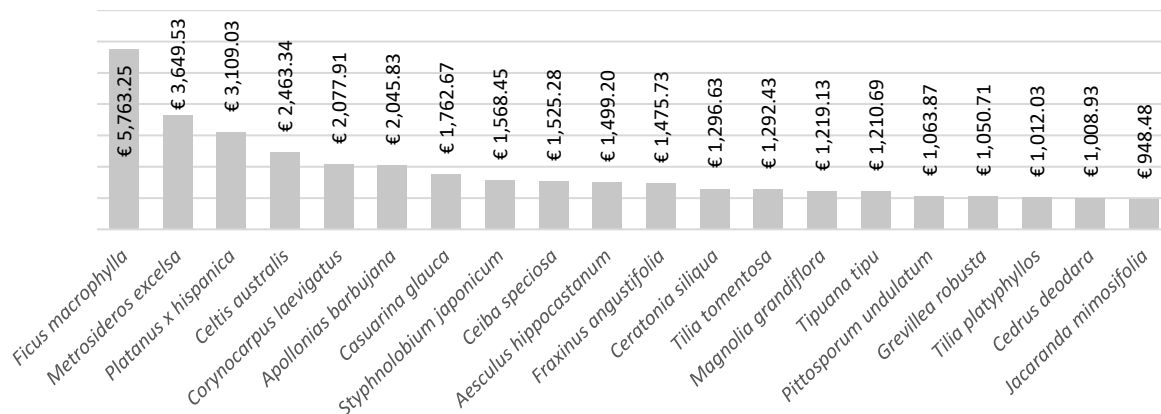


Figure 60 - Carbon Storage value by species (€)

In considering the mean value of the individual specimens belonging to the analysed species, *Ficus macrophylla* is surpassed by the only specimen of *Taxodium huegeii* (Figure 61). *Celtis australis*, which in total was ranked in fourth place, is not of sufficient value to be in the top 20 in the case mean of the individual trees. In terms of the value of the stored carbon, it is evident that the larger specimens are those that give their species a higher value, thus the trees classified as monumental are in the top 20.

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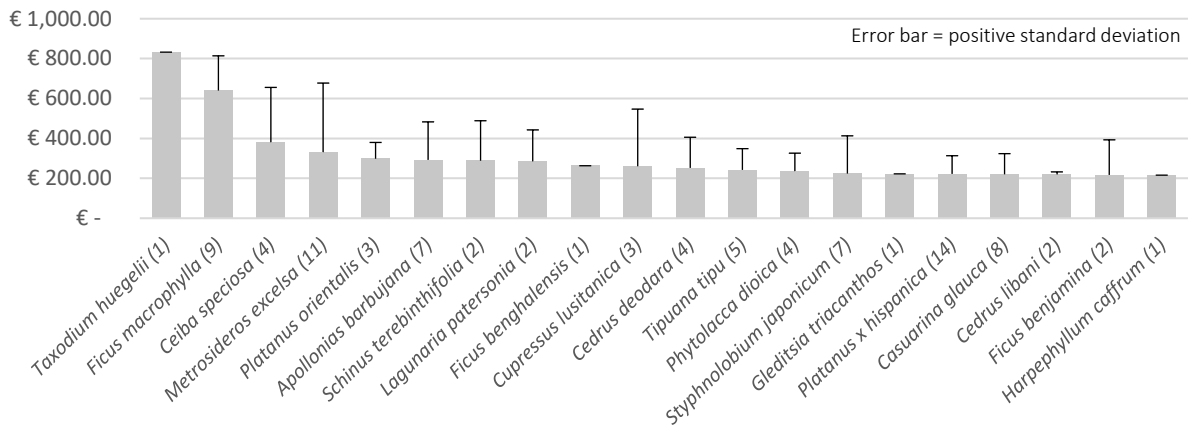


Figure 61 - Mean (+ standard deviation) Carbon Storage by tree (€)

Regarding the yearly carbon uptake by trees (Figure 62), the 0.62 tons metabolized by *Corynocarpus laevigatus* during a year, as a value of €68.97, higher than the €54 of *Metrosideros excelsa*. *C. laevigatus*, in contrast to the previous analysis regarding stored carbon, has a greater economic impact than *Celtis australis* despite having a significant lower abundance (< 33%). Still dealing with carbon, the economic conversion factor used by the iTree software, in this case, corresponds to the previous one used for the economic quantification of carbon stored by the tree.

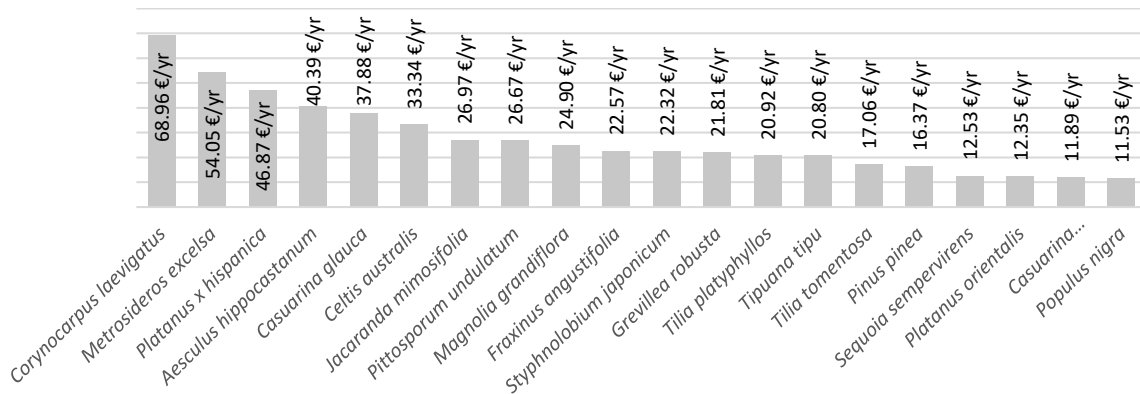


Figure 62 - Annual carbon sequestration by species (€/yr)

Regarding the mean value per species, Figure 63 shows the same differences as already observed in Figure 48. The value of the tree is no longer influenced by the recurrence of the species, as in the case of *Celtis australis*, but the importance of its foliage and the leaf area it can develop is emphasised.

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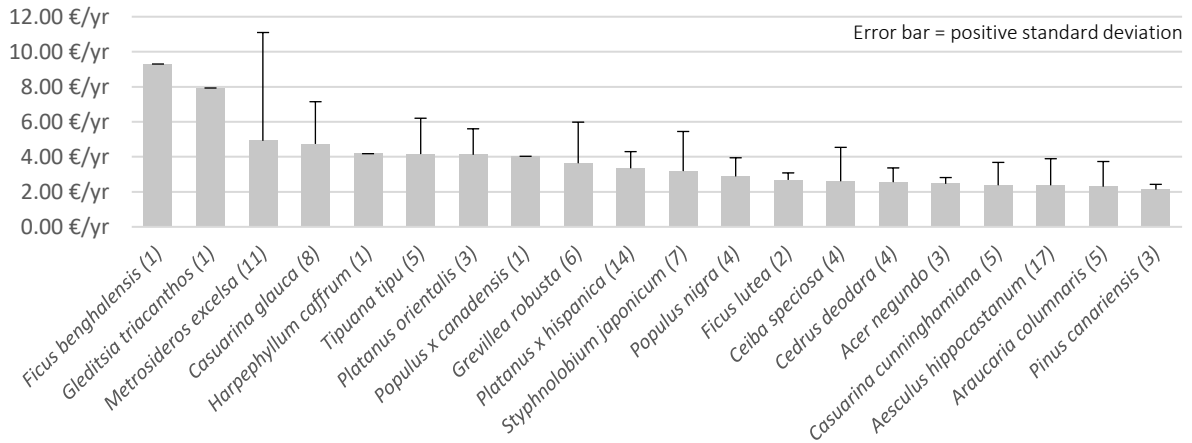


Figure 63 - Mean (+ standard deviation) annual carbon sequestration by tree (€/yr)

Quantifying the value of avoided surface run-off is perhaps one of the most complex conversions to make, since several environmental factors come into play (Dowtin et al. 2023). The software in this case propose a conversion factor of 9.270€ per cubic meter of water, which gives a standard method of comparison with the Lx Tree project (U.S. Forest Service 2021). Through this conversion, it is possible to appreciate, in the Figure 64, the value of 927.11€ attributed to the 100.01 cubic meters of water avoided by *C. australis*, as it is a significantly more numerous species. The total number of tree specimens in the three case study gardens is estimated to achieve 4948.66€ per year, based on the amount of water that can be intercepted. As previously mentioned, the best vegetation from this point of view is characterized by expansive canopies and large size, and such *P. orientalis*, *F. macrophylla*, *P. hispanica* etc. are the specimens that will most promote this ecosystem service.

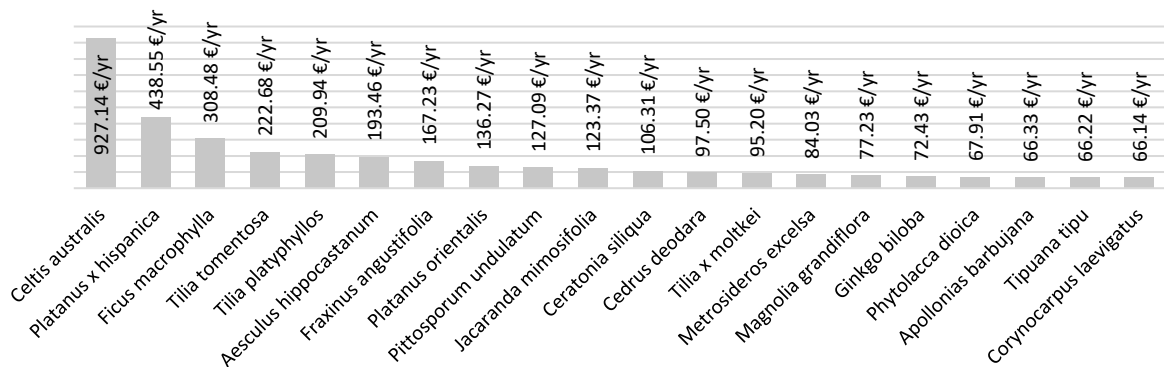


Figure 64 - Avoided runoff value by species (€/yr)

As far as the value of individual specimens is concerned, *Platanus orientalis* is the specimen that on mean assumes the highest value, at around 45€ per year (Figure 65). The link between this information and that of the Figure 64 is the observed in the Figure 52. It is the situation in which the number of individuals for a given species does not directly influence the result of the analysis but assist in determine what is the value of an individual is for the benefit it provides.

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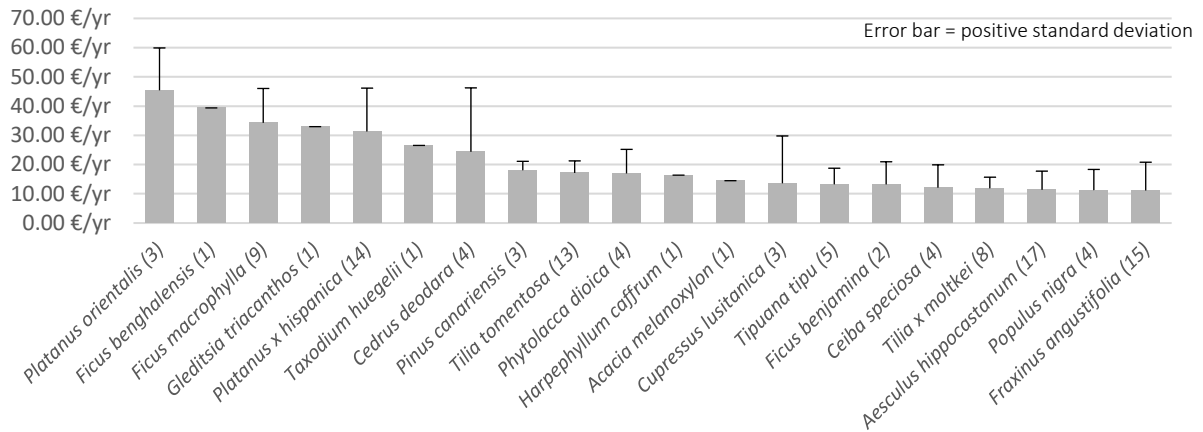


Figure 65 - Mean (+ standard deviation) avoided runoff value by tree (€/yr)

The removal of air pollutants by the trees in the studied gardens, has a total value of 11947.74€ per year, according to the different conversion coefficients used by iTree-eco to calculate the economic value (U.S. Forest Service 2021). The coefficients applied to convert the uptake of different pollutants into economic value are:

- €1,053.03 per metric ton of carbon monoxide,
- €26.85 per metric ton of ozone,
- €3.40 per metric ton of nitrogen dioxide,
- €1.13 per metric ton of sulfuric dioxide,
- €1,021.36 per metric ton of PM2.5,
- €1,999.44 per metric ton of PM10.

The value considers that, as far as air pollutants are concerned, vegetation has a dual effect, as it is itself an emitter of VOCs. Given this bilaterality, it is necessary to consider the difference between the pollutants retained and emitted, with the understanding that, in most cases, these are different pollutants. Among the specimens studied, *C. australis* is undoubtedly the most effective, with a total of 0.10 tons per year retained, which translates into 2238.35€ per year (Figure 66). This value is strongly related to the large number of specimens; in fact, there is a large gap with the others, for example, *P. hispanica*, which holds second place, corresponds to a value of only 1058.78€ annually, significantly less than *C. australis*.

While carrying out the analysis through the iTree-Eco software, it was possible to verify how the economic value attributed to the absorption of these air pollutants is, in relation to the population density of the area of interest. Thus, it must be remembered that the areas analysed here do not correspond to the entire urban area of Lisbon but to three specific gardens although iTree estimation are considering the population density of the municipality of Lisbon. This situation makes the observed results probably unrepresentative compared to the other quantified ecosystem benefits.

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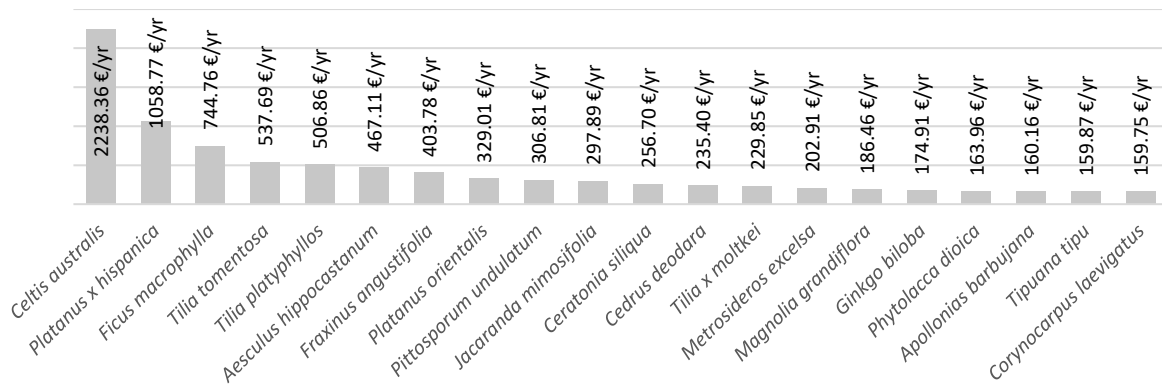


Figure 66 - Pollution Removal value by species (€/yr)

From the Figure 67 we can see how the mean value of the various specimens can vary depending on the species we have analysed. In this case, *Platanus orientalis* provides a mean benefit of 110€ per year, considering the number of pollutants that a single individual can remove. The relationship found between Figure 67 and the Figure 66 is similar the one observed in the Figure 65. In this case, it is of great importance the crown development and the leaf area according to its architecture for the attribution of an economic value to the individual specimen.

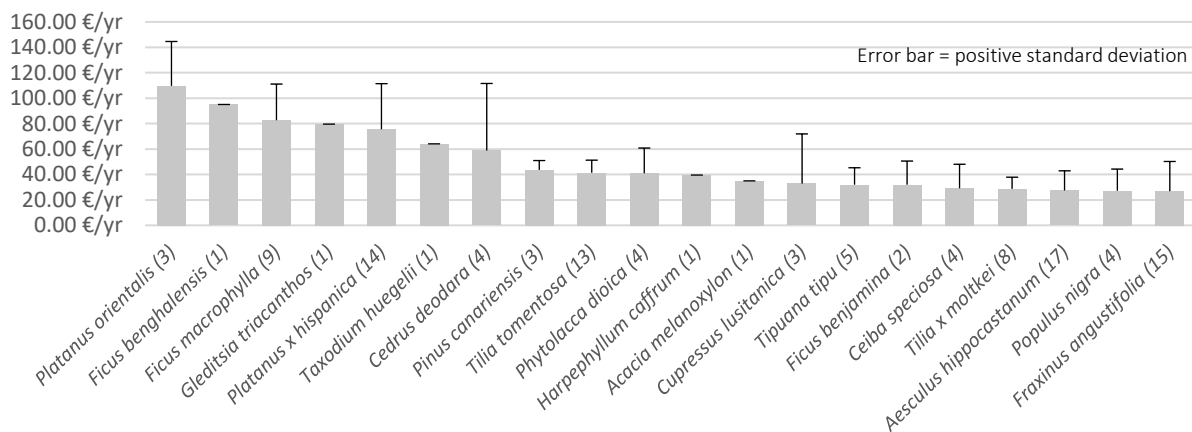


Figure 67 - Mean (+ standard deviation) value of pollution removal by tree (€/yr)

The total ecosystem benefits provided by the species analysed within the three gardens is represented in Figure 68. As might be expected from the data analysed so far, *C. australis* is the species that generates the highest value, given the preponderant representation of specimens, with a total of €3198 per year. Next, *P.hispanica* generates half the value with 1544€ per year, and so on, the remaining species generate less and less. This disparity is affected by the composition of the gardens (see section 6.1), showing that a large part of the ecosystem services and consequently the value they generate comes from one species in particular, *C.australis*.

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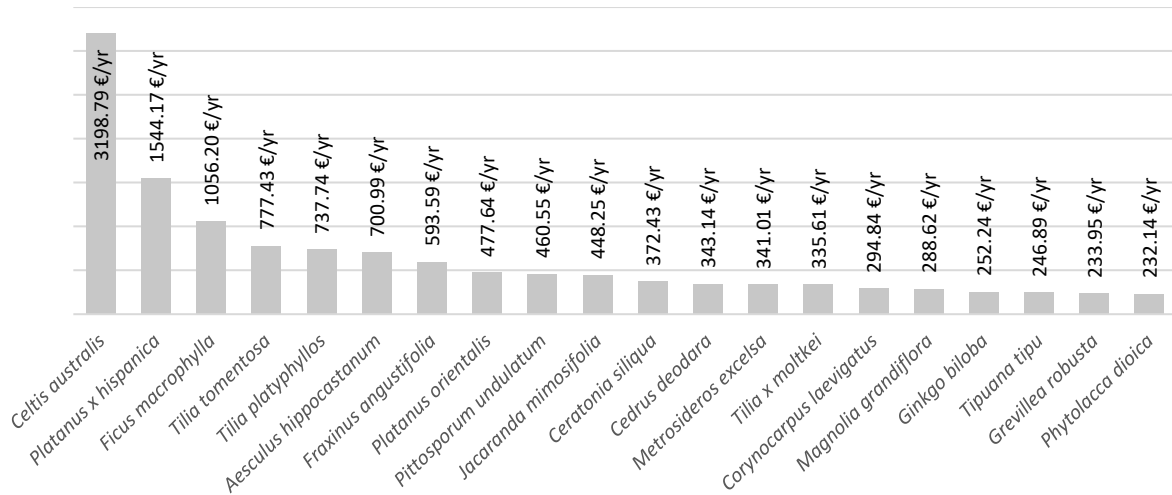


Figure 68 - Total annual benefits by species (€/yr)

The last evaluation regarded the replacement value, calculated by iTREE-eco based on the market price of trees in the reference area, to buy back and replace the analysed trees in the present (Figure 69). This is an indicative value and for these case studies it amounts to 2'083'226.64€. However, it is necessary to look at this value with a critical eye since, especially dealing with ornamental and urban trees, it is very complex landscape-wise to replace specimens even classified as monumental, with something of equal value, whether spiritual, ecological or social (Telles 1957). The value reported here is purely economic and cannot consider many factors, foremost among them the growth time, economically speaking externalities. It can be seen from the graph below (Figure 67) that *Celtis australis* is the species with the highest replacement value, given the large number of specimens, followed by *Ficus macrophylla*, although it corresponds to less than half the value of *Celtis*.

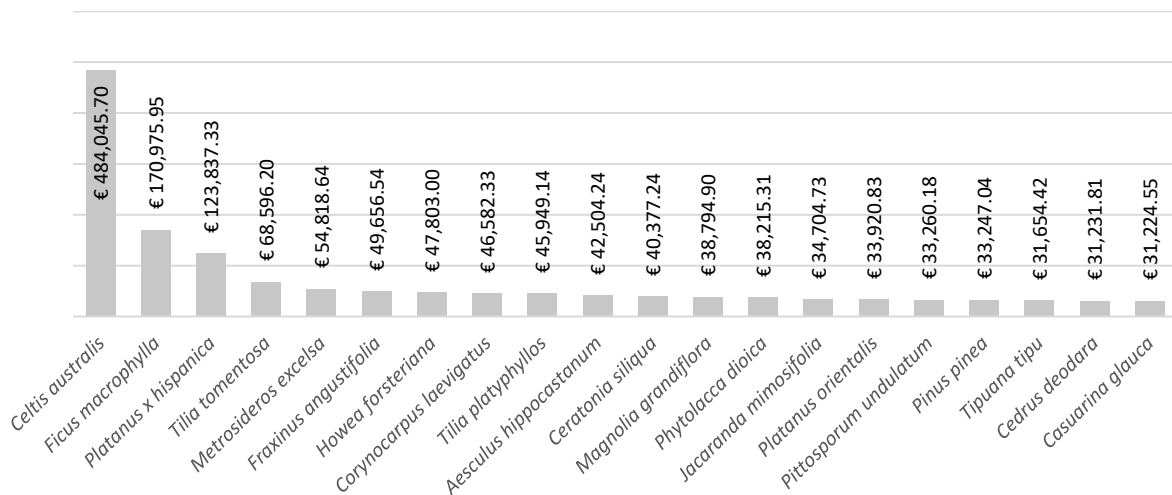


Figure 69 - Replacement value by species (€)

6.4 Comparison with streets trees data

6.4.1 General comparison

Using the data collected during the Lx-Tree project and cross-referencing it with the information obtained for the studied gardens, it is possible to understand the structural differences between the plant composition that characterizes Lisbon's streets and gardens, consequently highlighting the differences they may have in terms of ecosystem benefits.

In the previous sections was mentioned how the richness found within the gardens, from Lx-Garden project, is far higher than the species used for street green (799-469), although this fact does not recur within our analysis. In fact, 130 tree species were found within the three gardens studied, compared to 157 analysed with iTree in the street green, thus upsetting the previous proportion. This data can easily be attributed to a number of factors: first, two of the three gardens studied are relatively small in size and strongly related to the street greens, from here we can guess how the trees in them can be largely comparable to the vegetation also used on the roadsides; a second point can be attributed to the type of garden, age of construction and location within the Lisbon area, we can see from the descriptions of the gardens how they date from roughly the same historical period and are located in areas of the city adjacent to each other; third factor that we have to consider is the selection of so-called neighbourhood gardens, no consideration was given to parks or botanical gardens, which, as already pointed out earlier, inherently contain a greater variety of species; finally, we have to consider the area taken into analysis, when the 469 recognized species of street greenery, belong to the entire extent of the Lisbon municipality, the 130 species we confirmed, are found in a total area slightly larger than six hectares.

Looking at the two figures below (Figure 70, Figure 71), in which the ten most representative species of the roadside arboretum and the three studied gardens are shown, we can see that the composition, while maintaining common traits, contains different characteristics.

It is immediately clear how *Celtis australis*, which deeply characterizes the structure of the studied gardens, is also preponderant in the street green, albeit in a smaller percentage; in fact, within the gardens, *Celtis* corresponds to 20% of the tree vegetation while in the street trees, it corresponds to a 16%. This figure is strongly influenced by the Jardim Teófilo Braga and the Jardim França Borges, characterized by a perimeter of *Celtis australis* that play a dual role, on the one hand they can be considered elements belonging to the structure of the garden itself, and on the other hand they generate continuity with the surrounding street green. It is important to point out that, in the case of the Jardim França Borges, the peripheric *Celtis*, belonging to the structure of the garden, were considered within the census done during the Lx-Tree project, since one of the discriminating criteria, used in the previous study, for the selection of trees to be considered roadside, was a distance of 15m from the roadside, thus including specimens that from the ambiguous characterization. During our study, although the perimeter *Celtis australis*, are characterized by a type of maintenance that conforms to that characteristic of roadside greenery, they are reported within the historical documents, so they must be considered structuring elements of the Jardim França Borges (Soares 2021).

DATA TREE CONTRIBUTION TO URBAN FOREST PLANNING

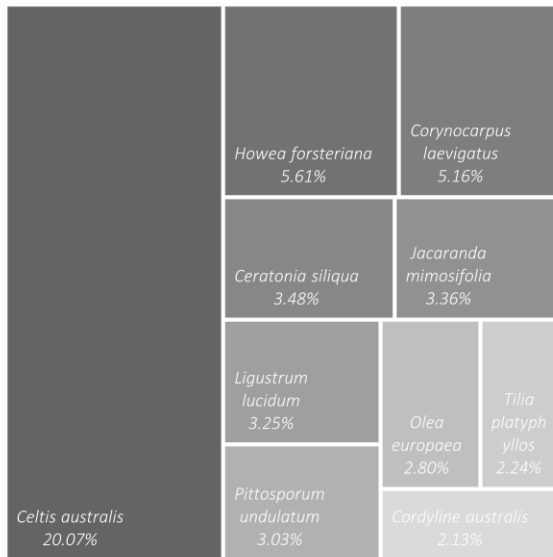


Figure 70 - Most representative species in garden

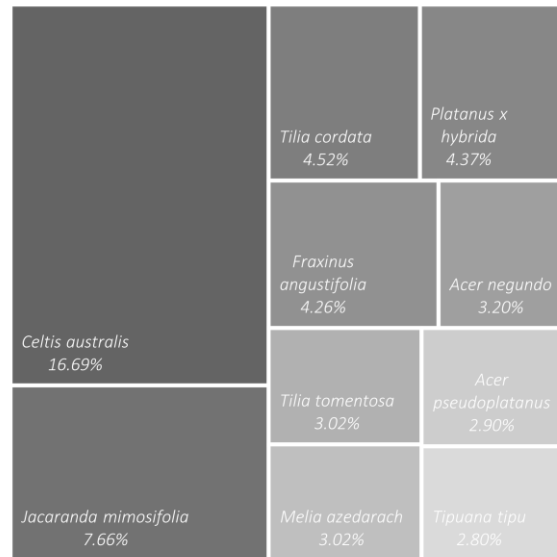


Figure 71 - Most representative species in studied street trees

In both graphs (Figure 70, Figure 71) about one third of the tree component is composed of only four main species, of which only *Celtis australis* is common. *Jacaranda mimosifolia*, an extremely important species within the street green, where we can place it in second place at the level of representativeness, characterized by a percentage of about 8%, is equally present within the composition of the studied gardens, in which it holds, however, the fifth place. Similarly, species of the genus *Tilia* characterize both studies but assume greater importance at the street level.

From the figures shown below (Figure 72, Figure 73), it is possible to observe how, generically, the same species within a garden exhibits larger dimensions than when placed in a street context. This data is evidence of how the two types of urban greenery follow different standards. It is worth noting that the gardens studied are more than a century old, consequently there is a good chance that the plants within present considerable age and size. Furthermore, these data show that the management of street greenery needs to maintain stricter standards, while avoiding the generation of dangerous situations for road traffic.

In the next paragraphs were summarised the main differences found during the comparative analysis of the structure belonging to the twelve selected species (see section 5.3.5).

One of the size indicators of a tree, and often used to estimated age class of the specimen, is undoubtedly the diameter at breast height (DBH). Given the presence of an interchangeable meristem and the consequent ability of higher plants to grow radially as well as vertically, an aging specimen leads, in most cases, to significant radial growth (Raven, Evert, and Eichhorn 2007). This development is different for each species and changes, depending on climatic conditions (Muscas et al. 2023); Under the current study it was possible to compare between specimens of the same species and within the same climatic conditions, but not to delve into the topic regarding the microclimatic conditions of growth of the specimens, although, almost certainly this is an influential variable (Kjelgren and Clark 1992). Figure 72 compares the mean diameter for the 12 species, common in gardens and Lisbon trees. For seven species, DBH is significantly ($\alpha < 0.05$) in the higher for trees

placed within gardens then when in the streets. In the case of *Aesculus hippocastanum*, *Ginkgo biloba*, *Platanus hispanica*, and *Tilia tomentosa*, this difference is so pronounced, corresponding to almost double what can be found in the street trees. Species that we see following a different trend, however, are *Jacaranda mimosifolia*, *Ligustrum lucidum* and *Olea europea* of which specimens, on mean, are found to don't have a significant ($\alpha < 0.05$) larger diameter among roadside specimens.

Comparisons regarding mean canopy size were also analysed using three variables: the mean height of the species, and the width of the canopies (Figure 73, Figure 74). The data of the three dimensions present an approximately regular trend. In the case of mean height, the dimensions are significantly (for $\alpha < 0.05$) larger for almost the trees species analysed within the gardens, except for the mean heights found in *Ligustrum lucidum*. Although the mean height is slightly higher for street specimens, looking at the confidence interval, an almost complete overlap can be seen, confirming that statistically there is no significant difference between the mean heights measured in gardens and on the street. At the same time, it is possible to find this similarity about crown width (Figure 74). Thus, within a garden, saplings could develop a more balanced structure without the intervention of destructive pruning frequently used to keep the street trees shaped and dimensioned (Konijnendijk et al. 2005).

In addition to the linear dimensions of the trees analysed, the results highlight differences in the areas they produce such as canopy cover and leaf area, which in relation to each other give the Leaf Area Index, in the Figure 77. As with the previous dimensions, tree canopy cover is generically higher for trees belonging to gardens, since these variables are closely correlated (for a $\alpha < 0.05$) with the width of canopies mentioned above. The same was observed regarding the leaf area of the studied specimens (Figure 76). On mean, the trees found in gardens develop a significant (at $\alpha < 0.05$) larger leaf area, obviously connected with the larger species, like *P. hispanica*, as seen above. In both cases, whether it is the area covered by the canopy projection or whether it is the estimated leaf area, *Platanus x hispanica* specimens reach a much more considerable size when placed within a garden where, it is possible consider, they have less influence, given by pruning and a longer life range, being able to grow according to their own intrinsic tree architecture, thus reaching notoriously higher values. As for LAI, a not dimensional value, the difference between mean values for gardens and street trees decrease, showing how the different growth of street trees consequently affects the amount of foliage produced (as far as estimated by the iTree-Eco software). In fact, *Celtis australis*, *Jacaranda mimosifolia*, *Ligustrum lucidum*, *Olea europea*, *Pinus pinea*, and *Tilia tomentosa*; show a higher LAI value among street trees than that found in gardens. As previously mentioned, the *L. lucidum* and *O. europea* were characterized by a larger trunk diameter, being probably long aged elements. It is possible to infer, that in the five species listed above, maintenance interventions and growing conditions had a greater influence on canopy expansion than actual leaf area and as such, when placed within a roadside context, are able to maintain a considerable in leaf area, forming denser structures, despite being greatly affected in terms of canopy extension (Hipps et al. 2014).

A broader look at the data shown in the totality of the graphs below (Figure 72, Figure 73, Figure 74, Figure 75) can reveal how *Aesculus hippocastanum* and *Platanus x hispanica* are the two species that show the greatest physiognomy differences between trees belonging to gardens and street trees.

DATA TREE CONTRIBUTION TO URBAN FOREST PLANNING

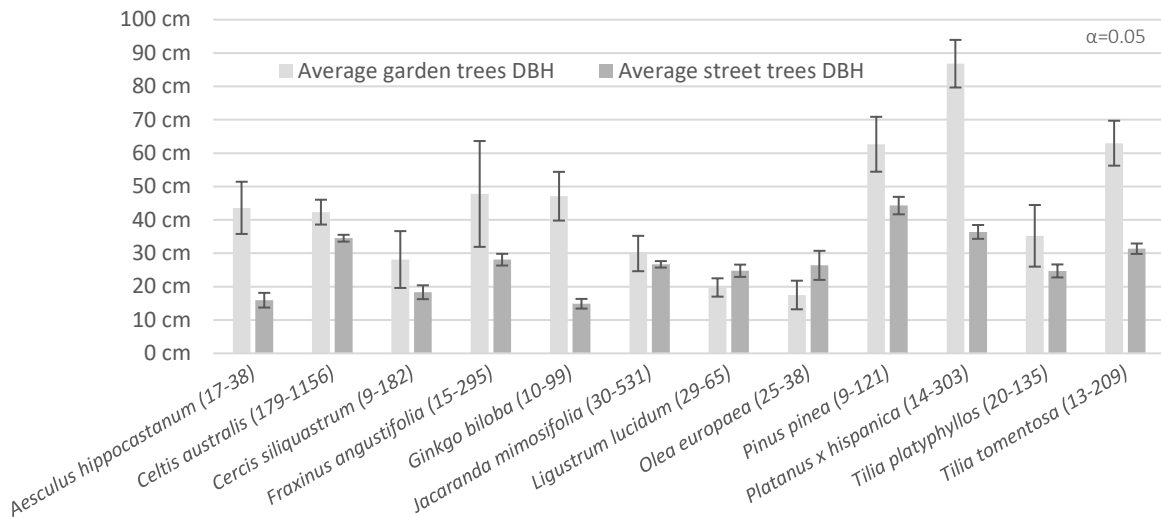


Figure 72 - Comparison between mean tree DBH (cm) with confidence interval 95%

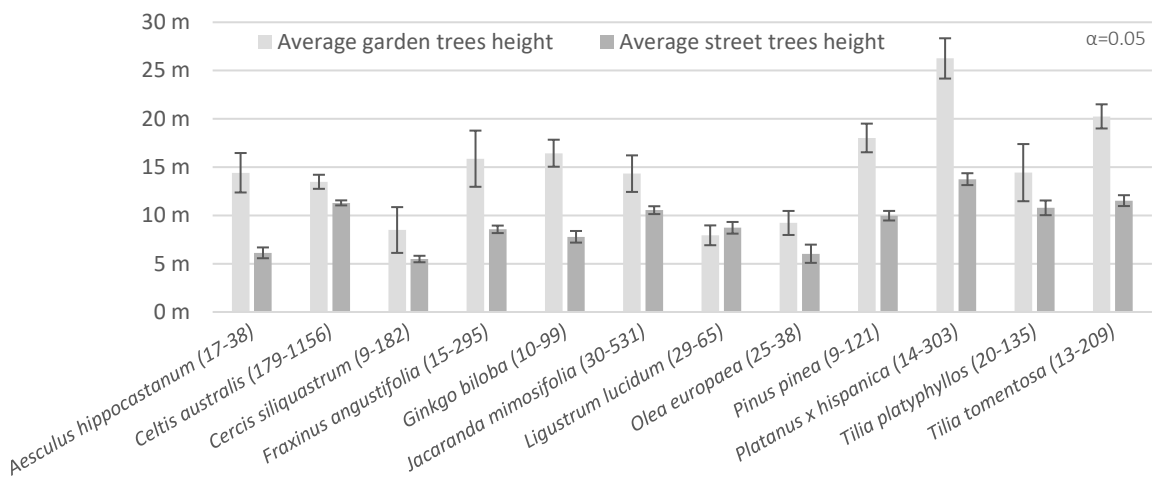


Figure 73 - Comparison between mean tree height (m) with confidence interval 95%.

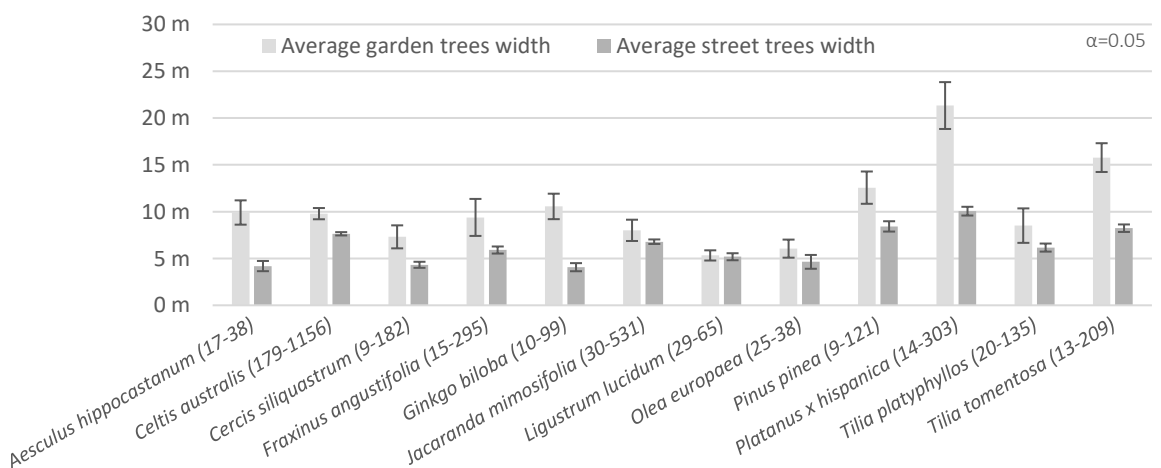


Figure 74 - Comparison between mean crown width (m) with confidence interval 95%.

DATA TREE CONTRIBUTION TO URBAN FOREST PLANNING

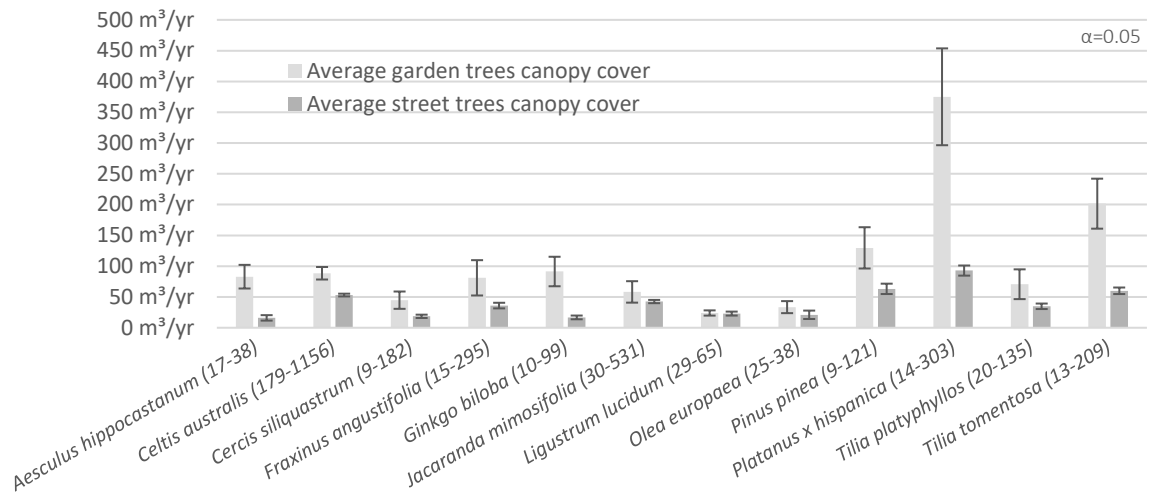


Figure 75 - Comparison between mean canopy cover (m2) with confidence interval 95%.

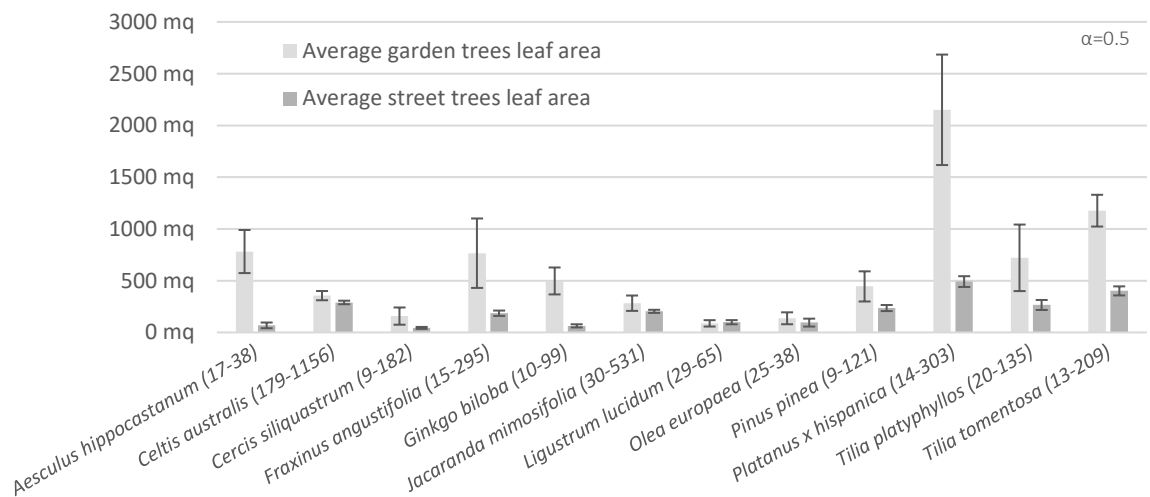


Figure 76 - Comparison between mean leaf area (m2) with confidence interval 95%.

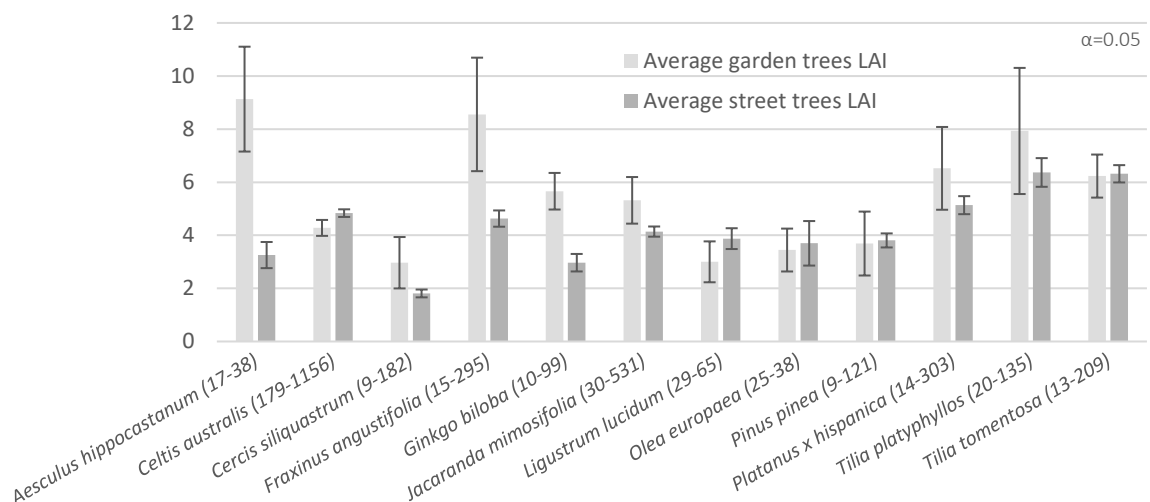


Figure 77 - Comparison between mean leaf area index (LAI) with confidence interval 95%.

The above differences regarding the size characteristics of the twelve species analysed can also be found in a comparison of the ecosystem benefits these species are able to provide. The data analysed here always refer to mean (and confidence interval at 95%) among the individuals surveyed. This allows focusing analysis on a typical individual and not fall into borderline cases. So far, results showed that, specimens within gardens are characterized by greater development, both in age and habit.

Looking at the Figure 78 regarding the Tree Carbon Storage mean, the trees belonging to the three gardens accumulated a higher amount of carbon. This figure is closely related to DBH, as the carbon in question is largely located within the woody organs measurable by stem diametrical growth (DBH) and canopy expansion. *Ligustrum lucidum* and *Olea europea* are the two species characterized by greater growth of the specimens inserted within the roadside green, show a higher value of accumulated carbon. Other species showed extremely different values, such as *Platanus x hispanica*, whose mean accumulated carbon value in gardens is 2121.96kg while the same species placed in street green is estimated to have accumulated in mean 321.38kg.

In the context of carbon sequestration capacity (Figure 79), the results of this study put in evidence how street greenery regains importance, partially filling the existing gap in carbon accumulation. For four species out of twelve studied (*Celtis australis*, *Jacaranda mimosifolia*, *Ligustrum lucidum* and *Olea europea*), it appears that street trees are more effective in annual carbon uptake. For *Ligustrum* sp. and *Olea* sp., the difference in uptake between street and non-road trees is visually very interesting. If we take the *O. europea* as a reference, we estimated with iTree software that a specimen placed in gardens on mean absorbs 3.90kg of carbon per year while a street specimen 8.47kg; the value in this case is more than doubled. Similarly, *L. lucidum* surveyed within the gardens absorbs on mean 3.38kg of carbon while in the street green 7.79kg. For the remaining analysed species, we can observe a greater uptake between the mean of the individuals surveyed in the gardens. In some cases, such as for *P. hispanica*, *A. hippocastanum*, *G. biloba* and *T. tomentosa* there is such a significant difference that there is no overlap between the confidence intervals. In other cases, like *C. siliquastrum* or *T. platyphyllos*, there is an overlap of confidence interval showing that the differences are not so pronounced. We can infer how the greater growth of certain species within gardens generates greater ecosystem services.

Regarding stormwater interception and avoided surface runoff, the specimens belonging to the three gardens, on mean, always offer a greater benefit in terms of water regulation, an element that is closely related to the ability of the canopies to intercept rainfall Figure 80. Not even the specimens of *Jacaranda mimosifolia*, *Ligustrum lucidum* or *Olea europea*, which showed greater growth in terms of leaf area or canopy cover, manage to outweigh the benefits provided by the gardens' vegetation. The same trend is visible in the graph regarding the removal of air pollutants (Figure 81). Again, *Platanus x hispanica* with its almost unattainable mean canopy expansion and leaf area, reach much higher values than the other species, especially among the specimens included in the three gardens. The pollutant removal action, especially regarding fine particulate matter (PM2.5 or PM10), is at the expense of plant surfaces, particularly leaf area. The species capable of developing a high leaf area, in addition to the *Platanus: Tilia tomentosa*, *Aesculus hippocastanum*, *Fraxinus angustifolia* and *Pinus pinea*, are those that stand out the most for this specific ecosystem benefit.

DATA TREE CONTRIBUTION TO URBAN FOREST PLANNING

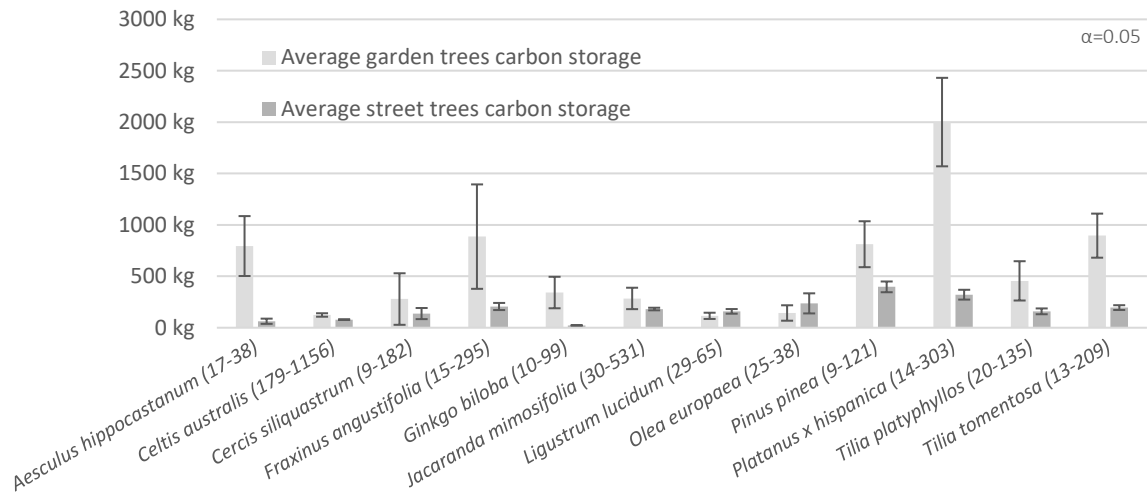


Figure 78 - Comparison between mean carbon storage (kg) with confidence interval 95%.

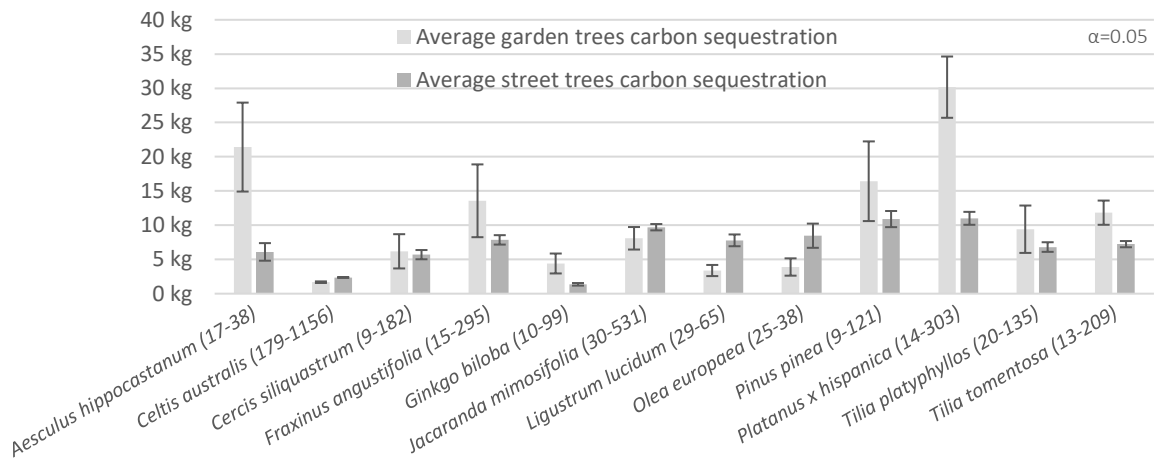


Figure 79 - Comparison between mean annual carbon sequestration (kg/yr) with confidence interval 95%.

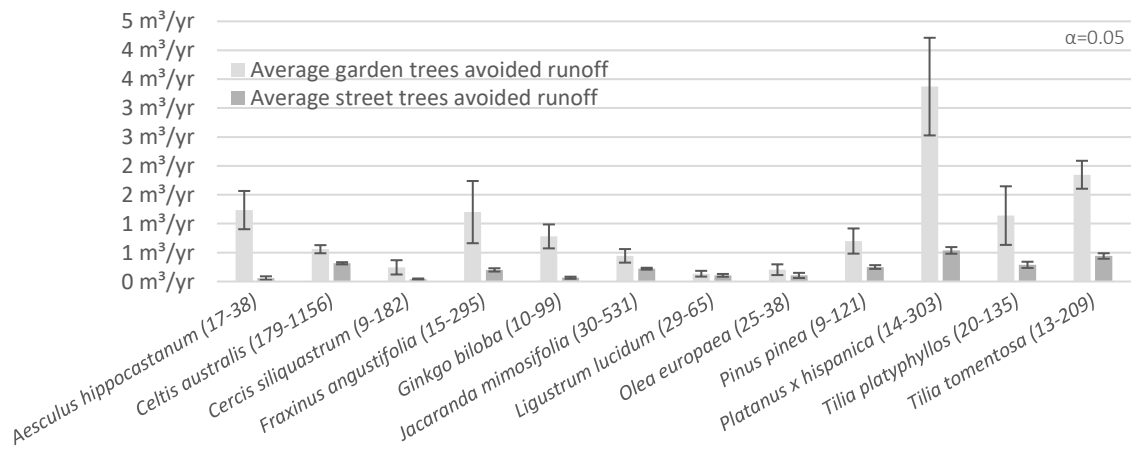


Figure 80 - Comparison between mean avoided runoff (m³/yr) with confidence interval 95%.

DATA TREE CONTRIBUTION TO URBAN FOREST PLANNING

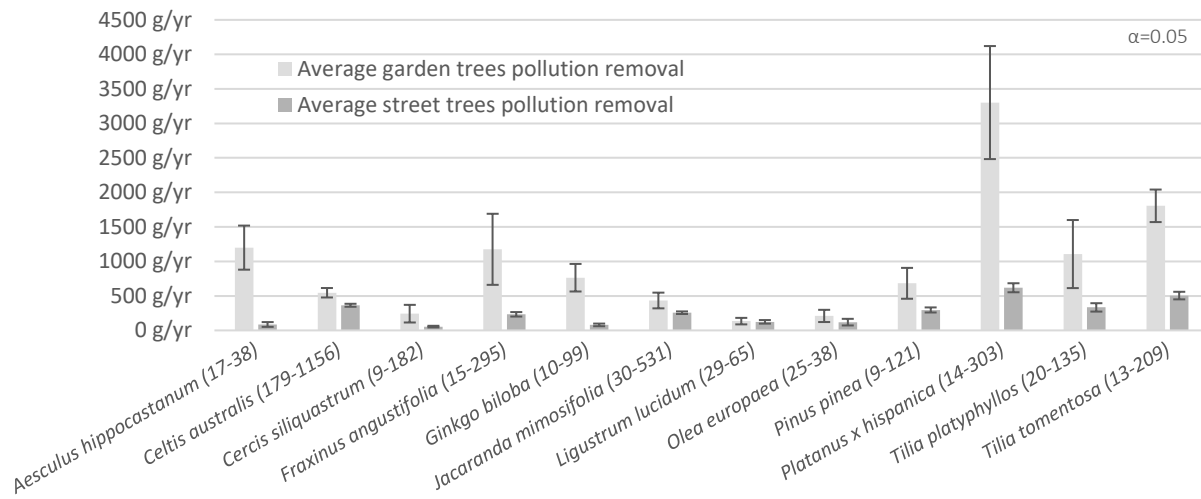


Figure 81 - Comparison between mean pollution removal (g/yr) with confidence interval 95%.

According to the differences between street context and gardens of the twelve species taken into analysis, on mean more benefits are obtained from trees placed in gardens. This result is strongly influenced by the degree of growth of the specimens, so it would be more correct to argue that more benefits are obtained if the vegetation is placed in the conditions to grow freely, developing according to its own needs and architecture, reaching higher ages and sizes. According to the estimates reported here, roadside vegetation could provide greater ecosystem benefits if it were not subject to the radical maintenance that roadside greenery requires, which is the cause of lower growth and limited longevity. The detrimental effects of radical maintenance on public trees were already mentioned, illustrated with several examples in different contexts (e.g. Cecil Konijnendijk et al. 2005; Pinto et al. 2022).

6.4.2 Comparison between garden and road's *Celtis australis* and *Platanus x hispanica*

To confirm the results concerning the comparison between street and garden trees, specimens belonging to the same DBH class were identified. The observations shown below are the result of filtering the data as stated in the section 5.3.5. As we can observe in Figure 83 and Figure 82, the percentage of specimens with a 'CRITICAL' or 'DYING' condition among the analysed data is practically zero for specimens belonging to gardens and minimal for street trees. Looking instead at the specimens with an 'EXCELLENT' condition, we can see that a higher percentage is to be found among street trees. The *C. australis* analysed show a higher percentage in 'GOOD' condition among the street trees, while garden specimens predominate in 'FAIR' and 'POOR' conditions. Looking at *P. hispanica*, however, we see that garden specimens show a higher percentage of individuals in 'good' and 'fair' condition than roadside specimens. We must specify, in making this analysis, that the assessment of the condition of the trees was a purely visual assessment, carried out in the field and expressed in percentages as detailed in Appendix No.01 - Field data collection. Since the field data collection was carried out at different times, by different operators for garden and roadside trees, even though the same assessment method was applied, this is affected by a variable linked to subjective evaluation. The data shown here must therefore be considered as indicative.

DATA TREE CONTRIBUTION TO URBAN FOREST PLANNING

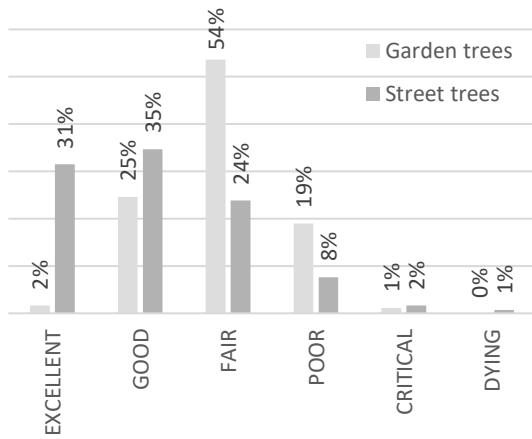


Figure 82 - *C. australis* condition comparison between garden and street trees (in %).

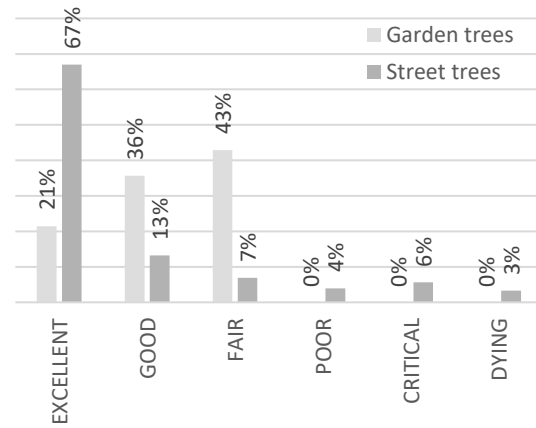


Figure 83 - *P. hispanica* condition comparison between garden and street trees (in%).

As mentioned in the section 5.3.5, specimens with an 'EXCELLENT', 'GOOD' or 'FAIR' condition will be considered in this comparative analysis.

In the Figure 84 we can observe that, independently of the observed DBH class, the mean crown height is higher for trees within gardens, but with statistical significance ($\alpha < 0.05$) for the intermediate classes. The same tendency, even if less pronounced, can be observed in the Figure 85, for crown width. Interestingly, a statistical significance (with $\alpha < 0.05$) occurred only for two of the DBH classes: 20-30cm and 50-60cm; highlighting how these are the two growing stages of the species, within which the influence of the surrounding environment generates greater differences. The difference between the species is explained by the perimeter arrangement of the *C. australis*, which, as previously pointed out, although part of the garden, play a hybrid role, acting as roadside greenery and consequently being affected by its maintenance practices. Despite this ambiguous nature, the specimens belonging to the studied gardens have a greater development, in height as well as in width of foliage, for the same stem diameter (DBH).

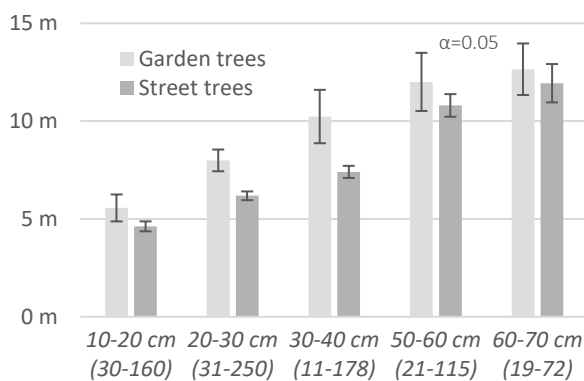


Figure 84 - *C. australis* crown height (m) comparisons with statistical significance ($\alpha < 0.05$)

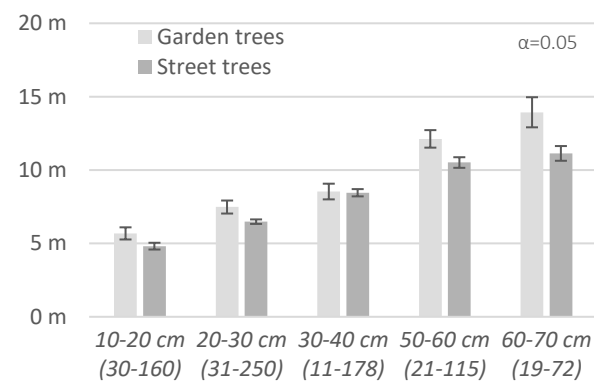


Figure 85 - *C. australis* crown width (m) with comparisons with statistical significance ($\alpha < 0.05$)

The comparison is very interesting when referring to canopy cover and leaf area, both expressed in square metres. We find a tendency for the tree gardens exhibit larger leaf areas, but only for 20-30cm class these

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differences have statistical meaning ($\alpha < 0.05$). When, on the other hand, the DBH increases to 50-60cm these differences decrease until they almost completely disappear. The mean results were obtained with a great disparity in terms of sample size. In this regard, it should be noted that the number of specimens (indicated in brackets under the DBH class) is considerably larger for the street trees. The 30-40cm class is the perfect example as 11 specimens belonging to the gardens, compared with 178 specimens surveyed on the roadside; with this difference the confidence interval obtained will be much greater for the garden trees, generating data strongly influenced by differences in sample size.



Figure 86 - *C. australis* canopy cover (m2) with confidence interval 95%.



Figure 87 - *C. australis* leaf area (m2) with confidence interval 95%.

As a confirmation of the results observed for *C. australis*, we can observe the data for *P. hispanica* for the DBH 70-80 cm class. This class is composed by three specimens for gardens and six specimens among street trees. A general tendency for higher values for garden trees but statistically significant differences are observed only for height and leaf area.

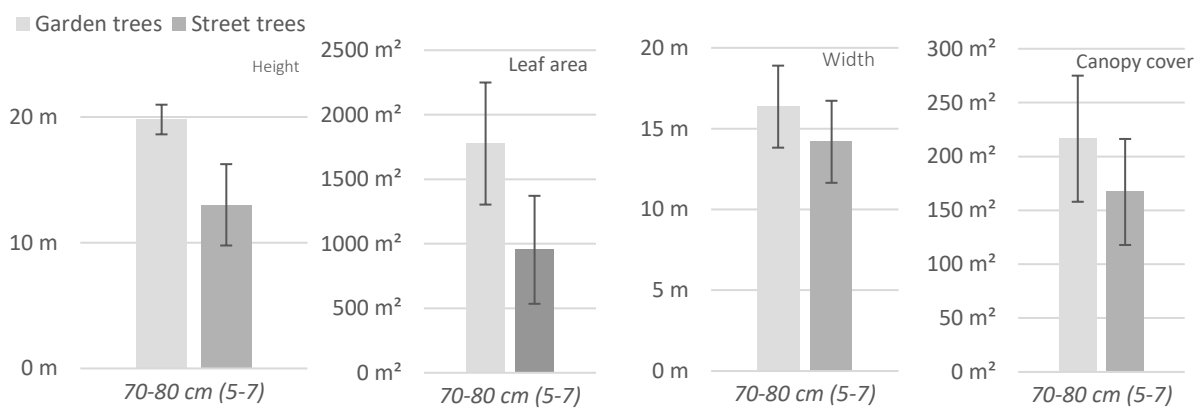


Figure 88 - *P. hispanica* comparison of various dendrometry attributes between garden and street trees - $\alpha = 0.05$

7 Forecasting results

7.1.1 General forecast

The next sections summarize the main results of the projection for gardens development according to different scenarios for a period of 30 years. In the case of no replacement practice for dead trees, the total number of individuals would drop dramatically (Figure 89). Within thirty years, considering the default mortality rates indicated in section 5.4.2, the total number of individuals would drop from 892 to 322, corresponding to a reduction of . 64% of the current population. This first trend, proposed by the iTree software, shows the fundamental importance of urban arboretum planning, since without adequate maintenance policies, would probably lose a large part of the current stock. However, this first forecast does not necessarily imply a loss of ecosystem services due to a reduction in number of specimens. Previous analyses showed how most of the quantifiable benefits derived from vegetation come from large specimens. it is possible, therefore deepen the predictions, again using the default settings, and understand how gardens will behave in terms of ecosystem benefits.

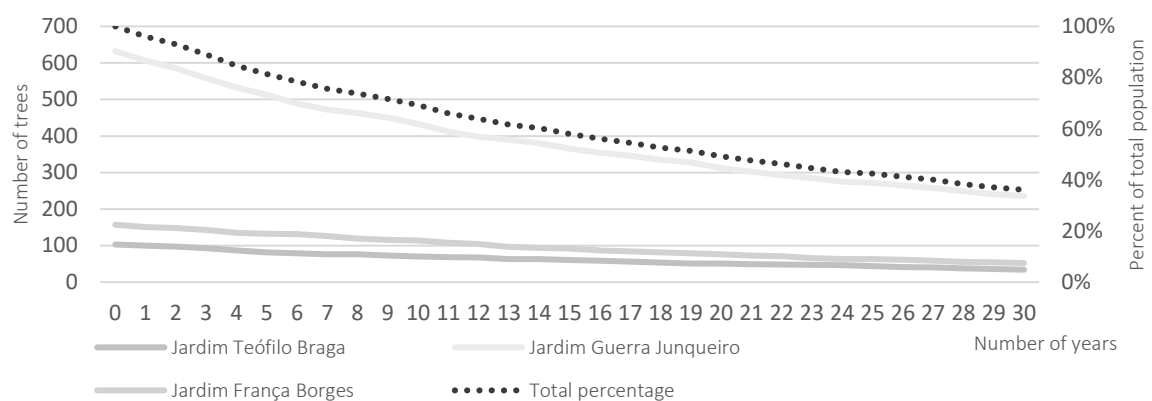


Figure 89 - Tree number general forecast

The outcomes derived from the application of the methodologies delineated in Section 5.4.3 above are presented herewith, pertaining to four distinct hypothetical scenarios.

7.1.2 Specific forecast on Jardim Teofilo Braga

7.1.2.1 Economic value at the first moment

The first appreciable result of the scenario methodology applied here is certainly how the value of trees changes (Figure 90). As already indicated in the section 5.4.1, the software used here calculates a replacement value for the trees inserted. At time zero, any imagined scenario, other than scenario one, in which nothing will be changed, will result in a reduction of the total value of the arboretum which, for the Jardim da Parada, was estimated to be around 318610.48€. This sudden decrease is due to an unequivocal decrease in the number of trees in the garden. Under the third scenario, a situation in which the fungus *Inonotus rickii* (see section 5.4.3.3) caused serious damage to the *C. australis* population, it expected to have the highest loss of value (up to 84729.83€). Similarly, the fourth scenario, in which the elimination of the two *Metrosideros excelsa* specimens is imagined, also shows a decrease in replacement value of 28713.12€. The intervention proposed by the

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Metropolitano del Lisboa, aggravated by the removal of two more specimens, in addition to those envisaged in the section 5.4.3.2, entails a loss, in replacement value, of 24194.72€, lower than any other scenario except the first. This value is an indicative estimate and, thanks to the replacement of some of the removed specimens, can probably be recuperated within a few years.

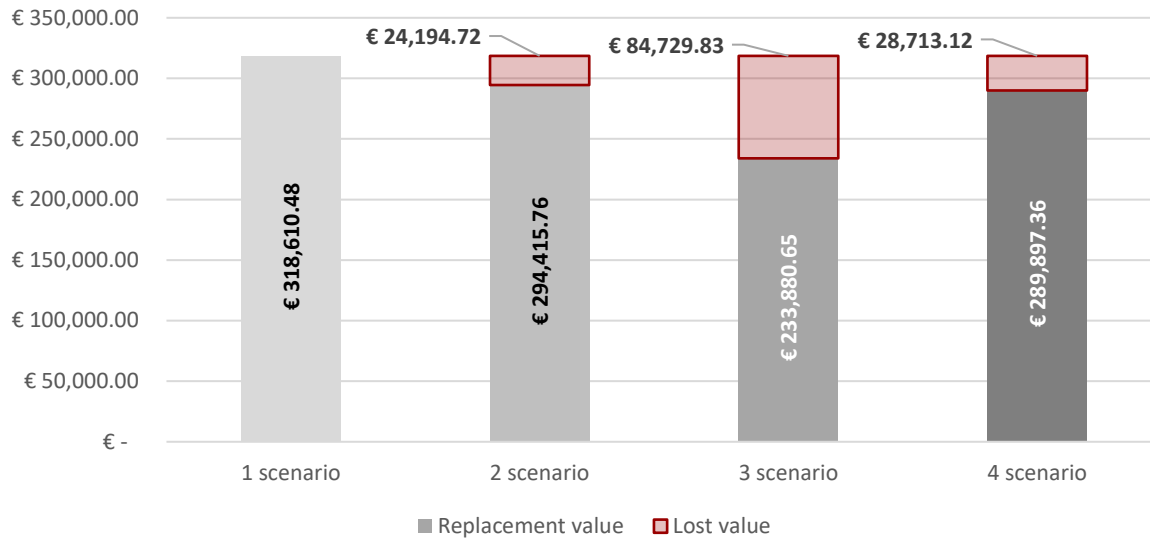


Figure 90 - Replacement value by scenarios

7.1.2.2 Garden structure evolution

Depending on the scenario applied to the studied gardens, its structure will show different patterns of behaviour over time. As pointed out in the section 7.1.1, in our forecast system, in which for any scenario, it was not foreseen the insertion of new trees, the number of specimens will decrease, since are only estimating a loss.

The trend in the number of specimens might behave over the next thirty years for the four proposed scenarios, shows in many cases a considerable decrease in the first five years. Interestingly, the inclusion of four new trees in the second scenario leads to a higher number of trees, compared to scenario one, within the first five years of the forecast (Figure 91). Furthermore, focusing on the evolution of scenario four, the accidental loss of the two *M. excelsa* specimens could generate a lower loss of trees in the long run. This is matched by the canopy cover forecast (Figure 92), which shows a greater development, compared to the other scenarios, between the 25th and 30th year of the forecast.

The most drastic decrease can be observed in the third scenario, in which the population of *C. australis* suddenly decrease and continuing its decline over the 30-year period (Figure 91). The same trend can be observed on the canopy cover, as the loss of *C. australis*, as the dominant species in the garden, would generate a large loss in canopy area and consequently less shade. This increase in solar infiltration could results in a better development of the remaining specimens, which observed in the Figure 93 for the annual growth in terms of DBH. In this case, the third scenario maintain the highest values for the first twenty-five years, only to be surpassed around the thirtieth year by scenario one, whose vegetation has not suffered any external influences.

DATA TREE CONTRIBUTION TO URBAN FOREST PLANNING

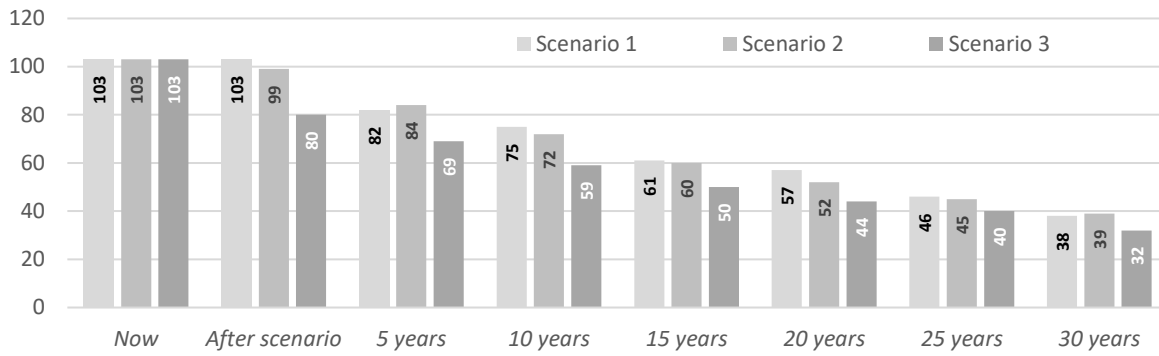


Figure 91 - Tree number forecast

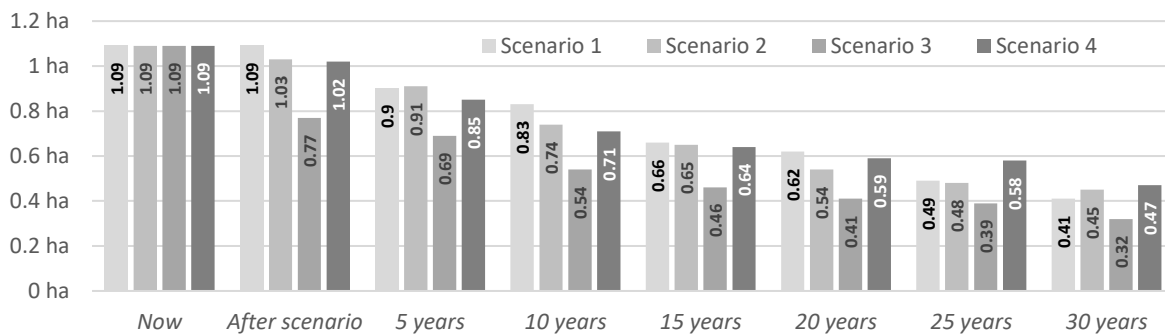


Figure 92 - Canopy cover forecast

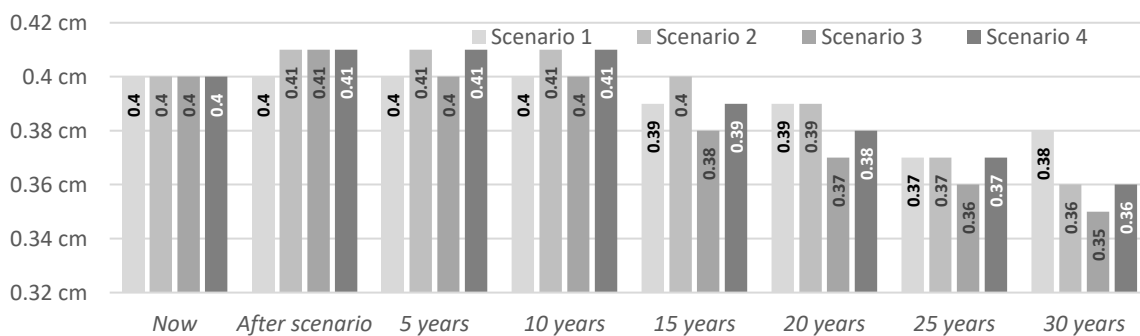


Figure 93 - Mean DBH growth forecast

Among the fundamental elements for the quantification of ecosystem benefits, the estimated leaf area, shows different trends in the case of the four proposed scenarios. In the hypothetical case of a decrease in the number of trees in the garden, a relative decrease in leaf area is to be expected and almost taken for granted (Figure 94). This data, however, does not agree with the estimated trend for Leaf Area Index (LAI), which will tend to increase as the number of specimens and leaf area decrease (Figure 95). A decrease in leaf area but an increase in LAI suggests that is expected to have a more intense decrease in vegetation characterised by more expansive and less dense canopies. In this case, it is envisaged that the area covered by canopies will decrease more than the total leaf area, resulting in a garden with fewer but denser canopies.

The third scenario, in which a greater number of specimens (Figure 91), leaf area and canopy cover area have been lost (Figure 92, Figure 94), shows a marked increase in LAI (Figure 95), probably resulting from a more intense activity on the part of the remaining vegetation.

DATA TREE CONTRIBUTION TO URBAN FOREST PLANNING

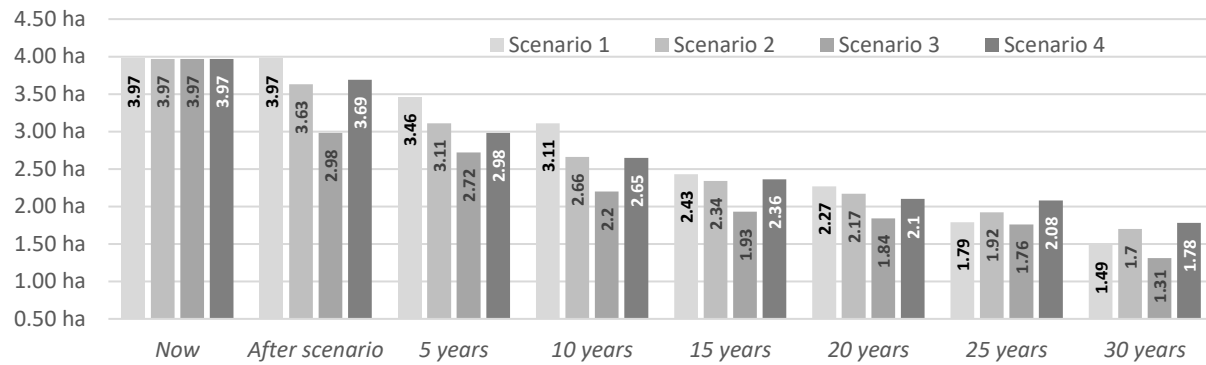


Figure 94 - Leaf area forecast (ha)

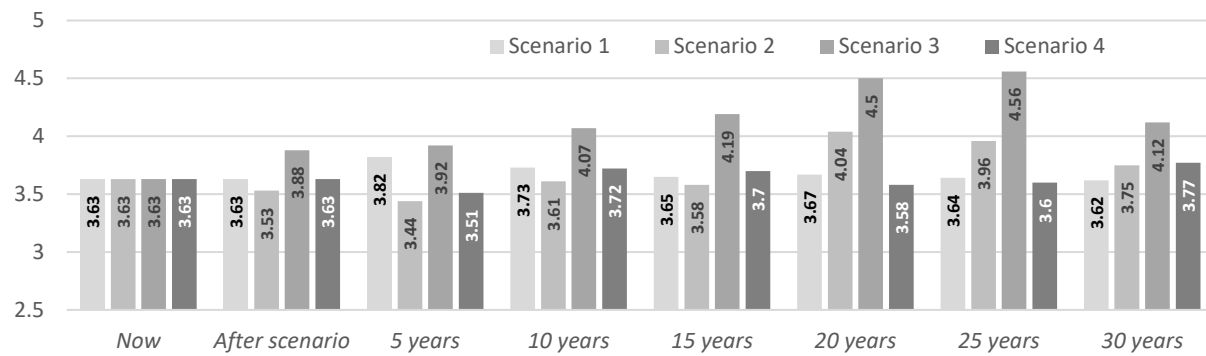


Figure 95 - Leaf area index forecast

7.1.2.3 Carbonic effect

The growth in DBH and the quantification of leaf area allowed estimate the ecosystem benefits related to the carbon provided by the garden over the next thirty years, relative to the four different scenarios. More specifically, the loss of the two monumental *M. excelsa* specimens generates a sudden loss of carbon stored in the garden's vegetation (Figure 96). This can easily be related to the large size of the two specimens, for which they are equally important in terms of landscape. This important loss is not prolonged excessively since at year 30, the four scenarios are aligned on the same value of stored carbon. This prediction can make an alarming reading, which can be combined with the estimated decrease in the number of trees (Figure 91), according to which, at the current state of the garden, with the losses predicted by the iTree-eco software, the number of specimens and the carbon stored by them will be significantly lower than at present. This result would seem, over the thirty-year period, to be minimally influenced by the imagined scenarios which, at the end of the period, show only slight differences between one and the other. It is interesting to note in the Figure 97, how the two *M. excelsa* specimens have a much greater influence than the loss of many *C. australis* as assumed in the third scenario, at least in the short term.

Looking instead at the annual carbon sink capacity (Figure 97), according to the iTree-eco predictions, there is no substantial decrease as a first consequence of the different scenarios. In fact, only in the third and fourth scenarios it is observe a slight decrease from 0.35 to 0.34 metric tons of carbon. Each scenario shows a constant decrease in the amount of carbon absorbed annually, which can be related to the decrease of specimens in the

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garden (Figure 91). The best of the projected scenarios, despite the high rate of vegetation mortality, proposed by the iTree-eco software, turns out to be scenario number one, which maintains, at year 30, a value of 0.17 metric tons of carbon absorbed, higher than the 0.12 metric tons absorbed by the worst scenarios (number 3 and 4), well below the 0.35 currently estimated.

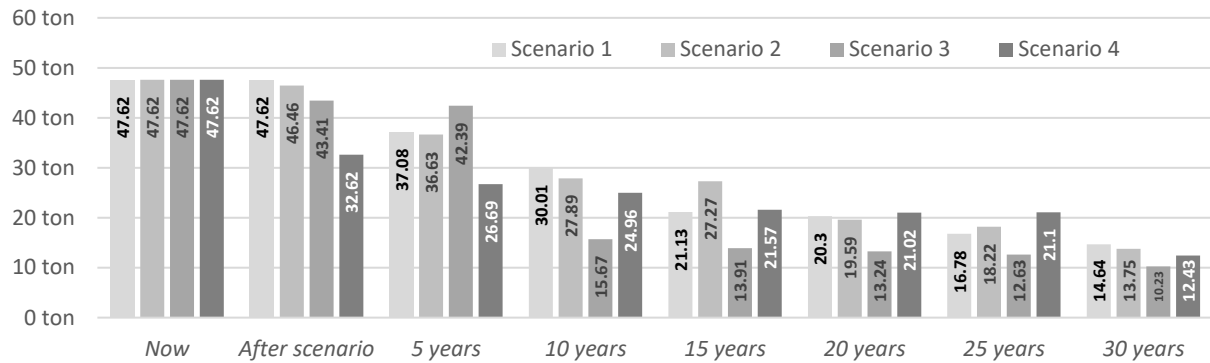


Figure 96 - Carbon storage forecast

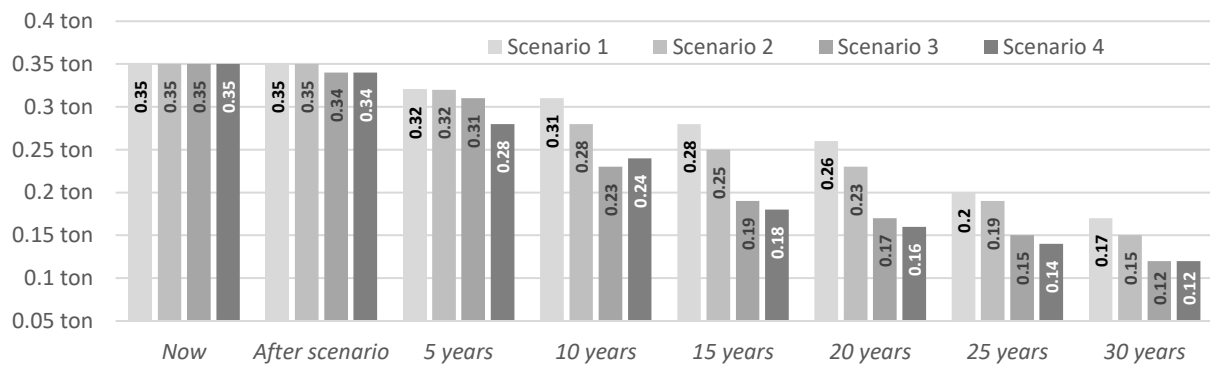


Figure 97 - Annual carbon sequestration forecast

7.1.2.4 Hydrologic effect

An ecosystem benefit of fundamental importance, and whose trends can be estimated for different scenarios, is the hydrological effect that vegetation can have on the surrounding environment. Figure 98, highlight how a sudden reduction in *C. australis*, as the most influential species for the hydrological context, leads to a sudden decrease in avoided runoff. The same trend can be observed for the third scenario in the different graphs (Figure 98, Figure 99, Figure 100, Figure 101, Figure 102) relating to the hydrological effect.

Dealing with the management of the water component by the studies trees, it is interesting to note that the absence of the two *M. excelsa*, corresponding to the fourth scenario, over the long term leads to a lower decrease in water intercepted, compared to the other scenarios imagined (Figure 99). The same trend can also be seen in the other hydrogeological elements. Besides the fourth scenario, a positive long-term effect of the second scenario stands out, both farming a removal and partial replacement of selected specimens of *C. australis*. After the twenty-fifth year, the values of evaporation (Figure 100), transpiration (Figure 101) and potential evapotranspiration (Figure 102) under these scenarios, exhibit a lower reduction than under the first

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and third scenarios. From this prediction it is possible deduce that a gradual replacement of selected trees with young specimens could guarantee a better result in hydrogeological terms.

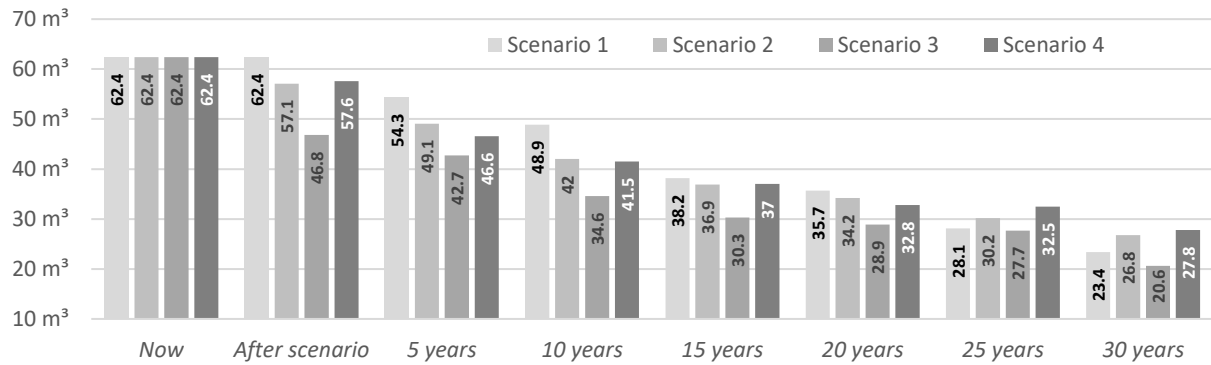


Figure 98 - Avoided runoff (in m³) forecast according to 30 years evolution of the four scenarios.

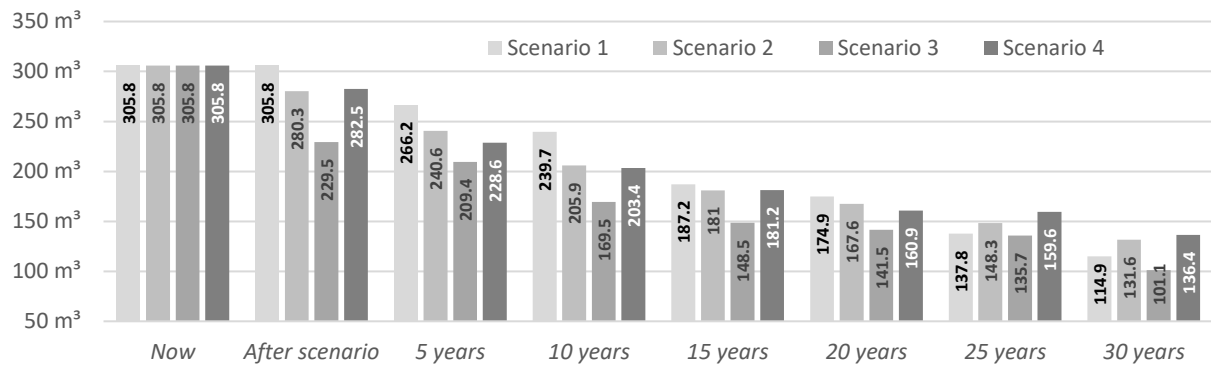


Figure 99 - Interception (in m³) forecast according to 30 years evolution of the four scenarios.

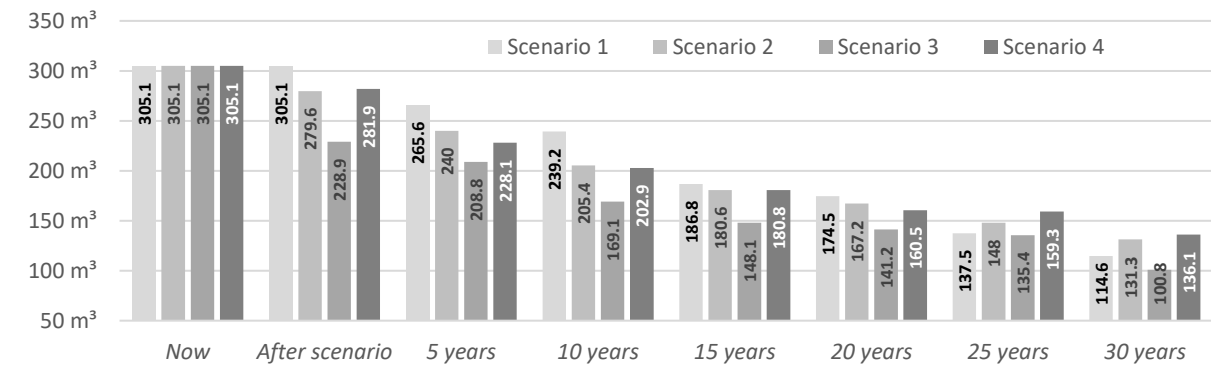


Figure 100 - Evaporation (in m³) forecast according to 30 years evolution of the four scenarios.

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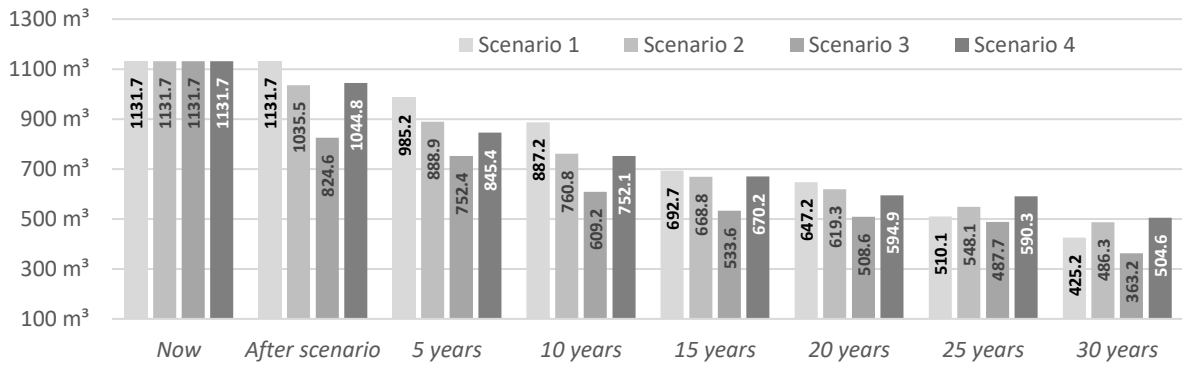


Figure 101 – Transpiration (in m³) forecast according to 30 years evolution of the four scenarios.

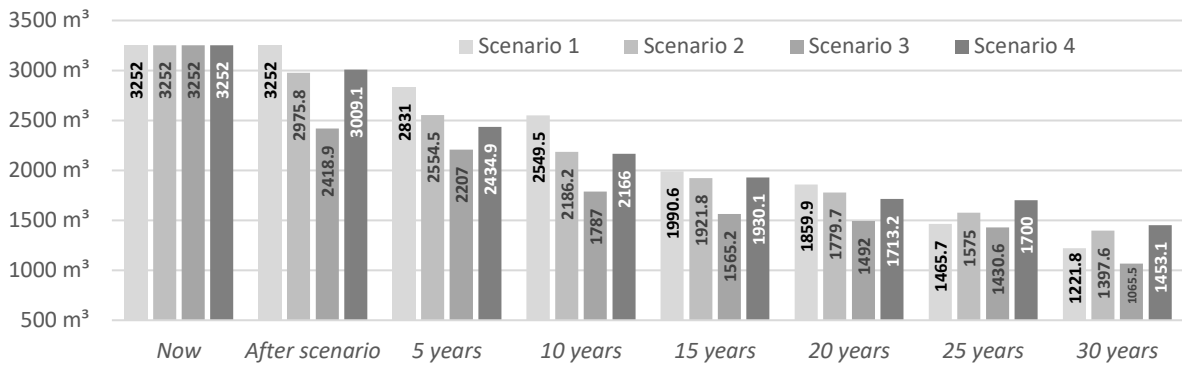


Figure 102 - Potential evapotranspiration (in m³) forecast according to 30 years evolution of the four scenarios.

8 Conclusions

8.1 Conclusions and final considerations

The urban landscape, with its vast possibilities and contradictions, is experiencing an era of radical change; both structurally and ideologically. The need to look at our everyday living environments as part of a larger system, closely interconnected with what is around us, has given rise to a new reading of urban ecology (Grimm et al. 2000)(see section 2.1).

With the goals set by the United Nations for the creation of a sustainable development model, and the new Portuguese legislation on urban arboretum management, vegetation assumes a leading role in management of man-dominated systems (see sections 2.2, 2.3, 2.4, 2.5,2.6).

In recent years, we have found ourselves managing more and more information, and in various fields it has been discovered that data, their interpretation, and the knowledge they generate, are the real source of wealth, and with this, the possibility of making targeted choices represents a considerable added value (Rossi et al. 2022). Also in the case of urban vegetation, sufficient information is beginning to accumulate and available to provide detailed knowledge of our environments aiming possible future projects (see section 2.7, 2.8). The analysis of dendrometry data, combined with tree condition information can be of outmost importance in supporting management objectives and underlying decisions (Nowak and Crane 2000). Testing and improving tools available for quantifying the implications of these management decisions (planting, pruning etc) in the provision of ecosystem services by trees, is thus the necessary next step for urban forest sustainability (Owuor et al. 2022). In the present study these topics were addressed by characterized three historical gardens and comparing the performance of some of the tree species under different contexts and scenarios.

In this study, we were able to collect data on 892 trees belonging to 130 different taxa. This is therefore only 3% of the specimens recognised to date in the gardens of Lisbon in the work of Soares (2021), and only 16% of the taxa. Compared to the taxa studied within Lisbon's street vegetation, 26% were covered (Cunha et al., 2022); a higher percentage than the 16% that occurred with the total gardens, demonstrating how species richness within gardens is higher than within street trees. With the external available information and the field data collected specifically for these analyses, the results of this study show how the vegetation presents characteristics that differs between gardens. The Jardim Guerra Junqueiro presents a much higher species diversity than the others, while the Jardim Teófilo Braga is characterised by a strong dominance of a single species (see section 6.1). These structural differences between one garden and another combined with the knowledge that higher species heterogeneity generates more resilient environments helps to understand which of the study areas may be more susceptible to change due to external influences (Alberti et al. 2003). In our case, the Jardim Teófilo Braga is characterised by less species diversity and greater dominance, making it the least ecologically resilient studied area (see section 6.1). Furthermore, it was possible to estimate that the Jardim Guerra Junqueiro has the highest annual oxygen production per unit area, exceeding 15.000 kg/yr of oxygen emitted into the atmosphere (see section 6.3.5). Among the gardens studied, it was observed that the Jardim França Borges is characterised by the smallest leaf area per unit area (see section 6.2), information that will

affect the ecosystem benefits it provides, since there is a close relationship between the capacity of the vegetation to provide ecosystem benefits and the estimated leaf area (Nowak et al. 2008).

Using iTree-eco software, it was possible to understand which species have the greatest influence on the ecosystem benefits provided by each garden. Specifically, within the gardens studied, a specimen of *Taxodium huegelii* had the highest carbon sequestration. (see section 6.3.3), while *Ficus benghalensis* is the most influential specimen in terms of annual carbon removal (see section 6.3.3). As for the hydrological effect of the vegetation, *C. australis*, given the large number of specimens present, is the species that contributes the most in terms of stormwater management, although at the specimen level it is *Platanus orientalis*, with its considerable tree size, that provides the highest benefits (see section 6.3.4). Likewise, *Platanus orientalis* specimens dominates over the rest in terms of the quantity of air pollutants removed (see section 6.3.6). Of the genus *Platanus*, it was observed that it is the surveyed specimens of *P. hispanica* that have the highest VOC production (see section 6.3.6). According to the quantification in section 6.3.2 and 6.3.3, the largest trees studied can store around 7000kg of carbon in their tissues and withdraw at most around 80kg per year from the atmosphere. These results seem far greater than those obtained from other studies that speak of large specimens (Geraldes 2022).

Conversions of ecosystem benefits into economic values have confirmed that *C. australis* is the species that generates the highest economic value, given its high representativeness in the study sites, exceeding 3000€ per year in benefits (see section 6.3.7). This economic quantification is somehow underestimated, as the tool used for the analysis do not consider the landscape and social value that the Flora component is able to provide in urban space, confirming the work of Soares (2006), namely that the quantification of ecosystem benefits still has difficulty in taking into account some of the ecosystem services from which we benefit.

By cross-analysing the data from the Lx-Tree project with those collect during the current study, it was possible to identify a difference in terms of structure and ecosystem benefits between street trees and garden trees (see section 6.4.1). It was thus highlighted how the architecture developed by street trees, strongly influenced by their location and the dendrometry features they must assume in order to avoid damage and risk to humans, generates a difference in their growth and consequently in the benefits provided when compared to in the gardens (see section 6.4.2). These results are in accordance with the ones referred by Muscas et al. (2023) demonstrating the effect that the urban environment has on tree growth.

Regarding possible future scenarios, this study tested the “forecast” function within the iTree-eco software, verifying how, in the absence of information regarding garden maintenance and mortality of the specimens, it is foreseen a continuous decrease in the number of trees (see section 7.1.1). The outputs from four possible development scenarios on the Jardim Teofilo Braga, stressed how different interventions can generate different results within 30 years (see section 7.1.2). This analysis was proof of the extreme importance that models made with the existing data can have to weight design choices over a long period of time.

Taken together, the different analyses carried out during this study show how the data currently available is a very valuable resource for those dealing with the design and planning of our urban landscapes. This study depicts the use of qualitative and dimensional data, relating to the current state of vegetation, to weigh up

design choices that could make a difference to the positive outcome of an urban intervention in Lisbon. It might be interesting to integrate within the preliminary analyses, which every project must have, a component like the one proposed here, which could assess the quality and quantity of the ecosystem benefits (a positive trade-of between services and disservices) generated by the proposed interventions to increase future sustainability in man-made landscapes.

8.2 Suggestion for future studies

This study was carried out with limited data and time constraints. In future studies, it might be interesting to re-propose the methodology used here to verify how more data (i.e., more gardens, expanding comparisons to other species, contexts and scenarios) can influence the results obtained, confirming, or denying our conclusions. In addition, considering that the data processed are geo-localised, analyses could be carried out that include the spatial variable, thus yielding mappable results. Through the inclusion of the spatial attributes, microclimatic conditions could then be taken into account, highlighting more precisely the differences between the environments in which the various specimens are located and their development (Alcoforado et al. 2005).

In conducting analyses using the iTree-eco software, limitations were noted, especially about the 'forecast' function. In the present study, these were bypassed by adapting the data library supplied to the software for analysis. In this regard, it might be interesting to have more freedom in the manipulation of future scenarios, such as the possibility of indicating the species of the new specimens introduced.

Dealing with the taxonomic component of the analysis performed, it was not possible to integrate the option of evaluating the inclusion of new plant species into the study. For this purpose, the iTree platform provides software called iTree-species, which can guide a plant selection based on the desired ecosystem benefits. iTree-species has already been tested within scenario planning models, demonstrating its great potential (Amini Parsa et al. 2020). Like many others in the iTree family, iTree-species has not yet been developed for our geographical area, so caution must be taken when evaluating the results obtained from the software by checking the recommended species according to our specific needs.

To conclude, a further point of controversial nature is certainly the need to include social, cultural and landscape value in the quantification of ecosystem benefits (Keeler et al. 2019). These elements are economically considered externalities, the quantification of which is as dubious as it is difficult (Tyrväinen and Väänänen 1998). Fortunately, in recent years, several valuation methods are emerging for the quantification of the value of green infrastructure, among them, for example, the Analytical Green Estimation Method (Frontini 2023). This and others are trying to bridge the gap that exists between the economic value given to vegetation and the real benefit it provides (Roy, Byrne, and Pickering 2012). Including such an evaluation within the analysis of Lisbon's urban forest would seem almost obligatory, since the capital of Portugal is able to offer spectacular environments, in which the landscape and the vegetation that stands out are the undisputed protagonists

8.3 One last thing

Finally, to emphasise once again the daily importance of the tree component within the ecosystems, I would like to express my apologies to those who, reading this document, have seen plants treated as mere numbers or monetary values. Several times within the text the word 'green' has been used to refer to a group of plants without defining them specifically, but as Metta (2022) teaches us, the term green is improper and does not honour the plants we are referring to. Although up to this point, we have looked at trees as if they were tools within an industrialised system aimed at achieving maximum productivity, in our case of ecosystem services, we must strive to get out of "plant blindness" by reminding ourselves that they are living organisms and not delude ourselves that they are tools at our disposal. In a utopian science-fiction idea, we should learn to consider the environments we live in every day, not as our own but as places where we coexist with different species, including plants, and as such, presuppose living together, a condition that we already know to be one of the fundamental strategies for our survival and not only.

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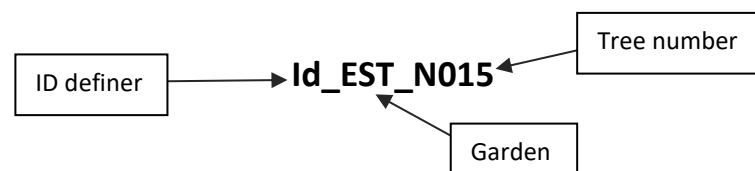
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Appendix No.01 - Field data collection

Data collection regarding the trees was carried out according to the procedures established for the census conducted during the Lx-Tree project (Soares et al. 2022). It was of paramount importance to keep the same methodology so that the data could be compared while minimizing the margin of error. The data collected in this way may later take part in the Lisbon municipality's urban forest database, so in addition to the information needed to describe the specimens within the iTree software, the information required by Law n59 of 2021 was also collected (Assembleia da República 2021).

The information thus collected for each specimen can be divided into visual and instrumental analyses. In the case of purely visual assessments, the data collected were:

- Tree Id. → owner identification code of the analysed specimen, consisting of an alphanumeric abbreviation capable of recognizing the garden to which it belongs and sequential numbering. The identification number consists of three elements divided by the underscore character (_). The first information is the data contained, in this case the wording id to signify that one is reading the identification number of the specimen. The second piece of information is the identification code for the garden to which it belongs: EST for the Jardim Guerra Junqueiro; PDR for the Jardim França Borges; TEO for the Jardim Teófilo Braga. Finally, the last piece of information is an increasing numbering, consisting of three digits and preceded by the character 'N', belonging to each garden. Below is an example of ID:
- Live tree in public space → the central element for data collection, as the specimens thus surveyed are found planted in public space, are still alive and are characterized by an arboreal phenological form.
- Garden name → the name of the garden in which the census specimen is found.
- Data → the day of field visit of the specimen.



- Typology → The type of space in which the tree is planted, which can be:
 - Caldeira, in case it is located within a proprietary flowerbed;
 - Green space (espaço verde), when the tree specimen is located within a green space of considerable size, which concerns accessibility for people.
 - Pot (floreira), when the specimen is placed inside an above-ground container, a casuistry that, in the gardens analysed, was never encountered.
 - “Sem caldeira”, in case the tree is in a borderline situation of soil impermeability, a situation encountered very infrequently;
 - “Canteiro”, perhaps the most present of the case histories, in which the tree is located within a flowerbed, in composition with other plant species, distinctly restricted and with interdicted access.
- Irrigation → necessary to determine the type of environment in which the specimen is growing. In this case, the categories used were:
 - Manual (manual), if the specimen was clearly watered manually using a watering can, a situation never encountered.
 - Mobile sprinkler system (brotado), irrigation through a mobile sprinkler system, used when needed.
 - “Aspersor/Pulverizador”, a fairly frequent casuistry, especially in ‘canteiro’ situations in which there was a fixed, concealed sprinkler irrigation system.
 - Tire (mangueira), where irrigation was by an operator using a tire.

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- Without irrigation (sem rega), where the plant was evidently developing in the complete absence of an irrigation system.
- No information (Não sabe), If there was no clear information regarding the presence or absence of irrigation for that specimen.
- “Doença ou praga” → Generic information indicating whether disease, damage, or malformation has been found in the tree specimen.
- Species → Species recognition reported with the Latin name of the specimen analysed.
- Percentage of missing canopy → Knowing the species being evaluated and the architecture it is expected to develop, it was possible to estimate a percentage of missing canopy, as reported in the iTree manual (U.S. Forest Service 2021)
- Percentage of canopy health → as in the previous indicator, based on the assessment required for analysis through the iTree software, we went to indicate a percentage of canopy health (U.S. Forest Service 2021)
- CLE (Crown light exposure) → that is, the exposure of the specimen to direct sunlight, expressed as a value from 0 to 5, where 0 will refer to a dead specimen while 5 will be a specimen that receives full light on all 4 sides and above.
- Percentage of impervious under canopy → element estimated visually and expressed as a percentage like the previous specimen canopy information.
- Percentage of shrubs under canopy → element estimated visually and expressed as a percentage like the previous specimen canopy information.
- Status → necessary in case the tree specimen does not meet the live condition in the public space, it may bear the inscriptions:
 - Private, in case the tree is in private space and cannot be accessed to do data collection.
 - Downed/stump, in case the tree has been felled but the stump is still present.
 - Inexistent/deleted, the situation in which the specimen is no longer present but traces of it can be seen.
 - “Caldeira vazia”, a case in which only an empty flower bed is present, and it is not possible to tell whether or not there was previously a tree stand
 - Paved, a situation in which the area has been paved and no longer has the conditions to accommodate a tree line.
 - Dry, dead tree, dry but still in situ
 - Shrub, it is a shrubby form.
 - Site under construction, the area is currently under construction and cannot be accessed to conduct data collection.

The information gathered through instrumental analysis was:

- Geographic coordinates → The geolocation of the specimen, reported through XY coordinates in decimal form, in accordance with the ETRS96 georeferencing system.
- Perimeter of the trunk at breast height → instrumental measurement, taken using a metric string at the indicative height of 130cm from the tree collar. This measurement was repeated up to 6 times for multi-stem specimens.
- Diameter of canopy → measured according to the North-South and East-West axes by using a metric string with a length of 30m.
- Total height → total height of the arboreal specimen, starting from the base to the highest point, measured using a digital hypsometer of the Vertex III brand. Measurements were made in accordance with the indications given in the instrument manual (SWEDEN AB 2005).
- Height of the live crown → refers to the height of the last leaf, as, in some cases, a difference has been found between the total height of the specimen and the height attained by the crown due to the presence of dry branches, otherwise known as dieback.

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- Height at the base of the crown → one element that easily distinguishes one species from another is the height from which the foliage begins to develop. In addition, the architecture of the plant is strongly influenced by its maintenance and containment especially in urban environments.
- Photo → collection of one or two photos, necessary to identify accurately in the future the specimen described here and any special marks it has.

For greater productivity in the data collection process, we made use of two software tools and a methodology already used within the CEABN applied ecology research centre. The first tool, necessary for geolocation of specimens, was Alpine Quest. On the application it was possible to upload the databases already present in KML/KMZ format to follow up with a verification and integration of tree information (Psybria 2023). For the proper data collection, a customised Google form was developed, in which the different parameters listed above were entered (Google 2023a).

Appendix No.02 - Post collection corrections and additions

Corrections and additions had to be made to the data collected in the field. The process of data collection in the field, which is conducted using digital technologies that simplify the subsequent transcription and arrangement of the collected information, is always simplified as much as possible to implement productivity in site. For this purpose, simplifications of the information to be collected were agreed upon and some data were integrated secondarily. Specifically, the simplifications introduced were as follows:

- As there was no opportunity to collect information from two different gardens on the same day, the name of the garden was integrated secondarily for each individual surveyed on a given day.
- The date was extracted independently from the data registration information.
- The height of the crown was measured and entered manually, only if it differed from the total height of the tree; otherwise, the data was left null and supplemented secondarily by copying the height value of the specimen.

The remaining information was reported internally with corrections required. The manual entry of the specific Latin name for each specimen generated typing errors for which corrections were necessary. The specific names of the various recognised plant species have been checked and corrected based on the information contained in Plants of the World Online (Royal Botanic Gardens 2023). On rare occasions, a metric measurement was reported incorrectly due to a typing error. Once the inconsistency of the data was detected, it was corrected on the spot, if possible, while field measurements were repeated when necessary.

To the table resulting from the information gathered in the field, four columns were added containing information on: the genus and family to which it belongs; the geographical origin of the species (autochthonous, allochthonous, invasive); and the type of vegetation, phenology (deciduous, evergreen, decaying). This additional information allowed us to proceed to a detailed characterisation of the vegetation of the three gardens studied. The information added here has been extracted from the vegetation information provided by the municipality of Lisbon, The Lx-Tree data base and from the information contained within the Lx-Garden project documents; if necessary confirmed and corrected through the use of the database available from the Royal Botanic Garden (Royal Botanic Gardens 2023).

Appendix No.03 - iTree project submission

The data after eventual corrections were prepared for processing by the iTree-eco software, by selecting and organising the information required for the software to read the data. Of the 997 georeferenced points during field work, the iTree software had 892 tree specimens analysed, as the remaining 105 did not comply with the condition of Live tree in public space; a considerable proportion of these were in fact specimens that had been surveyed during the Lx-Gardens data collection but did not currently exist.

The 892 specimens to be analysed were assigned an increasing numbering under the name 'I-Tree ID' following the temporal order of the collected data. In this case, the first tree surveyed was given the numbering 1 and consequently the last tree surveyed was given the numbering 892. In addition to the new ID, the correspondence with the original ID was maintained to keep a reference with the data collected in the field.

Not all plant species recognised during the census operations are present within the iTree-eco software database, which refers to more than 6,500 different species of trees and shrubs (U.S. Forest Service 2021). If the species recognised in the field did not correspond with the data library, it was necessary to limit entry to the previous taxonomic level, the genus.

The value identified as 'Status' was set to P for each specimen, as only voluntarily planted trees were analysed. Similarly, in the information requested, concerning Land Use, the value P was placed, this time referring to the area's use as a park.

For the 'STRATUM' data, three categories were generated corresponding to the three gardens studied. The value '1' was then attributed to the Jardim Guerra Junqueiro; the value '2' to the Jardim Teófilo Braga; and the value '3' to the Jardim França Borges. The creation of three different stratum will allow us to subsequently organise our data processing by garden and thus create a comparative analysis between the three. Similarly, the address entered corresponds to the name of the garden in which the specimen was censused.

The software requires the indication for each element entered, whether it is a street tree (Y) or not (N). In our case, as the analysis refers to three gardens, the value N was placed for all the specimens entered.

A conversion of the values recorded in the field had to be applied to enter the trunk diameter information. Since the instrument used to measure the trunk diameter of the trees was a metric string, it was possible to measure not so much the diameter as the perimeter with acceptable accuracy. The value of the perimeter in centimetres (p) was converted into diameter(d) using pygreco (π):

$$d = \frac{p}{\pi}$$

For each tree analysed, a minimum of one to a maximum of six dimensions were entered, depending on the architecture of the plant. In the case of a single-stem plant, most situations, it was sufficient to indicate only one value as the diameter. For multi-stem specimens, as many measurements as possible were collected to best describe the specimen. The limit of six was defined based on the data limit accepted by the iTree-Eco software.

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Table 5 - iTree data submission percentage conversion

Collected percentage value	Corresponding iTree-eco value
0	0
0-5	3
5-10	8
10-15	13
15-20	18
20-25	23
25-30	28
30-35	33
35-40	38
40-45	43
45-50	48
50-55	53
55-60	58
60-65	63
65-70	68
70-75	73
75-80	78
80-85	83
85-90	88
90-95	93
95-100	98
100	100

Changes had to be made to the values collected in the field, including the percentage values. During data collection, as the information was collected visually by approximate estimation, percentage values with a deviation of 5% (0-5; 5-10; 10-15; etc.) were indicated. To enter these values into the iTree software, it was necessary to apply the conversion to the corresponding values, which can be seen in the Table 5. This equivalence was applied to the fields measured in percentages, which we remember to be:

- Percentage of missing canopy
- Percentage of canopy health
- Percentage of waterproofing under canopy
- Percentage of shrubs under canopy

The remaining information required for analysis by the iTree software did not need to be adapted. The directly entered data were:

- Diameter of canopy (NS; EW)
- Total height (m)
- Height of the live crown (m)
- Height at the base of the crown (m)
- Coordinates (longitude; latitude).

With the information processed in this way, according to the conditions of the software used, it was possible to proceed with data processing. The processing by the iTree-eco software, once the data has been entered correctly, is automatic and takes place remotely. It was sufficient to upload the processed data to the iTree server (www.itreetools.org/support) to obtain, within a few hours, the output analyses regarding structure and ecosystem benefits for the vegetation studied.

The processed information was exported in XLSX format to be interpreted through graphs and displayed within this document

Appendix No.04 - Calculations and applied indices

Different ecological indices were applied to best characterise the study areas, identifying similarities and differences at the tree level. Based on species richness (S) and abundance (p_i), species diversity is then calculated and expressed through the Shannon-Wiener index (H'):

$$H' = - \sum_{i=1}^S p_i \ln p_i$$

The Shannon index (H') applied here will give us a dimensionless result. When reading this result, we must consider that the lower the number, the more our analysed area will be characterised by only one dominant species, specifically if the result is zero, it will show us that we are in the presence of only one species. Similarly, the higher the value, the more our analysed area will be characterised by an equal distribution of different taxa (Peet 1974).

To give legibility to the diversity value (H') obtained through Shannon's index, Pielou's index (E) was added (Heip, Herman, and Soetaert 1998). This index, called evenness, shows us how far our case study deviates from a perfect uniformity situation. The index relates our diversity to a maximum potential diversity value ($H_{max} = \ln S$) obtained through the following calculation:

$$E = \frac{H'}{H_{max}}$$

Since it is a ratio between our diversity and the maximum possible, the result will be between 0 and 1. If the value were 1, we would be in a situation of maximum diversity; in the opposite case, the closer the value is to 0, the further we deviate from maximum diversity. The diversity and evenness indices obtained in this way have been reported in the results overview, where they were used for the composition characterisation of each garden and a comparative evaluation between them.

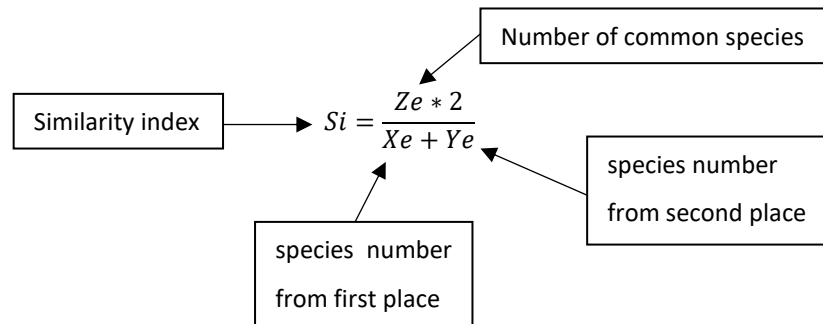
Finally, the dominance index (Odum and Barrett 1971) was obtained for each garden with the percentage of individuals belonging to the two dominant species within each garden. This is a value between 0 and 100, calculated using the formula:

$$iD = (X_i + Y_i) * 100$$

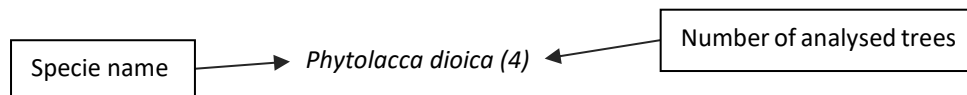
:

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To identify the degree of similarity that exists between the gardens studied, the Sørensen index was used (Jost 2006). This index takes a value between 0 and 1 and can be expressed as a percentage to indicate what proportion of species are in common between the two gardens. It was calculated using the following formula:



For the data analyses and the output graphs, the PivotTable of the Microsoft Excel software was used. The data mean over the individuals belonging to the varied species were obtained by using the function "AVERAGE". For the comparison analysis between garden and streets trees, the function "CONFIDENCE" was used to calculate the confidence interval of the mean included in the graphs shown in the section 0, which was given a value of $\alpha=0.05$, the mean standard deviation calculated through the function "STDEV.P" and a frequency of individuals calculated through the function "COUNT". The factor $\alpha=0.05$ stands for an accuracy of 95% (error probability of 0.05). In this regard, it is necessary to emphasise that on the X-axis of the graphs showing a description of individual specimens, the number of specimens taken has been indicated in addition to the species, see example below



In the remaining analyses in which a mean value appears, due to the minimal numerical representativeness of some species, the standard deviation value has been added to emphasise the dispersion around the mean, how far the collected data deviate from the mean obtained.

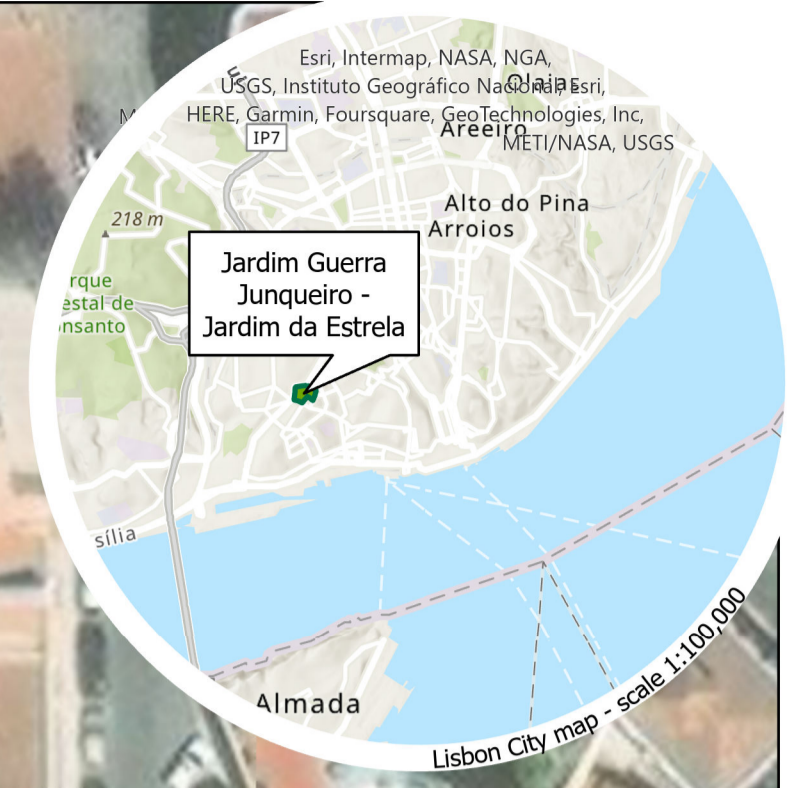
Appendix No.05 - Random selection of trees

To use the 'Random' function called =RAND () within Excel, the following process was performed:

1. Create a new column in the Excel table containing only *C. australis* specimens, within the Jardim Teófilo Braga, with a DBH greater than 40cm. A total of 55 specimens.
2. Associate the =RAND () function with the column to generate a random number between 0 and 1.
3. Reorder the cells according to the random numbering just assigned.
4. Select the number corresponding to the percentage of interest:
 - a. In the first case 92%, equivalent to 51 trees (50.6).
 - b. In the second case 45.7%, equivalent to 23 trees (23.31).
5. The 22 randomly selected specimens are visible in the Figure 12 of the main text.

Table 6 - Random selected trees in Jardim Teófilo Braga

id_TEO_N025	id_TEO_N061	id_TEO_N068	id_TEO_N065	id_TEO_N032	id_TEO_N055
id_TEO_N012	id_TEO_N031	id_TEO_N071	id_TEO_N057	id_TEO_N079	id_TEO_N002
id_TEO_N056	id_TEO_N070	id_TEO_N045	id_TEO_N066	id_TEO_N011	id_TEO_N021
id_TEO_N064	id_TEO_N077	id_TEO_N098	id_TEO_N009	id_TEO_N018	




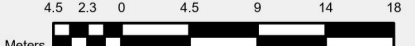
Tree inventory of Jardim Guerra Junqueiro - Jardim da Estrela

Local: Jardim Guerra Junqueiro - Jardim da Estrela
 Estrela parish, Lisbon, Portugal
 Surveying date: 2023
 Scale 1:500
 Student: Eugénio Ferretti
 Cod: 25703
 Professor:
 Ana Luísa Brito dos Santos de Sousa Soares
 Susana Maria de Abreu Dias

In collaboration with the Centre for Applied Ecology Prof. Beata Neves (CEABN)
 Data collection conducted during the master thesis project in the landscape architecture degree course at the School of Agronomy, University of Lisbon

Annex No. 06

Legend
 Tree (632)
 See detailed legend in Annex No. 07

Center: 9°9'32"W 38°42'53"N

 Meter

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Appendix No.07 - Trees index of Jardim Guerra Junqueiro

Table 7 - Detailed legend of Appendix No.06

Id	Tree Id	Scientific name
1	Id_EST_N008	<i>Fraxinus angustifolia</i>
2	Id_EST_N009	<i>Celtis australis</i>
3	Id_EST_N737	<i>Arbutus andrachne</i>
4	Id_EST_N012	<i>Platanus orientalis</i>
5	Id_EST_N013	<i>Corynocarpus laevigata</i>
6	Id_EST_N085	<i>Bauhinia purpurea</i>
7	Id_EST_N015	<i>Apollonias barbujana</i>
8	Id_EST_N016	<i>Pittosporum undulatum</i>
9	Id_EST_N017	<i>Styphnolobium japonicum</i>
10	Id_EST_N048	<i>Bauhinia forficata</i>
11	Id_EST_N019	<i>Apollonias barbujana</i>
12	Id_EST_N020	<i>Aesculus hippocastanum</i>
13	Id_EST_N021	<i>Pittosporum undulatum</i>
14	Id_EST_N070	<i>Bauhinia forficata</i>
15	Id_EST_N484	<i>Bauhinia forficata</i>
16	Id_EST_N024	<i>Cupressus lusitanica</i>
17	Id_EST_N025	<i>Quercus robur</i>
18	Id_EST_N026	<i>Erythrina crista-galli</i>
19	Id_EST_N027	<i>Erythrina crista-galli</i>
20	Id_EST_N609	<i>Bauhinia forficata</i>
21	Id_EST_N029	<i>Pittosporum undulatum</i>
22	Id_EST_N030	<i>Pittosporum undulatum</i>
23	Id_EST_N381	<i>Beaucarnea stricta</i>
24	Id_EST_N601	<i>Brugmansia suaveolens</i>
25	Id_EST_N034	<i>Pittosporum undulatum</i>
26	Id_EST_N365	<i>Betula pubescens</i>
27	Id_EST_N036	<i>Platanus orientalis</i>
28	Id_EST_N037	<i>Pittosporum undulatum</i>
29	Id_EST_N289	<i>Butia capitata</i>
30	Id_EST_N039	<i>Pittosporum undulatum</i>
31	Id_EST_N329	<i>Buxus sempervirens</i>
32	Id_EST_N041	<i>Corynocarpus laevigata</i>
33	Id_EST_N042	<i>Pittosporum undulatum</i>
34	Id_EST_N043	<i>Corynocarpus laevigata</i>
35	Id_EST_N044	<i>Pinus canariensis</i>
36	Id_EST_N046	<i>Araucaria columnaris</i>
37	Id_EST_N047	<i>Jacaranda mimosifolia</i>
38	Id_EST_N507	<i>Calocedrus decurrens</i>
39	Id_EST_N050	<i>Aesculus hippocastanum</i>
40	Id_EST_N051	<i>Metrosideros excelsa</i>
41	Id_EST_N052	<i>Cordyline australis</i>
42	Id_EST_N053	<i>Cordyline australis</i>
43	Id_EST_N055	<i>Cordyline australis</i>
44	Id_EST_N056	<i>Cordyline australis</i>
45	Id_EST_N057	<i>Cordyline australis</i>
46	Id_EST_N058	<i>Cercis siliquastrum</i>
47	Id_EST_N059	<i>Cordyline australis</i>
48	Id_EST_N060	<i>Cordyline australis</i>
49	Id_EST_N061	<i>Cordyline australis</i>
50	Id_EST_N062	<i>Cedrus deodara</i>
51	Id_EST_N063	<i>Fraxinus angustifolia</i>
52	Id_EST_N065	<i>Cordyline australis</i>
53	Id_EST_N066	<i>Ficus macrophylla</i>
54	Id_EST_N068	<i>Apollonias barbujana</i>
55	Id_EST_N313	<i>Brugmansia x candida</i>
56	Id_EST_N148	<i>Camellia japonica</i>
57	Id_EST_N549	<i>Brugmansia x candida</i>
58	Id_EST_N073	<i>Taxus baccata</i>
59	Id_EST_N074	<i>Taxus baccata</i>
60	Id_EST_N075	<i>Phoenix canariensis</i>
61	Id_EST_N076	<i>Cupressus sempervirens</i>
62	Id_EST_N077	<i>Cupressus sempervirens</i>
63	Id_EST_N078	<i>Celtis australis</i>
64	Id_EST_N079	<i>Celtis australis</i>
65	Id_EST_N080	<i>Aesculus hippocastanum</i>
66	Id_EST_N149	<i>Camellia japonica</i>
67	Id_EST_N082	<i>Acer negundo</i>
68	Id_EST_N084	<i>Aesculus hippocastanum</i>
69	Id_EST_N010	<i>Celtis australis</i>
70	Id_EST_N086	<i>Brachychiton acerifolius</i>
71	Id_EST_N087	<i>Bauhinia variegata</i>
72	Id_EST_N088	<i>Bauhinia variegata</i>
73	Id_EST_N090	<i>Ceiba speciosa</i>
74	Id_EST_N091	<i>Aesculus hippocastanum</i>
75	Id_EST_N014	<i>Celtis australis</i>
76	Id_EST_N155	<i>Celtis australis</i>
77	Id_EST_N094	<i>Populus nigra</i>
78	Id_EST_N095	<i>Bauhinia variegata</i>
79	Id_EST_N096	<i>Bauhinia variegata</i>
80	Id_EST_N097	<i>Cordyline australis</i>
81	Id_EST_N098	<i>Cordyline australis</i>
82	Id_EST_N099	<i>Cordyline australis</i>
83	Id_EST_N100	<i>Ficus elastica</i>
84	Id_EST_N162	<i>Celtis australis</i>
85	Id_EST_N102	<i>Metrosideros excelsa</i>
86	Id_EST_N167	<i>Celtis australis</i>
87	Id_EST_N170	<i>Celtis australis</i>
88	Id_EST_N172	<i>Celtis australis</i>
89	Id_EST_N106	<i>Aesculus hippocastanum</i>
90	Id_EST_N107	<i>Aesculus hippocastanum</i>
91	Id_EST_N108	<i>Aesculus x carnea</i>
92	Id_EST_N243	<i>Celtis australis</i>
93	Id_EST_N640	<i>Celtis australis</i>
94	Id_EST_N115	<i>Platanus orientalis</i>
95	Id_EST_N116	<i>Aesculus hippocastanum</i>
96	Id_EST_N117	<i>Aesculus hippocastanum</i>
97	Id_EST_N118	<i>Celtis australis</i>
98	Id_EST_N668	<i>Celtis australis</i>
99	Id_EST_N120	<i>Celtis australis</i>
100	Id_EST_N121	<i>Celtis australis</i>
101	Id_EST_N122	<i>Jacaranda mimosifolia</i>
102	Id_EST_N123	<i>Jacaranda mimosifolia</i>
103	Id_EST_N124	<i>Jacaranda mimosifolia</i>
104	Id_EST_N672	<i>Celtis australis</i>
105	Id_EST_N126	<i>Ficus macrophylla</i>
106	Id_EST_N127	<i>Howea forsteriana</i>
107	Id_EST_N128	<i>Howea forsteriana</i>
108	Id_EST_N129	<i>Howea forsteriana</i>
109	Id_EST_N130	<i>Howea forsteriana</i>
110	Id_EST_N131	<i>Howea forsteriana</i>
111	Id_EST_N132	<i>Howea forsteriana</i>
112	Id_EST_N133	<i>Howea forsteriana</i>
113	Id_EST_N134	<i>Howea forsteriana</i>
114	Id_EST_N677	<i>Celtis australis</i>
115	Id_EST_N720	<i>Celtis australis</i>
116	Id_EST_N137	<i>Apollonias barbujana</i>
117	Id_EST_N138	<i>Howea forsteriana</i>
118	Id_EST_N140	<i>Grevillea robusta</i>

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119	Id_EST_N141	<i>Howea belmoreana</i>
120	Id_EST_N142	<i>Grevillea robusta</i>
121	Id_EST_N562	<i>Camellia japonica</i>
122	Id_EST_N144	<i>Howea forsteriana</i>
123	Id_EST_N145	<i>Howea forsteriana</i>
124	Id_EST_N146	<i>Ficus macrophylla</i>
125	Id_EST_N147	<i>Pittosporum undulatum</i>
126	Id_EST_N615	<i>Camellia japonica</i>
127	Id_EST_N552	<i>Cascabela thevetia</i>
128	Id_EST_N726	<i>Celtis australis</i>
129	Id_EST_N735	<i>Celtis australis</i>
130	Id_EST_N163	<i>Ulmus minor</i>
131	Id_EST_N166	<i>Phillyrea latifolia</i>
132	Id_EST_N169	<i>Phytolacca dioica</i>
133	Id_EST_N171	<i>Ceratonia siliqua</i>
134	Id_EST_N174	<i>Ligustrum lucidum</i>
135	Id_EST_N175	<i>Ligustrum lucidum</i>
136	Id_EST_N176	<i>Ligustrum lucidum</i>
137	Id_EST_N177	<i>Corynocarpus laevigata</i>
138	Id_EST_N178	<i>Corynocarpus laevigata</i>
139	Id_EST_N179	<i>Celtis australis</i>
140	Id_EST_N180	<i>Celtis australis</i>
141	Id_EST_N181	<i>Celtis australis</i>
142	Id_EST_N182	<i>Pittosporum tobira</i>
143	Id_EST_N183	<i>Corynocarpus laevigata</i>
144	Id_EST_N184	<i>Araucaria columnaris</i>
145	Id_EST_N018	<i>Casuarina glauca</i>
146	Id_EST_N187	<i>Celtis australis</i>
147	Id_EST_N189	<i>Corynocarpus laevigata</i>
148	Id_EST_N190	<i>Corynocarpus laevigata</i>
149	Id_EST_N191	<i>Howea forsteriana</i>
150	Id_EST_N022	<i>Casuarina glauca</i>
151	Id_EST_N028	<i>Casuarina glauca</i>
152	Id_EST_N194	<i>Corynocarpus laevigata</i>
153	Id_EST_N195	<i>Sequoia sempervirens</i>
154	Id_EST_N196	<i>Sequoia sempervirens</i>
155	Id_EST_N199	<i>Apollonia barbujana</i>
156	Id_EST_N200	<i>Corynocarpus laevigata</i>
157	Id_EST_N201	<i>Acer negundo</i>
158	Id_EST_N202	<i>Corynocarpus laevigata</i>
159	Id_EST_N203	<i>Corynocarpus laevigata</i>
160	Id_EST_N204	<i>Howea belmoreana</i>
161	Id_EST_N205	<i>Howea belmoreana</i>

162	Id_EST_N206	<i>Howea forsteriana</i>
163	Id_EST_N207	<i>Howea forsteriana</i>
164	Id_EST_N208	<i>Howea forsteriana</i>
165	Id_EST_N210	<i>Howea forsteriana</i>
166	Id_EST_N211	<i>Howea forsteriana</i>
167	Id_EST_N212	<i>Howea forsteriana</i>
168	Id_EST_N213	<i>Howea forsteriana</i>
169	Id_EST_N214	<i>Ficus macrophylla</i>
170	Id_EST_N215	<i>Ficus macrophylla</i>
171	Id_EST_N216	<i>Jacaranda mimosifolia</i>
172	Id_EST_N217	<i>Howea forsteriana</i>
173	Id_EST_N218	<i>Howea forsteriana</i>
174	Id_EST_N219	<i>Howea forsteriana</i>
175	Id_EST_N220	<i>Howea forsteriana</i>
176	Id_EST_N031	<i>Casuarina glauca</i>
177	Id_EST_N222	<i>Howea forsteriana</i>
178	Id_EST_N223	<i>Corynocarpus laevigata</i>
179	Id_EST_N032	<i>Casuarina glauca</i>
180	Id_EST_N035	<i>Casuarina glauca</i>
181	Id_EST_N226	<i>Howea forsteriana</i>
182	Id_EST_N227	<i>Howea forsteriana</i>
183	Id_EST_N228	<i>Howea forsteriana</i>
184	Id_EST_N229	<i>Corynocarpus laevigata</i>
185	Id_EST_N038	<i>Casuarina glauca</i>
186	Id_EST_N233	<i>Metrosideros excelsa</i>
187	Id_EST_N234	<i>Howea forsteriana</i>
188	Id_EST_N235	<i>Howea forsteriana</i>
189	Id_EST_N236	<i>Howea forsteriana</i>
190	Id_EST_N237	<i>Howea forsteriana</i>
191	Id_EST_N238	<i>Howea forsteriana</i>
192	Id_EST_N239	<i>Ilex aquifolium</i>
193	Id_EST_N240	<i>Howea forsteriana</i>
194	Id_EST_N241	<i>Howea forsteriana</i>
195	Id_EST_N040	<i>Casuarina glauca</i>
196	Id_EST_N247	<i>Celtis australis</i>
197	Id_EST_N248	<i>Jacaranda mimosifolia</i>
198	Id_EST_N249	<i>Styphnolobium japonicum</i>
199	Id_EST_N251	<i>Aesculus x carnea</i>
200	Id_EST_N252	<i>Corynocarpus laevigata</i>
201	Id_EST_N253	<i>Prunus laurocerasus</i>
202	Id_EST_N254	<i>Acca sellowiana</i>
203	Id_EST_N255	<i>Aesculus hippocastanum</i>
204	Id_EST_N257	<i>Populus nigra</i>
205	Id_EST_N259	<i>Howea forsteriana</i>
206	Id_EST_N261	<i>Tilia platyphyllos</i>

207	Id_EST_N150	<i>Cupressus sp</i>
208	Id_EST_N690	<i>Cupressus sp</i>
209	Id_EST_N697	<i>Cupressus sp</i>
210	Id_EST_N268	<i>Phoenix reclinata</i>
211	Id_EST_N269	<i>Pinus canariensis</i>
212	Id_EST_N270	<i>Ceiba speciosa</i>
213	Id_EST_N271	<i>Morus alba</i>
214	Id_EST_N272	<i>Lagerstroemia indica</i>
215	Id_EST_N273	<i>Quercus robur</i>
216	Id_EST_N274	<i>Taxus baccata</i>
217	Id_EST_N275	<i>Pinus pinea</i>
218	Id_EST_N276	<i>Jacaranda mimosifolia</i>
219	Id_EST_N277	<i>Jacaranda mimosifolia</i>
220	Id_EST_N278	<i>Jacaranda mimosifolia</i>
221	Id_EST_N279	<i>Jacaranda mimosifolia</i>
222	Id_EST_N280	<i>Jacaranda mimosifolia</i>
223	Id_EST_N281	<i>Pinus pinea</i>
224	Id_EST_N282	<i>Pinus pinea</i>
225	Id_EST_N283	<i>Pinus canariensis</i>
226	Id_EST_N284	<i>Taxus baccata</i>
227	Id_EST_N285	<i>Magnolia grandiflora</i>
228	Id_EST_N286	<i>Magnolia grandiflora</i>
229	Id_EST_N287	<i>Magnolia grandiflora</i>
230	Id_EST_N382	<i>Cycas revoluta</i>
231	Id_EST_N290	<i>Celtis australis</i>
232	Id_EST_N291	<i>Howea forsteriana</i>
233	Id_EST_N295	<i>Pinus pinea</i>
234	Id_EST_N296	<i>Pinus pinea</i>
235	Id_EST_N502	<i>Dodonaea viscosa</i>
236	Id_EST_N298	<i>Prunus dulcis</i>
237	Id_EST_N300	<i>Schinus molle</i>
238	Id_EST_N301	<i>Cedrus deodara</i>
239	Id_EST_N302	<i>Celtis australis</i>
240	Id_EST_N303	<i>Robinia pseudoacacia</i>
241	Id_EST_N304	<i>Grevillea robusta</i>
242	Id_EST_N305	<i>Grevillea robusta</i>
243	Id_EST_N306	<i>Acer negundo</i>
244	Id_EST_N307	<i>Tilia tomentosa</i>
245	Id_EST_N308	<i>Sequoia sempervirens</i>
246	Id_EST_N309	<i>Aesculus x carnea</i>
247	Id_EST_N310	<i>Sequoia sempervirens</i>
248	Id_EST_N311	<i>Pinus halepensis</i>
249	Id_EST_N314	<i>Aesculus x carnea</i>
250	Id_EST_N315	<i>Hibiscus syriacus</i>
251	Id_EST_N316	<i>Celtis australis</i>
252	Id_EST_N318	<i>Cupressus sempervirens</i>
253	Id_EST_N319	<i>Celtis australis</i>

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254	Id_EST_N321	<i>Celtis australis</i>
255	Id_EST_N322	<i>Pittosporum tobira</i>
256	Id_EST_N323	<i>Jacaranda mimosifolia</i>
257	Id_EST_N324	<i>Ligustrum sinense</i>
258	Id_EST_N325	<i>Jacaranda mimosifolia</i>
259	Id_EST_N328	<i>Tilia tomentosa</i>
260	Id_EST_N760	<i>Duranta erecta</i>
261	Id_EST_N330	<i>Jacaranda mimosifolia</i>
262	Id_EST_N332	<i>Jacaranda mimosifolia</i>
263	Id_EST_N333	<i>Celtis australis</i>
264	Id_EST_N244	<i>Ficus benghalensis</i>
265	Id_EST_N335	<i>Jacaranda mimosifolia</i>
266	Id_EST_N336	<i>Celtis australis</i>
267	Id_EST_N337	<i>Jacaranda mimosifolia</i>
268	Id_EST_N338	<i>Washingtonia robusta</i>
269	Id_EST_N339	<i>Washingtonia robusta</i>
270	Id_EST_N081	<i>Ficus celebensis</i>
271	Id_EST_N341	<i>Ceratonia siliqua</i>
272	Id_EST_N342	<i>Jacaranda mimosifolia</i>
273	Id_EST_N344	<i>Robinia pseudoacacia</i>
274	Id_EST_N346	<i>Pittosporum tobira</i>
275	Id_EST_N347	<i>Aesculus x carnea</i>
276	Id_EST_N348	<i>Tilia tomentosa</i>
277	Id_EST_N350	<i>Jacaranda mimosifolia</i>
278	Id_EST_N351	<i>Schinus molle</i>
279	Id_EST_N352	<i>Celtis australis</i>
280	Id_EST_N353	<i>Celtis australis</i>
281	Id_EST_N354	<i>Acacia melanoxylon</i>
282	Id_EST_N262	<i>Ficus lutea</i>
283	Id_EST_N263	<i>Ficus lutea</i>
284	Id_EST_N362	<i>Magnolia grandiflora</i>
285	Id_EST_N363	<i>Cedrus deodara</i>
286	Id_EST_N364	<i>Taxus baccata</i>
287	Id_EST_N185	<i>Harpephyllum caffrum</i>
288	Id_EST_N367	<i>Cedrus libani</i>
289	Id_EST_N368	<i>Celtis australis</i>
290	Id_EST_N369	<i>Sequoia sempervirens</i>
291	Id_EST_N370	<i>Phytolacca dioica</i>
292	Id_EST_N371	<i>Howea forsteriana</i>
293	Id_EST_N372	<i>Brachychiton populneus</i>
294	Id_EST_N373	<i>Brachychiton populneus</i>
295	Id_EST_N376	<i>Tilia tomentosa</i>
296	Id_EST_N377	<i>Livistona chinensis</i>
297	Id_EST_N297	<i>Juniperus chinensis</i>
298	Id_EST_N379	<i>Celtis australis</i>
299	Id_EST_N380	<i>Cedrus libani</i>

300	Id_EST_N384	<i>Dracaena draco</i>
301	Id_EST_N385	<i>Chamaerops humilis</i>
302	Id_EST_N389	<i>Dracaena draco</i>
303	Id_EST_N390	<i>Apollonias barbujana</i>
304	Id_EST_N391	<i>Phytolacca dioica</i>
305	Id_EST_N392	<i>Dracaena draco</i>
306	Id_EST_N396	<i>Lagerstroemia indica</i>
307	Id_EST_N397	<i>Jacaranda mimosifolia</i>
308	Id_EST_N400	<i>Jacaranda mimosifolia</i>
309	Id_EST_N401	<i>Tipuana tipu</i>
310	Id_EST_N404	<i>Tilia tomentosa</i>
311	Id_EST_N414	<i>Metrosideros excelsa</i>
312	Id_EST_N415	<i>Cercis siliquastrum</i>
313	Id_EST_N416	<i>Cercis siliquastrum</i>
314	Id_EST_N417	<i>Phytolacca dioica</i>
315	Id_EST_N419	<i>Cercis siliquastrum</i>
316	Id_EST_N420	<i>Morus alba</i>
317	Id_EST_N422	<i>Metrosideros excelsa</i>
318	Id_EST_N423	<i>Jacaranda mimosifolia</i>
319	Id_EST_N424	<i>Howea forsteriana</i>
320	Id_EST_N425	<i>Howea forsteriana</i>
321	Id_EST_N426	<i>Corynocarpus laevigata</i>
322	Id_EST_N427	<i>Corynocarpus laevigata</i>
323	Id_EST_N428	<i>Corynocarpus laevigata</i>
324	Id_EST_N429	<i>Corynocarpus laevigata</i>
325	Id_EST_N430	<i>Corynocarpus laevigata</i>
326	Id_EST_N432	<i>Yucca gigantea</i>
327	Id_EST_N433	<i>Metrosideros excelsa</i>
328	Id_EST_N434	<i>Metrosideros excelsa</i>
329	Id_EST_N436	<i>Styphnolobium japonicum</i>
330	Id_EST_N437	<i>Tipuana tipu</i>
331	Id_EST_N439	<i>Acca sellowiana</i>
332	Id_EST_N443	<i>Magnolia grandiflora</i>
333	Id_EST_N445	<i>Aesculus hippocastanum</i>
334	Id_EST_N446	<i>Cedrus atlantica</i>
335	Id_EST_N447	<i>Brachychiton acerifolius</i>
336	Id_EST_N448	<i>Tipuana tipu</i>
337	Id_EST_N449	<i>Tilia tomentosa</i>
338	Id_EST_N450	<i>Celtis australis</i>
339	Id_EST_N451	<i>Cedrus atlantica</i>
340	Id_EST_N452	<i>Cordyline australis</i>
341	Id_EST_N453	<i>Cordyline australis</i>
342	Id_EST_N454	<i>Cordyline australis</i>
343	Id_EST_N456	<i>Cordyline australis</i>

344	Id_EST_N457	<i>Celtis australis</i>
345	Id_EST_N458	<i>Celtis australis</i>
346	Id_EST_N460	<i>Pittosporum undulatum</i>
347	Id_EST_N462	<i>Ficus rubiginosa</i>
348	Id_EST_N463	<i>Pittosporum undulatum</i>
349	Id_EST_N464	<i>Pittosporum undulatum</i>
350	Id_EST_N465	<i>Pittosporum undulatum</i>
351	Id_EST_N466	<i>Pittosporum undulatum</i>
352	Id_EST_N467	<i>Jacaranda mimosifolia</i>
353	Id_EST_N468	<i>Ficus rubiginosa</i>
354	Id_EST_N469	<i>Magnolia grandiflora</i>
355	Id_EST_N470	<i>Ficus rubiginosa</i>
356	Id_EST_N471	<i>Magnolia grandiflora</i>
357	Id_EST_N472	<i>Populus nigra</i>
358	Id_EST_N473	<i>Corynocarpus laevigata</i>
359	Id_EST_N474	<i>Corynocarpus laevigata</i>
360	Id_EST_N475	<i>Corynocarpus laevigata</i>
361	Id_EST_N476	<i>Corynocarpus laevigata</i>
362	Id_EST_N477	<i>Corynocarpus laevigata</i>
363	Id_EST_N480	<i>Magnolia grandiflora</i>
364	Id_EST_N481	<i>Pittosporum tobira</i>
365	Id_EST_N482	<i>Magnolia grandiflora</i>
366	Id_EST_N334	<i>Leptospermum laevigatum</i>
367	Id_EST_N486	<i>Celtis australis</i>
368	Id_EST_N488	<i>Ficus macrophylla</i>
369	Id_EST_N490	<i>Platycladus orientalis</i>
370	Id_EST_N491	<i>Platycladus orientalis</i>
371	Id_EST_N492	<i>Platycladus orientalis</i>
372	Id_EST_N493	<i>Platycladus orientalis</i>
373	Id_EST_N496	<i>Pittosporum tobira</i>
374	Id_EST_N497	<i>Platycladus orientalis</i>
375	Id_EST_N498	<i>Pittosporum undulatum</i>
376	Id_EST_N499	<i>Magnolia grandiflora</i>
377	Id_EST_N500	<i>Gleditsia triacanthos</i>
378	Id_EST_N501	<i>Erythrina crista-galli</i>
379	Id_EST_N221	<i>Livistona australis</i>
380	Id_EST_N503	<i>Pinus halepensis</i>
381	Id_EST_N504	<i>Pittosporum undulatum</i>
382	Id_EST_N505	<i>Pittosporum undulatum</i>
383	Id_EST_N508	<i>Erythrina crista-galli</i>
384	Id_EST_N509	<i>Erythrina crista-galli</i>
385	Id_EST_N510	<i>Erythrina crista-galli</i>

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386	Id_EST_N512	<i>Tilia tomentosa</i>
387	Id_EST_N513	<i>Platyclusus orientalis</i>
388	Id_EST_N357	<i>Montanoa bipinnatifida</i>
389	Id_EST_N519	<i>Styphnolobium japonicum</i>
390	Id_EST_N520	<i>Jacaranda mimosifolia</i>
391	Id_EST_N522	<i>Corynocarpus laevigata</i>
392	Id_EST_N531	<i>Aesculus hippocastanum</i>
393	Id_EST_N533	<i>Magnolia grandiflora</i>
394	Id_EST_N534	<i>Magnolia grandiflora</i>
395	Id_EST_N535	<i>Araucaria columnaris</i>
396	Id_EST_N536	<i>Cercis siliquastrum</i>
397	Id_EST_N537	<i>Citrus x aurantium</i>
398	Id_EST_N538	<i>Cupressus sempervirens</i>
399	Id_EST_N539	<i>Ligustrum lucidum</i>
400	Id_EST_N540	<i>Ligustrum lucidum</i>
401	Id_EST_N541	<i>Jacaranda mimosifolia</i>
402	Id_EST_N542	<i>Corynocarpus laevigata</i>
403	Id_EST_N543	<i>Casuarina cunninghamiana</i>
404	Id_EST_N544	<i>Casuarina cunninghamiana</i>
405	Id_EST_N545	<i>Casuarina cunninghamiana</i>
406	Id_EST_N546	<i>Casuarina cunninghamiana</i>
407	Id_EST_N547	<i>Casuarina cunninghamiana</i>
408	Id_EST_N548	<i>Aesculus x carnea</i>
409	Id_EST_N192	<i>Ocotea foetens</i>
410	Id_EST_N193	<i>Ocotea foetens</i>
411	Id_EST_N602	<i>Cordyline australis</i>
412	Id_EST_N604	<i>Cordyline australis</i>
413	Id_EST_N606	<i>Taxus baccata</i>
414	Id_EST_N607	<i>Howea forsteriana</i>
415	Id_EST_N608	<i>Olea europaea var. sylvestris</i>
416	Id_EST_N340	<i>Photinia serratifolia</i>
417	Id_EST_N611	<i>Howea forsteriana</i>
418	Id_EST_N614	<i>Howea forsteriana</i>
419	Id_EST_N378	<i>Photinia serratifolia</i>
420	Id_EST_N616	<i>Howea forsteriana</i>
421	Id_EST_N617	<i>Howea forsteriana</i>
422	Id_EST_N618	<i>Howea forsteriana</i>
423	Id_EST_N619	<i>Phoenix canariensis</i>
424	Id_EST_N620	<i>Fraxinus angustifolia</i>
425	Id_EST_N621	<i>Platyclusus orientalis</i>
426	Id_EST_N622	<i>Howea forsteriana</i>
427	Id_EST_N623	<i>Taxus baccata</i>
428	Id_EST_N624	<i>Acca sellowiana</i>

429	Id_EST_N625	<i>Howea forsteriana</i>
430	Id_EST_N627	<i>Brachychiton acerifolius</i>
431	Id_EST_N630	<i>Morus nigra</i>
432	Id_EST_N659	<i>Corynocarpus laevigata</i>
433	Id_EST_N660	<i>Corynocarpus laevigata</i>
434	Id_EST_N661	<i>Corynocarpus laevigata</i>
435	Id_EST_N662	<i>Corynocarpus laevigata</i>
436	Id_EST_N663	<i>Corynocarpus laevigata</i>
437	Id_EST_N664	<i>Corynocarpus laevigata</i>
438	Id_EST_N665	<i>Corynocarpus laevigata</i>
439	Id_EST_N669	<i>Phillyrea latifolia</i>
440	Id_EST_N671	<i>Phillyrea latifolia</i>
441	Id_EST_N674	<i>Olea europaea var. sylvestris</i>
442	Id_EST_N675	<i>Olea europaea var. sylvestris</i>
443	Id_EST_N676	<i>Quercus robur</i>
444	Id_EST_N680	<i>Pinus pinea</i>
445	Id_EST_N691	<i>Olea europaea var. sylvestris</i>
446	Id_EST_N693	<i>Olea europaea var. sylvestris</i>
447	Id_EST_N694	<i>Olea europaea var. sylvestris</i>
448	Id_EST_N695	<i>Pinus pinea</i>
449	Id_EST_N696	<i>Olea europaea var. sylvestris</i>
450	Id_EST_N698	<i>Olea europaea var. sylvestris</i>
451	Id_EST_N699	<i>Olea europaea var. sylvestris</i>
452	Id_EST_N700	<i>Olea europaea var. sylvestris</i>
453	Id_EST_N701	<i>Olea europaea var. sylvestris</i>
454	Id_EST_N704	<i>Olea europaea var. sylvestris</i>
455	Id_EST_N705	<i>Olea europaea var. sylvestris</i>
456	Id_EST_N706	<i>Olea europaea var. sylvestris</i>
457	Id_EST_N707	<i>Olea europaea var. sylvestris</i>
458	Id_EST_N708	<i>Olea europaea var. sylvestris</i>
459	Id_EST_N709	<i>Olea europaea var. sylvestris</i>
460	Id_EST_N710	<i>Olea europaea var. sylvestris</i>
461	Id_EST_N711	<i>Olea europaea var. sylvestris</i>
462	Id_EST_N712	<i>Olea europaea var. sylvestris</i>
463	Id_EST_N713	<i>Olea europaea var. sylvestris</i>
464	Id_EST_N714	<i>Olea europaea var. sylvestris</i>

465	Id_EST_N716	<i>Cupressus sempervirens</i>
466	Id_EST_N717	<i>Olea europaea var. sylvestris</i>
467	Id_EST_N719	<i>Olea europaea var. sylvestris</i>
468	Id_EST_N723	<i>Aesculus hippocastanum</i>
469	Id_EST_N152	<i>Ceratonia siliqua</i>
470	Id_EST_N153	<i>Ceratonia siliqua</i>
471	Id_EST_N154	<i>Ceratonia siliqua</i>
472	Id_EST_N157	<i>Ceratonia siliqua</i>
473	Id_EST_N158	<i>Ceratonia siliqua</i>
474	Id_EST_N159	<i>Ceratonia siliqua</i>
475	Id_EST_N164	<i>Ceratonia siliqua</i>
476	Id_EST_N165	<i>Ceratonia siliqua</i>
477	Id_EST_N641	<i>Ceratonia siliqua</i>
478	Id_EST_N643	<i>Ceratonia siliqua</i>
479	Id_EST_N645	<i>Ceratonia siliqua</i>
480	Id_EST_N648	<i>Ceratonia siliqua</i>
481	Id_EST_N649	<i>Ceratonia siliqua</i>
482	Id_EST_N666	<i>Ceratonia siliqua</i>
483	Id_EST_N752	<i>Araucaria columnaris</i>
484	Id_EST_N673	<i>Ceratonia siliqua</i>
485	Id_EST_N686	<i>Ceratonia siliqua</i>
486	Id_EST_N756	<i>Olea europaea var. sylvestris</i>
487	Id_EST_N689	<i>Ceratonia siliqua</i>
488	Id_EST_N692	<i>Ceratonia siliqua</i>
489	Id_EST_N143	<i>Rhopalostylis sapida</i>
490	Id_EST_N703	<i>Ceratonia siliqua</i>
491	Id_EST_N718	<i>Ceratonia siliqua</i>
492	Id_EST_N733	<i>Ceratonia siliqua</i>
493	Id_EST_N740	<i>Ceratonia siliqua</i>
494	Id_EST_N741	<i>Ceratonia siliqua</i>
495	Id_EST_N743	<i>Ceratonia siliqua</i>
496	Id_EST_N744	<i>Ceratonia siliqua</i>
497	Id_EST_N745	<i>Ceratonia siliqua</i>
498	Id_EST_N746	<i>Ceratonia siliqua</i>
499	Id_EST_N749	<i>Ceratonia siliqua</i>
500	Id_EST_N758	<i>Ceratonia siliqua</i>
501	Id_EST_N399	<i>Cercis siliquastrum</i>
502	Id_EST_N629	<i>Cestrum elegance</i>
503	Id_EST_N738	<i>Cupressus lusitanica</i>
504	Id_EST_N224	<i>Rhopalostylis sapida</i>
505	Id_EST_N225	<i>Rhopalostylis sapida</i>
506	Id_EST_N231	<i>Rhopalostylis sapida</i>
507	Id_EST_N101	<i>Dombeya x cayeuxii</i>
508	Id_EST_N103	<i>Dombeya x cayeuxii</i>
509	Id_EST_N109	<i>Dombeya x cayeuxii</i>

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510	Id_EST_N742	<i>Duranta erecta</i>
511	Id_EST_N092	<i>Fraxinus angustifolia</i>
512	Id_EST_N135	<i>Fraxinus angustifolia</i>
513	Id_EST_N136	<i>Fraxinus angustifolia</i>
514	Id_EST_N245	<i>Fraxinus angustifolia</i>
515	Id_EST_N418	<i>Fraxinus angustifolia</i>
516	Id_EST_N438	<i>Fraxinus angustifolia</i>
517	Id_EST_N495	<i>Fraxinus angustifolia</i>
518	Id_EST_N670	<i>Fraxinus angustifolia</i>
519	Id_EST_N678	<i>Fraxinus angustifolia</i>
520	Id_EST_N730	<i>Fraxinus angustifolia</i>
521	Id_EST_N739	<i>Fraxinus angustifolia</i>
522	Id_EST_N754	<i>Fraxinus angustifolia</i>
523	Id_EST_N071	<i>Ginkgo biloba</i>
524	Id_EST_N299	<i>Ginkgo biloba</i>
525	Id_EST_N479	<i>Ginkgo biloba</i>
526	Id_EST_N209	<i>Howea forsteriana</i>
527	Id_EST_N168	<i>Laurus nobilis</i>
528	Id_EST_N151	<i>Ligustrum lucidum</i>
529	Id_EST_N160	<i>Ligustrum lucidum</i>
530	Id_EST_N631	<i>Ligustrum lucidum</i>
531	Id_EST_N632	<i>Ligustrum lucidum</i>
532	Id_EST_N634	<i>Ligustrum lucidum</i>
533	Id_EST_N635	<i>Ligustrum lucidum</i>
534	Id_EST_N636	<i>Ligustrum lucidum</i>
535	Id_EST_N637	<i>Ligustrum lucidum</i>
536	Id_EST_N638	<i>Ligustrum lucidum</i>
537	Id_EST_N639	<i>Ligustrum lucidum</i>
538	Id_EST_N642	<i>Ligustrum lucidum</i>
539	Id_EST_N644	<i>Ligustrum lucidum</i>
540	Id_EST_N646	<i>Ligustrum lucidum</i>
541	Id_EST_N650	<i>Ligustrum lucidum</i>
542	Id_EST_N651	<i>Ligustrum lucidum</i>
543	Id_EST_N653	<i>Ligustrum lucidum</i>
544	Id_EST_N654	<i>Ligustrum lucidum</i>
545	Id_EST_N655	<i>Ligustrum lucidum</i>
546	Id_EST_N023	<i>Schinus terebinthifolia</i>
547	Id_EST_N657	<i>Ligustrum lucidum</i>
548	Id_EST_N658	<i>Ligustrum lucidum</i>
549	Id_EST_N687	<i>Ligustrum lucidum</i>
550	Id_EST_N731	<i>Ligustrum lucidum</i>
551	Id_EST_N515	<i>Schinus terebinthifolia</i>
552	Id_EST_N267	<i>Syagrus romanzoffiana</i>
553	Id_EST_N485	<i>Liquidambar styraciflua</i>
554	Id_EST_N626	<i>Lochroma cyaneum</i>
555	Id_EST_N605	<i>Nicoteta betonica</i>

556	Id_EST_N679	<i>Phillyrea latifolia</i>
557	Id_EST_N681	<i>Phillyrea latifolia</i>
558	Id_EST_N682	<i>Phillyrea latifolia</i>
559	Id_EST_N359	<i>Syagrus romanzoffiana</i>
560	Id_EST_N683	<i>Phillyrea latifolia</i>
561	Id_EST_N685	<i>Phillyrea latifolia</i>
562	Id_EST_N688	<i>Phillyrea latifolia</i>
563	Id_EST_N747	<i>Phillyrea latifolia</i>
564	Id_EST_N748	<i>Phillyrea latifolia</i>
565	Id_EST_N750	<i>Phillyrea latifolia</i>
566	Id_EST_N755	<i>Phillyrea latifolia</i>
567	Id_EST_N715	<i>Pinus pinea</i>
568	Id_EST_N759	<i>Pinus pinea</i>
569	Id_EST_N156	<i>Pittosporum undulatum</i>
570	Id_EST_N343	<i>Pittosporum undulatum</i>
571	Id_EST_N516	<i>Pittosporum undulatum</i>
572	Id_EST_N517	<i>Pittosporum undulatum</i>
573	Id_EST_N633	<i>Pittosporum undulatum</i>
574	Id_EST_N652	<i>Pittosporum undulatum</i>
575	Id_EST_N656	<i>Pittosporum undulatum</i>
576	Id_EST_N734	<i>Pittosporum undulatum</i>
577	Id_EST_N033	<i>Platanus x hispanica</i>
578	Id_EST_N069	<i>Platanus x hispanica</i>
579	Id_EST_N072	<i>Platanus x hispanica</i>
580	Id_EST_N119	<i>Platanus x hispanica</i>
581	Id_EST_N198	<i>Platanus x hispanica</i>
582	Id_EST_N230	<i>Platanus x hispanica</i>
583	Id_EST_N258	<i>Platanus x hispanica</i>
584	Id_EST_N292	<i>Platanus x hispanica</i>
585	Id_EST_N293	<i>Platanus x hispanica</i>
586	Id_EST_N356	<i>Platanus x hispanica</i>
587	Id_EST_N395	<i>Platanus x hispanica</i>
588	Id_EST_N459	<i>Platanus x hispanica</i>
589	Id_EST_N628	<i>Prunus lusitanica</i>
590	Id_EST_N398	<i>Prunus cerasifera</i>
591	Id_EST_N405	<i>Prunus cerasifera</i>
592	Id_EST_N406	<i>Prunus cerasifera</i>
593	Id_EST_N407	<i>Prunus cerasifera</i>
594	Id_EST_N410	<i>Prunus cerasifera</i>
595	Id_EST_N411	<i>Prunus cerasifera</i>
596	Id_EST_N431	<i>Prunus cerasifera</i>
597	Id_EST_N610	<i>Strelitzia nicolai</i>
598	Id_EST_N612	<i>Strelitzia nicolai</i>
599	Id_EST_N613	<i>Strelitzia nicolai</i>

600	Id_EST_N667	<i>Strelitzia nicolai</i>
601	Id_EST_N761	<i>Strelitzia nicolai</i>
602	Id_EST_N093	<i>Tilia platyphyllos</i>
603	Id_EST_N104	<i>Tilia platyphyllos</i>
604	Id_EST_N110	<i>Tilia platyphyllos</i>
605	Id_EST_N125	<i>Tilia platyphyllos</i>
606	Id_EST_N232	<i>Tilia platyphyllos</i>
607	Id_EST_N242	<i>Tilia platyphyllos</i>
608	Id_EST_N246	<i>Tilia platyphyllos</i>
609	Id_EST_N260	<i>Tilia platyphyllos</i>
610	Id_EST_N265	<i>Tilia platyphyllos</i>
611	Id_EST_N266	<i>Tilia platyphyllos</i>
612	Id_EST_N375	<i>Tilia platyphyllos</i>
613	Id_EST_N483	<i>Tilia platyphyllos</i>
614	Id_EST_N250	<i>Tilia x euchlora</i>
615	Id_EST_N105	<i>Tilia x moltkei</i>
616	Id_EST_N264	<i>Tilia x moltkei</i>
617	Id_EST_N393	<i>Tilia x moltkei</i>
618	Id_EST_N521	<i>Tilia x moltkei</i>
619	Id_EST_N532	<i>Tilia x moltkei</i>
620	Id_EST_N402	<i>Tipuana tipu</i>
621	Id_EST_N403	<i>Tipuana tipu</i>
622	Id_EST_N161	<i>Ulmus minor</i>
623	Id_EST_N727	<i>Ulmus minor</i>
624	Id_EST_N728	<i>Ulmus minor</i>
625	Id_EST_N729	<i>Ulmus minor</i>
626	Id_EST_N732	<i>Ulmus minor</i>
627	Id_EST_N173	<i>Ulmus x hollandica</i>
628	Id_EST_N647	<i>Vachellia farnesiana</i>
629	Id_EST_N684	<i>Vachellia farnesiana</i>
630	Id_EST_N721	<i>Vachellia farnesiana</i>
631	Id_EST_N724	<i>Vachellia farnesiana</i>
632	Id_EST_N725	<i>Vachellia farnesiana</i>



Tree inventory of Jardim Téofilo Braga - Jardim da Parada

Local: Jardim Téofilo Braga - Jardim da Parada
 Campo de Ourique parish, Lisbon, Portugal
 Surveying date: 2023
 Scale 1:500
 Student: Eugenio Ferretti
 Cod: 25703
 Professor:
 Ana Luísa Brito dos Santos de Sousa Soares
 Susana Maria de Abreu Dias

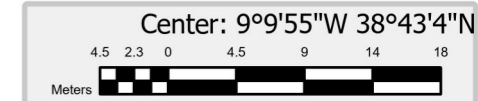
In collaboration with the Centre for Applied Ecology Prof. Beata Neves (CEABN)
 Data collection conducted during the master thesis project in the landscape architecture degree course at the School of Agronomy, University of Lisbon

Annex No. 08

Legend

 Parada_inventory (103)

See detailed legend in Annex No. 09

Maxar, Microsoft

Appendix No.09 - Trees index of Jardim Teófilo Braga

Table 8 - Detailed legend of Appendix No.08

Id	Tree Id	Scientific name
1	id_TEO_N002	<i>Celtis australis</i>
2	id_TEO_N003	<i>Celtis australis</i>
3	id_TEO_N004	<i>Celtis australis</i>
4	id_TEO_N005	<i>Celtis australis</i>
5	id_TEO_N006	<i>Celtis australis</i>
6	id_TEO_N008	<i>Celtis australis</i>
7	id_TEO_N009	<i>Celtis australis</i>
8	id_TEO_N010	<i>Celtis australis</i>
9	id_TEO_N011	<i>Celtis australis</i>
10	id_TEO_N012	<i>Celtis australis</i>
11	id_TEO_N013	<i>Celtis australis</i>
12	id_TEO_N014	<i>Celtis australis</i>
13	id_TEO_N015	<i>Celtis australis</i>
14	id_TEO_N016	<i>Celtis australis</i>
15	id_TEO_N017	<i>Celtis australis</i>
16	id_TEO_N018	<i>Celtis australis</i>
17	id_TEO_N019	<i>Celtis australis</i>
18	id_TEO_N020	<i>Celtis australis</i>
19	id_TEO_N021	<i>Celtis australis</i>
20	id_TEO_N022	<i>Celtis australis</i>
21	id_TEO_N023	<i>Celtis australis</i>
22	id_TEO_N024	<i>Celtis australis</i>
23	id_TEO_N025	<i>Celtis australis</i>
24	id_TEO_N026	<i>Celtis australis</i>
25	id_TEO_N027	<i>Celtis australis</i>
26	id_TEO_N028	<i>Celtis australis</i>
27	id_TEO_N029	<i>Celtis australis</i>
28	id_TEO_N030	<i>Celtis australis</i>
29	id_TEO_N031	<i>Celtis australis</i>
30	id_TEO_N032	<i>Celtis australis</i>
31	id_TEO_N033	<i>Celtis australis</i>
32	id_TEO_N034	<i>Celtis australis</i>
33	id_TEO_N035	<i>Celtis australis</i>
34	id_TEO_N036	<i>Celtis australis</i>
35	id_TEO_N037	<i>Celtis australis</i>
36	id_TEO_N038	<i>Celtis australis</i>
37	id_TEO_N039	<i>Celtis australis</i>
38	id_TEO_N040	<i>Celtis australis</i>
39	id_TEO_N041	<i>Celtis australis</i>
40	id_TEO_N042	<i>Celtis australis</i>
41	id_TEO_N043	<i>Celtis australis</i>
42	id_TEO_N044	<i>Celtis australis</i>
43	id_TEO_N045	<i>Celtis australis</i>
44	id_TEO_N046	<i>Celtis australis</i>
45	id_TEO_N047	<i>Celtis australis</i>
46	id_TEO_N048	<i>Celtis australis</i>
47	id_TEO_N050	<i>Celtis australis</i>
48	id_TEO_N051	<i>Celtis australis</i>
49	id_TEO_N052	<i>Celtis australis</i>
50	id_TEO_N053	<i>Celtis australis</i>
51	id_TEO_N054	<i>Celtis australis</i>
52	id_TEO_N055	<i>Celtis australis</i>
53	id_TEO_N056	<i>Celtis australis</i>
54	id_TEO_N057	<i>Celtis australis</i>
55	id_TEO_N059	<i>Celtis australis</i>
56	id_TEO_N060	<i>Celtis australis</i>
57	id_TEO_N061	<i>Celtis australis</i>
58	id_TEO_N062	<i>Celtis australis</i>
59	id_TEO_N063	<i>Celtis australis</i>
60	id_TEO_N064	<i>Celtis australis</i>
61	id_TEO_N065	<i>Celtis australis</i>
62	id_TEO_N066	<i>Celtis australis</i>
63	id_TEO_N067	<i>Celtis australis</i>
64	id_TEO_N068	<i>Celtis australis</i>
65	id_TEO_N070	<i>Celtis australis</i>
66	id_TEO_N071	<i>Celtis australis</i>
67	id_TEO_N072	<i>Celtis australis</i>
68	id_TEO_N077	<i>Celtis australis</i>
69	id_TEO_N078	<i>Celtis australis</i>
70	id_TEO_N079	<i>Celtis australis</i>
71	id_TEO_N080	<i>Celtis australis</i>
72	id_TEO_N084	<i>Celtis australis</i>
73	id_TEO_N085	<i>Celtis australis</i>
74	id_TEO_N098	<i>Celtis australis</i>
75	id_TEO_N058	<i>Dombeya × cayeuxii</i>
76	id_TEO_N106	<i>Ligustrum lucidum</i>
77	id_TEO_N107	<i>Ligustrum lucidum</i>
78	id_TEO_N076	<i>Pittosporum tobira</i>
79	id_TEO_N001	<i>Celtis australis</i>
80	id_TEO_N007	<i>Celtis occidentalis</i>
81	id_TEO_N073	<i>Pittosporum undulatum</i>
82	id_TEO_N049	<i>Corynocarpus laevigata</i>
83	id_TEO_N074	<i>Jacaranda mimosifolia</i>
84	id_TEO_N075	<i>Pittosporum tobira</i>
85	id_TEO_N081	<i>Corynocarpus laevigata</i>
86	id_TEO_N082	<i>Corynocarpus laevigata</i>
87	id_TEO_N086	<i>Corynocarpus laevigata</i>
88	id_TEO_N087	<i>Metrosideros excelsa</i>
89	id_TEO_N088	<i>Metrosideros excelsa</i>
90	id_TEO_N089	<i>Ginkgo biloba</i>
91	id_TEO_N090	<i>Taxodium huegelii</i>
92	id_TEO_N091	<i>Grevillea robusta</i>
93	id_TEO_N092	<i>Sequoia sempervirens</i>
94	id_TEO_N094	<i>Tilia tomentosa</i>
95	id_TEO_N095	<i>Apollonias barbujana</i>
96	id_TEO_N096	<i>Ceiba speciosa</i>
97	id_TEO_N097	<i>Phoenix canariensis</i>
98	id_TEO_N099	<i>Washingtonia filifera</i>
99	id_TEO_N100	<i>Ginkgo biloba</i>
100	id_TEO_N101	<i>Ginkgo biloba</i>
101	id_TEO_N102	<i>Ginkgo biloba</i>
102	id_TEO_N103	<i>Aesculus hippocastanum</i>
103	id_TEO_N105	<i>Phoenix canariensis</i>



Tree inventory of Jardim França Borges - Jardim do Príncipe Real

Local: Jardim França Borges - Jardim do Príncipe Real
 Misericórdia parish, Lisbon, Portugal
 Surveying date: 2023
 Scale 1:500
 Student: Eugenio Ferretti
 Cod: 25703
 Professor:
 Ana Luísa Brito dos Santos de Sousa Soares
 Susana Maria de Abreu Dias


In collaboration with the Centre for Applied Ecology Prof. Beata Neves (CEABN)
 Data collection conducted during the master thesis project in the landscape architecture degree course at the School of Agronomy, University of Lisbon

Annex No. 10

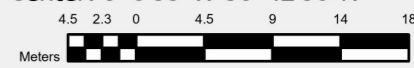
Legend

● Príncipe_inventory (156)

See detailed legend in Annex No. 11



Center: 9°8'55"W 38°42'58"N



Meters



Maxar, Microsoft

Appendix No.11 - Trees index of Jardim França Borges

Table 9 - Detailed legend of Appendix No.10

Id	Tree Id	Scientific name
1	id_PDR_N091	Bauhinia purpurea
2	id_PDR_N148	Ceiba speciosa
3	id_PDR_N001	Celtis australis
4	id_PDR_N002	Celtis australis
5	id_PDR_N003	Celtis australis
6	id_PDR_N004	Celtis australis
7	id_PDR_N005	Celtis australis
8	id_PDR_N006	Celtis australis
9	id_PDR_N007	Celtis australis
10	id_PDR_N008	Celtis australis
11	id_PDR_N009	Celtis australis
12	id_PDR_N010	Celtis australis
13	id_PDR_N011	Celtis australis
14	id_PDR_N012	Celtis australis
15	id_PDR_N013	Celtis australis
16	id_PDR_N014	Celtis australis
17	id_PDR_N015	Celtis australis
18	id_PDR_N016	Celtis australis
19	id_PDR_N017	Celtis australis
20	id_PDR_N018	Celtis australis
21	id_PDR_N019	Celtis australis
22	id_PDR_N020	Celtis australis
23	id_PDR_N021	Celtis australis
24	id_PDR_N022	Celtis australis
25	id_PDR_N023	Celtis australis
26	id_PDR_N024	Celtis australis
27	id_PDR_N025	Celtis australis
28	id_PDR_N026	Celtis australis
29	id_PDR_N027	Celtis australis
30	id_PDR_N028	Celtis australis
31	id_PDR_N029	Celtis australis
32	id_PDR_N030	Celtis australis
33	id_PDR_N031	Celtis australis
34	id_PDR_N032	Celtis australis
35	id_PDR_N033	Celtis australis
36	id_PDR_N034	Celtis australis
37	id_PDR_N035	Celtis australis
38	id_PDR_N036	Celtis australis
39	id_PDR_N037	Celtis australis
40	id_PDR_N038	Celtis australis
41	id_PDR_N039	Celtis australis
42	id_PDR_N065	Lagunaria patersonia
43	id_PDR_N078	Lagunaria patersonia
44	id_PDR_N040	Celtis australis
45	id_PDR_N041	Celtis australis
46	id_PDR_N042	Celtis australis
47	id_PDR_N043	Celtis australis
48	id_PDR_N044	Celtis australis
49	id_PDR_N045	Celtis australis
50	id_PDR_N046	Celtis australis
51	id_PDR_N047	Celtis australis
52	id_PDR_N048	Celtis australis
53	id_PDR_N049	Celtis australis
54	id_PDR_N051	Celtis australis
55	id_PDR_N052	Celtis australis
56	id_PDR_N053	Celtis australis
57	id_PDR_N054	Celtis australis
58	id_PDR_N056	Celtis australis
59	id_PDR_N057	Celtis australis
60	id_PDR_N058	Celtis australis
61	id_PDR_N059	Celtis australis
62	id_PDR_N060	Celtis australis
63	id_PDR_N141	Lonicera maackii
64	id_PDR_N061	Celtis australis
65	id_PDR_N062	Celtis australis
66	id_PDR_N063	Celtis australis
67	id_PDR_N064	Celtis australis
68	id_PDR_N122	Celtis australis
69	id_PDR_N152	Cercis siliquastrum
70	id_PDR_N159	Cercis siliquastrum
71	id_PDR_N200	Elaeagnus umbellata
72	id_PDR_N070	Ginkgo biloba
73	id_PDR_N077	Ginkgo biloba
74	id_PDR_N079	Grevillea robusta
75	id_PDR_N050	Robinia pseudoacacia
76	id_PDR_N055	Populus nigra
77	id_PDR_N067	Dracaena draco
78	id_PDR_N068	Ficus benjamina
79	id_PDR_N069	Ficus macrophylla
80	id_PDR_N071	Cercis siliquastrum
81	id_PDR_N072	Ginkgo biloba
82	id_PDR_N076	Corynocarpus laevigata
83	id_PDR_N080	Ficus rubiginosa
84	id_PDR_N081	Populus x canadensis
85	id_PDR_N082	Aesculus x carnea
86	id_PDR_N083	Cedrus deodara
87	id_PDR_N084	Metrosideros excelsa
88	id_PDR_N085	Cupressus lusitanica
89	id_PDR_N086	Magnolia grandiflora
90	id_PDR_N087	Magnolia grandiflora
91	id_PDR_N088	Magnolia grandiflora
92	id_PDR_N089	Magnolia grandiflora
93	id_PDR_N090	Howea forsteriana
94	id_PDR_N092	Araucaria columnaris
95	id_PDR_N093	Ficus macrophylla
96	id_PDR_N094	Metrosideros excelsa
97	id_PDR_N096	Ficus macrophylla
98	id_PDR_N097	Aesculus hippocastanum
99	id_PDR_N098	Juglans nigra
100	id_PDR_N099	Jacaranda mimosifolia
101	id_PDR_N100	Cedrus atlantica
102	id_PDR_N101	Brahea armata
103	id_PDR_N102	Jacaranda mimosifolia
104	id_PDR_N103	Jacaranda mimosifolia
105	id_PDR_N104	Strelitzia nicolai
106	id_PDR_N107	Taxus baccata
107	id_PDR_N108	Corynocarpus laevigata
108	id_PDR_N109	Styphnolobium japonicum
109	id_PDR_N110	Aesculus hippocastanum
110	id_PDR_N111	Corynocarpus laevigata
111	id_PDR_N112	Corynocarpus laevigata
112	id_PDR_N113	Corynocarpus laevigata
113	id_PDR_N114	Styphnolobium japonicum
114	id_PDR_N116	Jacaranda mimosifolia
115	id_PDR_N117	Tilia tomentosa
116	id_PDR_N147	Liquidambar styraciflua
117	id_PDR_N153	Liquidambar styraciflua
118	id_PDR_N157	Liquidambar styraciflua
119	id_PDR_N158	Liquidambar styraciflua
120	id_PDR_N123	Aesculus hippocastanum
121	id_PDR_N146	Magnolia grandiflora

DATA TREE CONTRIBUTION TO URBAN FOREST PLANNING

122	id_PDR_N156	Magnolia grandiflora
123	id_PDR_N127	Styphnolobium japonicum
124	id_PDR_N129	Corynocarpus laevigata
125	id_PDR_N133	Tilia tomentosa
126	id_PDR_N134	Tilia tomentosa
127	id_PDR_N135	Ficus benjamina
128	id_PDR_N137	Crataegus monogyna
129	id_PDR_N139	Sambucus nigra
130	id_PDR_N142	Tilia tomentosa
131	id_PDR_N144	Corynocarpus laevigata
132	id_PDR_N145	Tilia tomentosa
133	id_PDR_N149	Brahea armata

134	id_PDR_N155	Howea forsteriana
135	id_PDR_N160	Corynocarpus laevigata
136	id_PDR_N201	Nerium oleander
137	id_PDR_N202	Nerium oleander
138	id_PDR_N203	Nerium oleander
139	id_PDR_N204	Nerium oleander
140	id_PDR_N205	Nerium oleander
141	id_PDR_N206	Nerium oleander
142	id_PDR_N207	Nerium oleander
143	id_PDR_N106	Pittosporum undulatum
144	id_PDR_N119	Platanus X hispanica
145	id_PDR_N131	Platanus X hispanica

146	id_PDR_N115	Tilia platyphyllos
147	id_PDR_N118	Tilia platyphyllos
148	id_PDR_N124	Tilia platyphyllos
149	id_PDR_N125	Tilia platyphyllos
150	id_PDR_N132	Tilia platyphyllos
151	id_PDR_N143	Tilia platyphyllos
152	id_PDR_N138	Tilia x euchlora
153	id_PDR_N075	Tilia x moltkei
154	id_PDR_N126	Tilia x moltkei
155	id_PDR_N128	Tilia x moltkei
156	id_PDR_N074	Viburnum tinus