Stakeholder perspectives on an ecosystem service-based green infrastructure: the ”ROBUST” Lisbon Living Lab approach

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I declare that this document is an original work of my own authorship and that it fulfills all the requirements of the Code of Conduct and Good Practices of the Universidade de Lisboa.

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À minha família e aos meus amigos, alicerces constantes na minha vida e sem os quais não teria sido possível.

Abstract

As the world is becoming increasingly urbanized, the subject of territorial planning and management is becoming a central concern from a political and operational point of view. The management of the territory is thus a key factor towards sustainable economic and social development as well as for the achievement of the SDG[1].

One of the instruments required for territorial management is the green infrastructure, which seeks for the creation of a *continuum naturale*, a concept that arises from the need to incorporate and manage the landscape in a continuous way. In Portugal, the Ecological Structure (technical term used to define the green infrastructure network in the legislation) is a planning instrument which aims to identify areas in the territory which show a higher potential for the protection and enhancement of ecosystems and their services. However, it currently lacks concrete criteria regarding the mapping, regulation and management guidelines for its implementation.

Therefore, this study rises from the necessity of tackling the existing challenges regarding green infrastructure planning. At a first stage, it was considered relevant to perform an analysis and synthesis of the diversity of criteria currently used for green infrastructure mapping in the case-study area of this dissertation (the LMA[2]), in order to gain a deeper understanding of the limitations of the current approach.

Subsequently, an innovative approach for mapping ecosystem services was developed within the context of the ROBUST project Lisbon Living Lab, which focused on exploring the potential of using local stakeholder-based ecosystem service mapping as a tool to progress towards the development of a metropolitan green infrastructures network. The methodology developed is inspired on Burkhard et al. (2009) using a collaborative approach. To gather information regarding this developed methodology and its potential future applications and limitations, interviews were conducted to municipality stakeholders from the LMA.

To finish this study, some final remarks on the prospects for the future applicability of this approach were made.

Keywords Green Infrastructure; Territorial Planning; Ecosystem Service; Collaborative approach; Lisbon Metropolitan Area

[1] SDG- Sustainable Development Goals (available at: https://sdgs.un.org/goals)
[2] LMA – Lisbon Metropolitan Area

Resumo

Com a crescente urbanização que se verifica a nível mundial, a questão do planeamento e gestão territorial das cidades torna-se cada vez mais uma preocupação central, tanto do ponto de vista político como técnico. Para alcançar um desenvolvimento económico e social sustentável é imprescindível uma gestão correcta do território, assim como para alcançar os ODS[3].

Um dos instrumentos chave na gestão territorial é a infraestrutura verde, que visa a criação de um *continuum naturale*, conceito que nasce da necessidade de incorporar e gerir a paisagem de forma contínua. Em Portugal, a Estrutura Ecológica (termo técnico utilizado para definir a rede de infraestruturas verdes na legislação) é um instrumento de planeamento territorial que visa identificar as áreas do território que apresentam um maior potencial para a protecção e valorização dos ecossistemas e dos seus serviços. No entanto, esta estrutura carece actualmente de definições sólidas relativamente aos critérios e orientações referentes à sua delimitação, gestão e implementação.

Por conseguinte, este estudo surge da necessidade de enfrentar os desafios actuais no planeamento de infraestruturas verdes. Numa primeira fase, foi considerado relevante realizar uma análise e síntese da diversidade de critérios actualmente utilizados no mapeamento de infraestruturas verdes, na área do caso-estudo desta dissertação (a AML[4]), com o intuito de compreender melhor quais as principais limitações da abordagem actual.

Subsequentemente, desenvolveu-se uma abordagem inovadora de mapeamento de serviços de ecossistema, no contexto do projecto ROBUST Lisbon Living Lab, focada na exploração do potencial de utilizar stakeholders locais no mapeamento dos serviços de ecossistema como um instrumento para o desenvolvimento de uma rede metropolitana de infraestruturas verdes. A metodologia utilizada neste mapeamento foi inspirada em Burkhard et al. (2009), recorrendo a uma abordagem colaborativa. Posteriormente, com o intuito de recolher feedback face a esta metodologia desenvolvida bem como sobre as suas potenciais futuras aplicações e possíveis limitações, foram conduzidas entrevistas a técnicos municipais da AML.

Para concluir este estudo, foram feitas algumas observações finais sobre as perspectivas de aplicabilidade desta abordagem no futuro.

Palavras-Chave Infraestrutura Verde; Planeamento Territorial; Serviço de Ecossistema; Abordagem Colaborativa; Área Metropolitana de Lisboa

[3] ODS - Objectivos do Desenvolvimento Sustentável
[4] AML – Área Metropolitana de Lisboa

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List of Abbreviations

CICES	Common International Classification for Ecosystem Services
COS	Carta de Ocupação do Solo (Land cover map)
ERPVA	Estrutura Regional de Proteção e Valorização Ambiental
ES	Ecosystem Services
EU	European Union
GI	Green Infrastructure
LMA	Lisbon Metropolitan Area
MGI	Municipal Green Infrastructure
PDM	Plano Director Municipal (Municipal masterplan)
PEOT	Plano Especial de Ordenamento do Território
PNPOT	Programa Nacional da Política de Ordenamento do Território
PROT	Programa Regional de Ordenamento do Território (Regional territorial planning program)
PP	Plano de Pormenor (Detailed plan)
PU	Plano de Urbanização (Urban zoning plan)
RAN	Reserva Agrícola Nacional (National agriculture reserve)
REM	Rede Ecológica Metropolitana (Metropolitan ecological network)
REN	Reserva Ecológica Nacional (National ecological reserve)
RJIGT	Regime Jurídico dos Instrumentos de Gestão Territorial (Legal regimen for territorial management tools)
WG	Working Group

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Chapter 1. Introduction

1.1. Context

After the Industrial revolution, a pattern of disorganized urban growth started, which created several environmental, economic and social problems in the cities (Magalhães, 1994). Over the last 50 years, an unprecedented rate of global change in nature has occurred. Human direct and indirect drivers lead to the fragmentation of natural areas, climate change, loss of biodiversity, increasing of water, air and land pollution and an overall degradation of the human wellbeing and disruptive connection to nature. According to the typology adopted by the global assessment, direct human drivers include anthropogenic drivers (e.g., pollution, land/sea use change, over exploitation and extraction of resources) and drivers which derive from natural-anthropogenic interactions (e.g., climate change and invasive species) (IPBES, 2020). One way of addressing some of these issues lays within integrating the concept of green infrastructure (GI) as a fundamental piece in territorial planning, by promoting the creation of a green infrastructure network, which will contribute for a much more strategic vision and constitute a crucial step towards a sustainable development.

The EU Green Infrastructure Strategy[5], adopted in May 2013 (European Commission, 2013) is the central European level policy document regarding the development of GI. It's a key instrument of the EU Biodiversity Strategy to 2020, which calls on the Member States to develop a mapping and assessment of ecosystems and of their services (Maes et al., 2013) as a way to assess the condition of the different ecosystems and their biodiversity and, therefore, on the ability of nature to deliver services for human well-being.

More recently, the European Commission has adopted the **EU Biodiversity Strategy for 2030** (European Commission, 2020) containing concrete actions and commitments which aim to protect nature and reverse the current degradation state of the ecosystem services. This strategy advocates for "the promotion of healthy ecosystems, green infrastructure and nature-based solutions that should be systematically integrated into urban planning, including in public spaces, infrastructure, and the design of buildings and their surroundings" (EU Biodiversity Strategy for 2030, 2020).

In Portugal, the concept of GI was introduced into the legal framework at a national level in 1999, and since then it has been mandatory to be integrated in both regional and local plans. In 1999, the Legal Regimen for Territorial Management Tools (RJIGT[6]) requires that the municipal masterplans (PDM) integrate Green infrastructures [7] as a territorial planning instrument.

[5] Officially named Green Infrastructure (GI) - Enhancing Europe's Natural Capital
[6] Decreto-Lei nº 380/99, de 22 de Setembro - Estabelece o regime jurídico dos instrumentos de gestão territorial
[7] Designated as" Municipal Ecological Structures" in the national legal framework

Green Infrastructure in the Portuguese legislation is designated as “Municipal Ecological Structure” [8] in local planning tools and as "Regional Structure for Environmental Enhancement and Protection" (ERPVA)[9] in regional planning tools. For simplification purposes, in this dissertation the term “green infrastructure” (GI) will be used from here on, even when referring to the legal framework used in Portugal.

Even though GI have been used as a crucial tool in spatial territory planning for years, there are still several obstacles that need to be overcome, from both a legal and spatial perspective (Albert and von Haaren, 2017). The National Programme for Territorial Planning Policy (PNPOT[10]) is the top instrument of the territorial management system in Portugal. It “defines objectives and strategic options for territorial development and establishes the model for the organization of the national territory. The PNPOT is the reference framework for the other territorial programmes and plans and a guiding instrument for strategies with territorial incidence”[11]. At both a national and local level, there is a lack of clear guidelines for mapping GI. Both Correia (2011) at national scale and Vaz (2018) for the region of Alentejo have demonstrated that there is a need to find mapping approaches that provide harmonized information and ground for operational methodological guidelines.

In this dissertation, the potential of using ecosystem service mapping in order to promote the integration of GI in the spatial planning process will be explored. These two concepts - Ecosystem Services (ES) and GI are intertwined. Green infrastructures are a “strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services”[12]. Ecosystem services are” the ecological characteristics, functions, or processes that directly or indirectly contribute to human wellbeing: that is, the benefits that people derive from functioning ecosystems” (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005). GI are therefore areas that contribute to safeguarding ecosystems, thus assuring the provision of the ES these areas have the potential to provide.

The method of ES mapping is attracting increasing interest in policy-making and territorial planning, however, its operationalization in actual decision-making is still limited (Baró, 2016). This dissertation will explore the practical potential of ES mapping to GI planning at regional scale.

In this dissertation the Lisbon Metropolitan Area will be used as case study. The practical part of the case study was developed within the context of the work developed by Working Group (WG) 2.1. of the Lisbon Living Lab, which was set up in the framework of the ROBUST project[13]. This European project includes a total of 11 Living Labs in several cities around Europe. In Portugal, the Lisbon Living Lab is

[8] EEM - Estrutura Ecológica Municipal
[9] ERPVA - Estrutura Regional de Protecção e Valorização do Ambiente
[10] PNPOT – Programa Nacional da Política de Ordenamento do Território
[11] Lei nº 99/2019, 5 de Setembro – Primeira Revisão do Programa Nacional da Política de Ordenamento de território, Artigo 6º
[12] As defined by the European Commission.
[13] https://rural-urban.eu/

led by the Lisbon Regional Coordination and Development Commission (CCDR-LVT[14]) with support from Instituto Superior Técnico (IST).

Within the scope of the Lisbon Living Lab, WG 2.1. emerged with the aim of using GI as a connector between urban and rural areas by developing an ES mapping approach that could be used as a tool to create a metropolitan network of GI in the LMA (Lisbon Metropolitan Area). This way, the present dissertation was developed in partnership with the **Lisbon Living Lab WG 2.1. "From the Regional Ecological Network to a Metropolitan Green Infrastructure"** and the main goal of the procedure followed throughout this work was to find (and apply) a methodology for mapping ES at a metropolitan scale that could contribute to the development of a GI network, by using a collaborative co-creation process gathering local knowledge (using a "bottom up" approach). The aim was to achieve a coherent regional structure, instead of having a sum of "independent" municipal green infrastructures as well as to provide a bridge for synergetic linkages between urban and rural areas. This exploratory collaborative approach used an Burkhard et al. (2009) inspired methodology, producing reclassified land cover maps that relate the ability that each land cover class has to provide a given ecosystem service.

1.2. Objectives

The main goal of this dissertation is **to understand the potential of using an ES mapping collaborative approach** as a tool for GI mapping in the context of spatial planning and to see **how this approach could contribute for the development of a metropolitan GI network.**

To achieve this main purpose, specific objectives were outlined, namely:

1st Objective - Analyzing and synthesizing the mapping criteria of GI included in the masterplans; through the synthesis of the current mapping criteria and the study of the legal framework of the GI at a national level, leading to conclusions regarding the coherence of the existing mapping criteria;

2nd Objective - Explaining the conceptual model and the iterative methodology followed in the scope of WG 2.1. of the Lisbon Living Lab;

3rd Objective - Understanding the potential of mapping ES using a collaborative, bottom-up approach[15], that builds on local stakeholder knowledge;

4th Objective - **Collecting stakeholder perspectives** on the potential and future possible applicability of the developed approach: **discuss how to progress towards the integration of the ecosystem service mapping approach in GI planning, at both a local and metropolitan scale**;

[14] CCDR-LVT: Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo (http://www.ccdr-lvt.pt/pt/)

[15] In the bottom–up approach, the information requirements are defined at the local level and accumulated upwards(Lund, H.G, 2004).

5th Objective - Explaining the different integration approaches used for the statistical treatment of the results; developing an exploratory confidence analysis approach using the answers given in the interviews as a basis;

1.3. Methodology

In this section, the methodology outlined to respond to the research objectives of this dissertation will be explained, with each stage being clarified and visually represented (see figure 1).

Initially, a review of the literature regarding the concepts of “green infrastructure” and “ecosystem services” was carried out, in order to deepen the understanding of their evolution, as well as their current legal framework and the dynamic relationship between them. Still in this initial stage, an analysis was performed regarding the national legal framework for GI.

The existing approaches for modelling and mapping ecosystem services were described, giving special emphasis to the methodology used as a basis in this dissertation: “Burkhard’s Matrix” (Burkhard, 2009). This way, a section of chapter 2 (2.2.2.) was fully dedicated to the research and analysis of the existing literature on the use of Burkhard’s matrix and its use in ecosystem service mapping, as well as an evaluation on its potential and limitations.

Following this, an analysis of the 2nd generation municipal masterplans in the LMA was done in order to see the different criteria used in the delimitation of GI at a municipal level. Subsequently, both the masterplan’s regulation and report of the municipalities of the LMA that had 2nd generation masterplans were consulted. The collected information was then categorized and summarized only for these 10 municipalities of the LMA with revised masterplans (which include already the mapping criteria for GI).

As previously mentioned, the practical part of the case study was developed within the framework of **Lisbon Living Lab Working Group 2.1. “From the Regional Ecological Network to a Metropolitan Green Infrastructure”.** The work of the Lisbon Living Lab was coordinated by the CCDR-LVT with support from IST team, which was “responsible for the group dynamics throughout the different phases of the project and for leading the work of creating the Living Lab methodology, developed jointly with CCDR-LVT” (Lisbon Living Lab Report, 2021). The main goal of the Lisbon Living Lab WG 2.1. consists, as stated above, in the development of a methodology for the conceptualization of green infrastructure at a metropolitan scale, through ES mapping based on local stakeholder knowledge (using a "bottom up" approach).

The dynamic of the work developed by the Lisbon Living Lab WG. 2.1. involved a diverse group of participants. The WG was coordinated by a representative from Setúbal municipality, Vasco Raminhas. Under his coordination, several online workshops were organized, counting with the presence of a diverse group of stakeholders, which included stakeholders from the different municipalities of the LMA and representatives from regional entities (e.g., CCDR-LVT). The workshops were organized by a steering board, in a coordination between the municipality of Setúbal and FCT- NOVA.

Research partners (e.g., IST, FCT-NOVA) participated with a supporting role of contributing to suggesting methodologies, organization of sessions on demand and active participation in the discussions. The specific content of these online workshops and the iterative methodology followed throughout the process will be further detailed in Chapter 3.

Within the context of the Lisbon Living Lab WG 2.1., a final reclassified, by the capacity of providing ecosystem services, land cover map was created for the Lisbon Metropolitan Area. In order to perform the ES mapping, a Burkhard et al. (2009) inspired approach was used, using the knowledge from the stakeholders from the different municipalities and entities who engaged in the WG online workshops. To perform the reclassified land cover mapping, the land cover map (COS 2018) was used as a basis and associated in ArcGIS to the matrix of the capacity to provide ES and mapped. **All the maps produced within this WG were elaborated by members from FCT- NOVA.**

In parallel to the work produced within the group, **several interviews were conducted by me to the members of the WG**, with the aim of gathering information on how to progress towards the integration of this ES mapping approach in the planning of GI at both a local and metropolitan scale, as well as on their perceptions about the potential of using this tool in GI territorial planning.

The next step of the process within the context of the WG 2.1. was to define a set of exploratory approaches for the statistical treatment of the results in order to obtain a "uniform" cartography for the whole metropolitan area. Three different approaches were developed for this: an area-weighted average, the median and a confidence matrix. The first two were performed by the FCT- NOVA and the third - the confidence matrix – was an exploratory approach which used only information gathered from the interviews conducted as a basis.

The final step was the analysis of the adherence of the final ES provision map (ES HUBS map), elaborated for the LMA, to the Metropolitan Ecological Network (REM[16]) map. To verify the degree of matching between the two maps, both the REM map and the new reclassified map were overlaid.

The results obtained from this case study were discussed throughout Chapter 3, focusing on both the potential and the challenges associated to the iterative methodology followed. In the end, some final remarks on the prospects for the future applicability of this approach were made.

[16] REM – Rede Ecológica Metropolitana

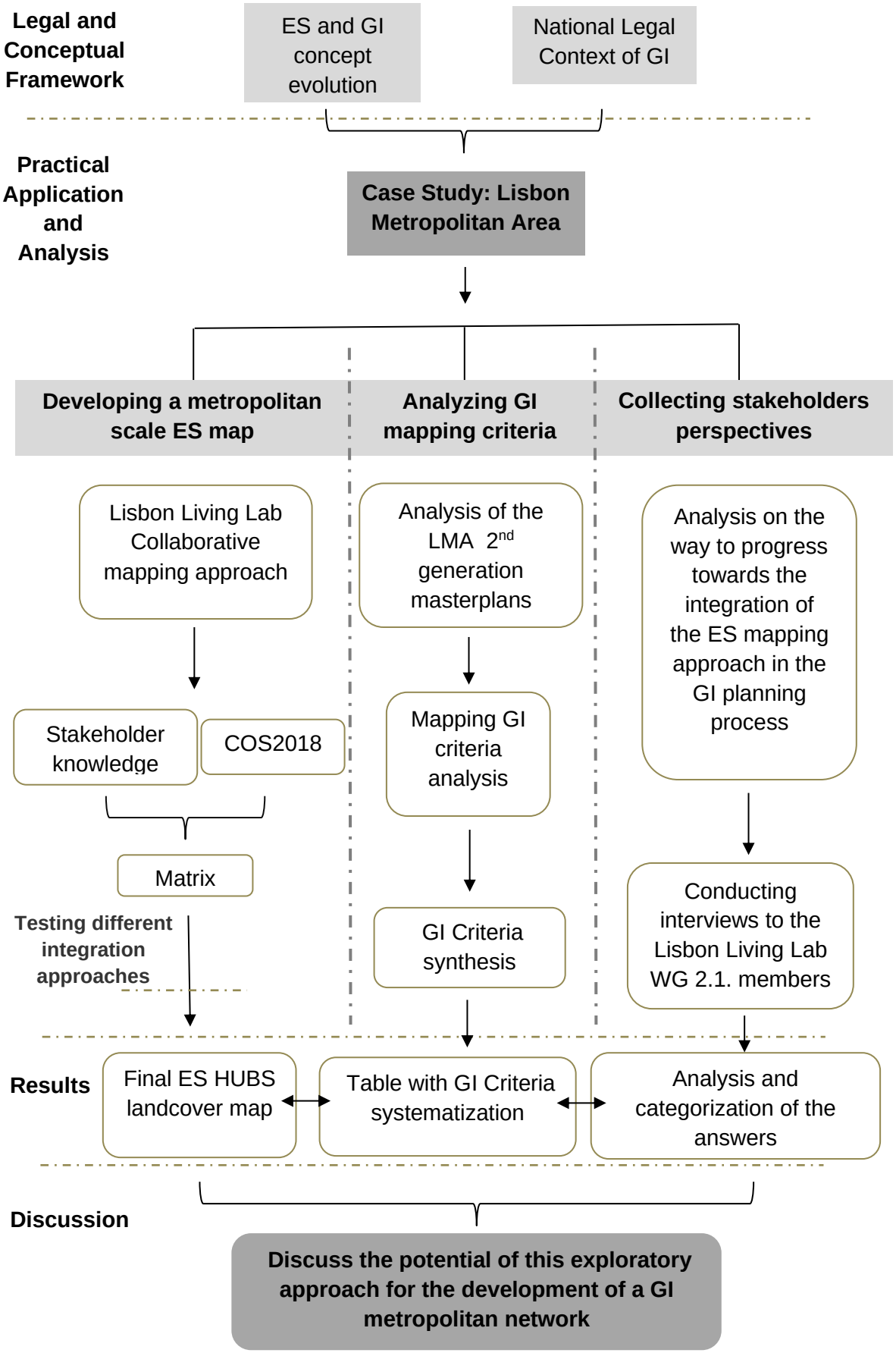


Figure 1 - Flowchart outlining the main methodological steps.

1.4 Structure of the document

This dissertation is divided into 4 chapters. In Chapter 1, the context and the main objectives of this study are outlined, and both the methodology followed as well as its structure are described carefully.

Chapter 2 consists mainly in a literature review regarding the themes of this study. Therefore, Chapter 2 begins with a description of the concepts of green infrastructure and of ecosystem services, as well as a description of the evolution of these concepts over the years. Following this, an analysis of the GI legal framework in Portugal is performed (2.1.1.). The second section of Chapter 2 (2.2) is dedicated to ES. At a first stage, the five main approaches for ES mapping are listed and described. Section 2.2.2. is dedicated specifically to the methodology used in this paper: Ecosystem Service mapping using Burkhard's matrix. The main integration approaches to this specific method are listed (2.2.3) and how they were used in this particular case-study is briefly explained (the more detailed description of the integration approaches used is presented in Chapter 3).

Chapter 3 focuses on the case study of the Lisbon Metropolitan Area, beginning with a characterization of this region (section 3.1.1.). In section 3.2, an analysis and categorization of the approaches used for GI mapping in the LMA was done. In order to perform it, the 2nd generation masterplans and reports were submitted to a process of content analysis and categorization following the methodology used by Vaz (2018) for the Alentejo Region. This was done only for the 10 municipalities with reviewed masterplans (out of the total of 18 municipalities from the LMA). The collected criteria for GI mapping in these municipalities was categorized and organized into two tables, which can be found in Annex (see Annex I).

In section 3.3., the iterative methodology followed throughout the development of the collaborative ES mapping approach used in Lisbon Living Lab WG 2.1 was detailed. The first set of reclassified, by the capacity of providing ES, land cover maps (which were produced by FCT-NOVA) are illustrated and analyzed.

In section 3.4., stakeholders' perspectives on how to progress towards the integration of ES mapping in GI planning at a local and regional level, as well as on their perspective regarding the main potentials and constraints of the approach developed within the WG, were collected through interviews made to stakeholders of some of the municipalities from the LMA. In this section of chapter 3, the information collected from the interviews was categorized according to four different subjects.

Section 3.5. was dedicated to the explanation of the 3 different approaches used by the WG 2.1. for the statistical treatment of the results produced.

In section 3.6. the final ES HUBS map in illustrated and then overlaid with the REM map, with the aim of checking the adherence between these two maps.

Finally, Chapter 4 summarizes the most relevant results and conclusions of this dissertation in an integrated manner.

Chapter 2. Linking Green Infrastructures and Ecosystem Services

2.1. Green Infrastructure

The concept of green infrastructure can be broadly defined as “a strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings” (European Commission, 2013)[17].

The notion of multifunctionality is at the basis of the EU GI Strategy (European Commission, 2013). In line with this strategy, one of the key purposes of GI is to serve various goals for a wide range of ecosystems crossing rural-urban divides, administrative scales and policy sectors (Hansen and Pauleit, 2014; Chatzimentor et al., 2020).

According to the Green Surge guide for practitioners[18], GI planning has four core principles (integration, connectivity, multifunctionality and social inclusion) and it aims to address the following challenges: adapting to climate change, protecting biodiversity, promoting a green economy and increasing social cohesion (Hansen et al., 2017). The image below illustrates these principles and objectives of GI planning (see fig. 2).

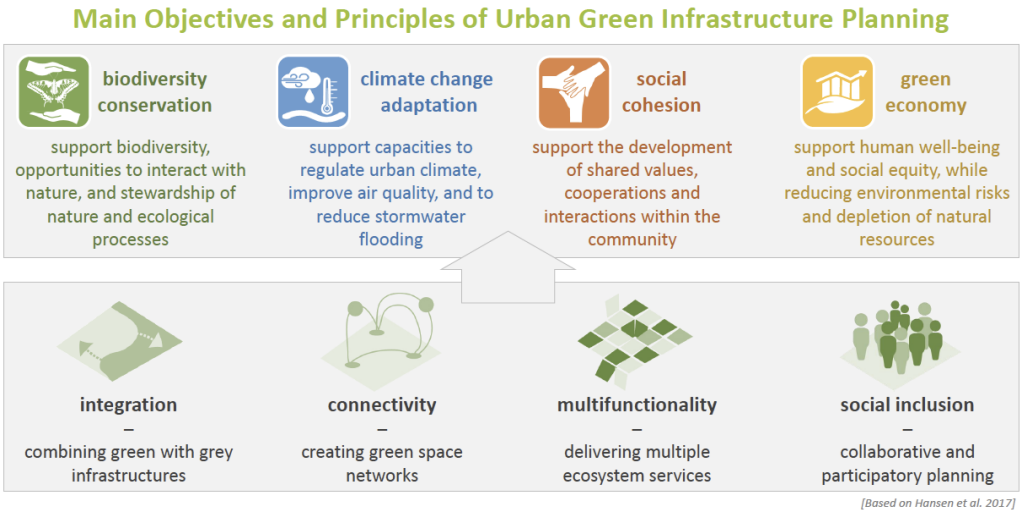


Figure 2- Main objectives and principles of GI planning (Hansen et al., 2017; Rolf, 2020).

Over the years, the term “GI” was preceded by others that conceptually overlapped and generically moved from an ecocentric to a more multifunctional perspective jointly addressing biodiversity and human well-being. Even though the roots of this concept date back to the 19th and 20th centuries, it was only more recently that the strategies of nature conservation started to include the concept of GI in territorial planning. In densely occupied regions the development of GI related to the development of

[17] European Commission - Building a Green Infrastructure for Europe. (2013).
[18] Green Surge: Urban Green Infrastructure Planning. A guide for practitioners. Available at: https://www.e-pages.dk/ku/1340/html5/

urban greening and the increasing need to integrate green areas in a consistent and efficient way (Beatley, 2000, 2009; Searns, 1995).

It was not until the year of 2001 that the concept of green infrastructure was introduced by Benedict & McMahon as an "interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations". Years later, this idea will be reinforced by Sandström, highlighting the multifunctionality of green infrastructures and their main role in territory planning, claiming that this planning tools are as important as any other "technological infrastructure" for healthy cities and for people's health and life quality (Sandström, 2006).

Even though the concept of green infrastructure is associated to a diversity of definitions, the promotion of landscape connectivity is the basic principle behind it. The implementation of the concept of green infrastructure does vary according to the different scales and the diversity of landscape along the urban-rural gradient.

Unlike the ecological driven but broader and more multifunctional European understanding of GI, Rouse (2013) in the US context described green infrastructures function at a local scale as a "stormwater management approach that mimics natural hydrologic processes" and at a city and regional scale as a "multifunctional open space network" (Cabral, 1980; Mell, 2008, 2012).

In Portugal, although industrialization occurred later and was less intensive compared to the countries of the center and north of the Europe, the cities have grown considerably since 1900, especially those of the coast, and in particular the metropolitan areas of Lisbon and Porto. Many inhabitants of rural areas abandoned the fields to work in industry and services in urban centers, particularly over the decades of the 50's and the 60's (Cabral, 1980 ; Ferrão, 2011).

This new reality gave rise to new needs and potentialities, which lead to the creation of strategies to increase sustainability and quality of life. Thus, opportunities are created for urban design, qualification and expansion while aiming at greater opportunities for better living conditions and for the protection and enhancement of the natural values. Alongside this development of urban areas, the history of green space planning has also been evolving. Considered a fundamental urban planning strategy, green infrastructure has been implemented for a long time and has accompanied the development of cities, in response to the constant challenges brought by the evolution of societies and cultures.

Caldeira Cabral was a pioneer in reincorporating nature in the urban network and the creation of rural management plans since the decade of the 40's, introducing the concept of green infrastructure in the form of the *continuum naturale* (Andresen, 2001). This concept was legally framed in 1987[19]. Although it only appeared in the Portuguese legislation at the end of the 80's, the concept of continuum naturale started to emerge at an international level in the beginning of the 20th century, with the need to

[19] Continuous system of natural occurrences which constitute wildlife support and the maintenance of genetic potential and that contributes for the stability and balance of the territory (Lei nº. 11/87 de 7 de Abril – Lei de Bases do Ambiente, artigo 5º.)

incorporate the natural landscape, in a continuous way, with the assurance of several functions, from ecological to social and aesthetic (Quintas, 2014).

Since the decade of 1930, the work developed first by Francisco Caldeira Cabral and later by Gonçalo Ribeiro Telles has been consolidating and supporting the design of a network of linear spaces that support the multiple uses of natural corridors, allowing the connection of spaces of different scales, protected natural areas and cultural and historical sites. In the planning process of the diverse Portuguese municipalities and cities, the concept of green structure and of green plans were developed in parallel, as supporting documents to the municipal masterplans (Quintas, 2014).

Since the year of 1999, the concept of green infrastructure has been integrated in the Portuguese legal framework and is translated by the designation of "Ecological Structure". It's compulsory for every municipality to have this planning tool. Nevertheless, there are still many limitations in the definition of a uniform and clear methodology when it comes to the mapping methods used and to the regulation of this instrument.

2.1.1. Green Infrastructures in the Portuguese Legal Framework

Despite the appearance of the continuum naturale concept at an international level in the beginning of the 20th century, in Portugal GI only found its way into the Portuguese legislation much later by the end of the 90's decade.

The Portuguese Constitution recognizes the existence of constitutional rights and duties in the area of the environment since 1976, stating that it is the State's responsibility to "organize the territorial space in order to build biologically balanced landscapes" and "to promote the rational use of natural resources, safeguarding their capacity for renewal and ecological stability"[20]. In other words, the Portuguese law considers environmental protection in a double perspective: it is a fundamental task of the State as well as a fundamental right of the citizens.[21]

Two fundamental nature planning tools are created in the beginning of the 80's, namely the National Agricultural Reserve[22] (1982) and the National Ecological Reserve[23] (1983). This constitutes a landmark, raising attention to the importance of protecting and enhancing the natural resources existing in the portuguese territory. In 1987, the Environment Policy Act[24] was published, calling for the right to quality of life, which results from the interconnection between social, biophysical and economic factors.

This Act defines the basis for environmental policies at a national level. These policies aim for the optimization and maintenance of the permanent utilization of natural resources, promoting a sustainable

[20] Constituição da República Portuguesa, 1º versão (Decreto de 10/04 de 1976) Artigo nº. 66, nº. 2, alíneas b) e d)
[21] Constituição da República Portuguesa, VIII Revisão Constitucional (2005) Artigo nº.9, alínea e) e Artigo nº.66
[22] RAN - Reserva Agrícola Nacional
[23] REN- Reserva Ecológica Nacional
[24] Lei nº. 11/87 de 7 de abril - Lei de Bases do Ambiente

development. In the light of the Portuguese Constitution, this Act establishes a tool to guarantee the "public right for a human and ecologically balanced environment as well as the duty of the state to promote this through individual and community initiatives".[25]The Environmental Policy Act 1987 version was revoked in 2014[26] and a new version was published. The revised policy act aims for the realization of the environmental rights by promoting sustainable development, supported by adequate management of the environment, in particular of ecosystems and natural resources, contributing to the development of a low carbon society and "green economy", rational and efficient use of natural resources, ensuring the well-being and improvement of the quality life of the citizens.

As previously stated, in 1999 the concept of Ecological Structure was formally introduced into the legislation. This concept can be adapted to both rural and urban landscapes and should be integrated into multiple plans with different scales. With the approval of the Decree-Law nº 380/99 (RJIGT 1999), the delimitation of the Municipal Ecological Structure becomes a mandatory municipal planning tool. According to the RJIGT, the Ecological Structure is defined as "(...)areas, values and systems fundamental to the protection and environmental assessment of rural and urban spaces (...)"[27].

In 2015 a revised RJIGT was published[28], constituting the new legal framework basis for territorial management. In this new decree the elements that must accompany municipal spatial planning are established, as well the specific criteria for land classification (basic purpose of the land: urban or rural)[29] and reclassification (alteration of the basic purpose of the land, for example, from urban to rural or vice versa)[30], for qualification of the dominant use and related categories to urban and rural land applicable to the national territory.

The regulatory decree of 2009[31] establishes the technical concepts in the field of spatial planning and urbanism to be used by the territorial management instruments. In these documents, in "Ficha nº 29", is included the definition of GI as well as elements that it integrates in rural and urban soil, respectively. According to this decree, the Municipal Ecologic Structure is defined as the "set of areas that due to its biophysical, cultural and landscape characteristics, its ecological continuity and structure has as a main function the contribution to the ecological balance, protection, conservation and environmental assessment, landscape and natural heritage of rustic and urban space"[32]. This regulatory decree was revoked in 2019 in order to ensure the update of the concepts related to indicators, parameters, symbology and graphic systematization to be used by the territorial management instruments and

[25] Artigo nº 2, Lei nº. 11/87 de 7 de abril - Lei de Bases do Ambiente
[26] Lei nº. 19/2014, 14 de abril - Lei de Bases do Ambiente
[27] Artigo nº. 14, Decreto-Lei nº 380/99, de 22 de Setembro - Regime Jurídico dos Instrumentos de Gestão Territorial
[28] Decreto-Lei nº 80/2015, de 14 de Maio - Regime Jurídico dos Instrumentos de Gestão Territorial
[29] Artigo nº 71, Decreto-Lei nº. 80/2015, 14 de Maio
[30] Artigos nº 72 e 73, Decreto-Lei nº. 80/2015, 14 de Maio

[31] Decreto Regulamentar nº9/2009, 29 de Maio
[32] Ficha 29, Decreto Regulamentar nº 9 /2009

following the evolution of the juridical regime. **In the new version, the concept of ecosystem services is integrated in "Ficha nº29"[33].**

The Basic Law for Spatial Planning (LBPOTU)[34]establishes the general basis for the public policy on soils, land use planning, and urbanism by defining the principles, objectives, goals, and architecture of the land management system and clarifying the duty to plan the territory as an obligation of public entities. It aims for the enhancement of the soil's potential, safeguarding its quality and the fulfillment of its environmental, economic, social and cultural functions and to guarantee a sustainable development, increasing the resilience of the territory. This framework is operationalized through the corresponding territorial management instruments, emphasizing the differentiation between **territorial programs** and **plans**.

The Territorial Management System (SGT), as it currently stands, is the basis of spatial planning policy, covering three scopes: national, regional and municipal.

Regarding the hierarchical structure that characterizes this systemic process, a "pyramid" type format is adopted (see figure 3), which is oriented in a descending direction, starting from a higher, generalist level (programs) and ending at a level characterized by high specificity and detail (plans). Programs establish the strategic framework for territorial development and its guidelines and/or define the spatial application of national policies to be considered at each level of planning. Plans, on the other hand, establish options and concrete actions within territorial planning and organization as well as defining the spatial uses for the land.

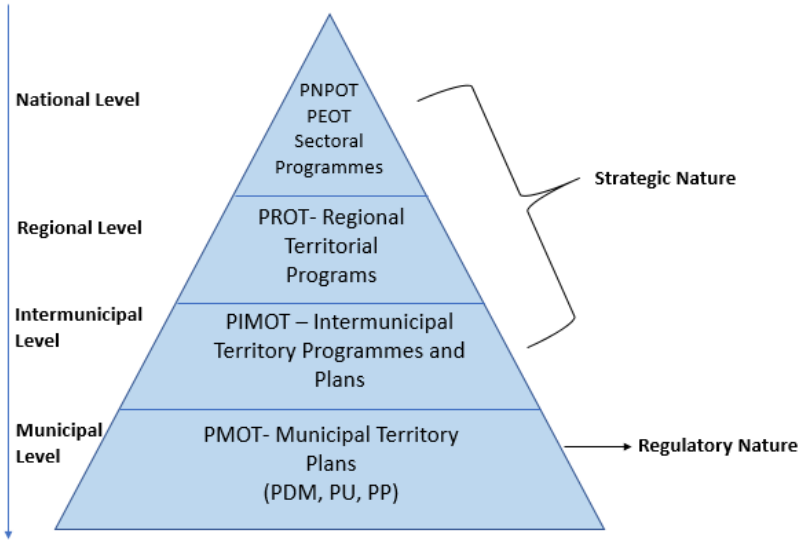


Figure 3- Portugal Territorial Management Legal Framework (adapted from Vaz, 2018)

At a national level, programs will define the strategies for the national territory planning as well as the integration within the EU. **The National Program for Territorial Management (PNPOT)** is at the top of

[33] Ver notas complementares da "Ficha nº29"do Decreto Regulamentar n.º 5/2019
[34] Lei nº 31/2014, de 30 de Maio - Lei de bases gerais da política pública de solos, de ordenamento do território e de urbanismo

the territorial management system instruments. It will define the objectives and strategic options for territorial development, as well as establish the model for organizing the national territory. It constitutes the reference framework for other territorial programs and plans and a guiding instrument for strategies with territorial incidence. Also a national level, there are the **Special Land Management Plans (PEOT)**, which are an instrument designed for particularly sensitive areas in the biophysical domain and especially susceptible to the materialization of various hazards and that aim, on the one hand, for the sustainable planning of occupation and use of the areas of incidence and, on the other hand, for the preventive management of risks potentially created there for the exposed elements. Still at national level there are the **Sectoral Programs**, which establish and justify the sectorial options and objectives with territorial incidence and define execution rules, integrating the necessary graphic pieces for the representation of the respective territorial expression.

At a regional level, the Regional Programs for Territorial Management (PROT) will define the regional strategy for territorial development, integrating the options established at the national level and considering the sub-regional and municipal strategies for local development and constituting the reference framework for the elaboration of programs, inter-municipal plans and municipal plans.

Regarding the plans, they are designed to establish options and define concrete actions for the planning and management of the territory, as well as defining land use. At a municipal level, there are three different types of plans, which are **Municipal Masterplan (PDM), Urban Zoning Plan (PU) and the Detailed Plan (PP)**.

Municipal masterplans are the instrument that establishes the municipal territorial development strategy, the municipal policy for the soil, land use planning and urban planning. They also integrate and articulate the guidelines established by the programs at a national, regional and inter-municipal level as well as promote the interdependence with neighboring municipalities. As previously mentioned, the GI is a compulsory element of the masterplans.

2.2. Ecosystem Services

The concept of ecosystem services has been gaining influence in the development of environmental research and policies, contributing to a redesign of the relations between humans and the environment (Chaudhary et al., 2015).

The concept emerged in the decade of the 70's as "environmental services" (Wilson and Matthews, 1970), being later renamed to ecosystem services in the 80's (Ehrlich and Mooney, 1983). The paper by Costanza et al. (1997) published in NATURE and designated "The value of the world's ecosystem services and natural capital" constituted a groundbreaking advance on this subject, by quantifying the value of the ecosystem services and natural capital.

With the Millennium Ecosystem Assessment the concept of ecosystem services makes its way into the policy agenda (Braat and de Groot, 2012). According to the Millennium Ecosystem Assessment (MA, 2005) **ecosystem services are defined** as "**the benefits ecosystems provide to human wellbeing**".

Initiated in 2001, the main goal of the Millennium Ecosystem Assessment was to perform an assessment on the effects of ecosystem change for human well-being as well as understanding the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being (MA, 2005)[35]. The MA was the first assessment at a global level of the effects of ecosystem changes in people.

Currently, the definitions and applications of this concept are evolving fast as researchers, policy makers and managers explore the benefits that ecosystems provide to people (Haines-Young and Potschin, 2009).

When it comes to the classification of ecosystem services there are several interpretations on the meaning of biophysical structure, ecological functions, intermediate services and final services (Haines-Young and Potschin, 2009). These differences will lead to a more difficult correspondence of services with benefits and also to blurred distinctions between intermediate and final services. In order to facilitate the mapping and/or the valuation and measurement of ecosystem services there is a need to adopt a standard categorization methodology for the classification of the ecosystem services (Burkhard and Maes, 2017).

Over the last years, the literature and investigation on ES has multiplied. An important example is the work developed by The Economics of Ecosystems and Biodiversity (TEEB). Its main goal is "to mainstream the values of biodiversity and ecosystem services into decision-making at all levels"[36].

According to TEEB, ES are divided into four main categories: **provisioning, regulating, cultural and supporting services** (MA, 2005; TEEB, 2010). **Provisioning ES** will include all the nutritional, non-nutritional, material and energetic outputs from living systems as well as abiotic outputs. **Regulating ES** include all the ways in which ecosystems can mediate or moderate the ambient environment and that will affect human health (e.g., climate regulation, moderation of extreme events, erosion prevention or biological control). **Cultural ES** are all the non-material and non-consumptive outputs of ecosystem (biotic and abiotic) that affect the physical and mental states of people (e.g., recreation, aesthetic pleasure, spiritual experiences). Finally, **supporting ES** are defined as the ecological processes and functions that are needed for the production of the previous final services (e.g., species habitats, pollination, maintenance of genetic diversity) (Baró, 2016).

The Common International Classification for Ecosystem Services (CICES) proposed by the European Environment Agency in 2009 sets a landmark, by creating a frame of reference for ecosystem services research (Maes et al., 2014). CICES developed out the work on environmental accounting undertaken by the European Environment Agency (EEA) and other international partners (Haines-Young and Potschin, 2018). However, its application has gone far beyond accounting. It has also been used as the basis of mapping and ecosystem assessment (Haines-Young and Potschin, 2018). The work in the European Union on Mapping and Assessment of Ecosystems and their Services (MAES),

[35] https://www.millenniumassessment.org
[36] Teebweb.org

for example, uses CICES as the framework for its work developing ecosystem service indicators (Czúcz et al., 2018). The MAES (Mapping and Assessment of Ecosystems and their Services) initiative constituted a key tool to reach the commitment made under Action 5 (of Target 2) of the EU biodiversity Strategy to 2020 (Maes et al., 2014). The first fully operational version of CICES (V4.3) was published in 2013. On the basis of the experience gained by the user community since then, its structure and scope has been reviewed. The latest version (V5.1.) was proposed in 2009 and aims to progress towards a standardization of ES classification. This policy brief explains what has been done and why CICES has evolved towards the present version (V5.1).

In figure 3 the **cascade model**, which provides the conceptual framework in which CICES is set, is represented. CICES aims to classify final ecosystem services (as shown in fig. 4), focusing on the final outputs of ecosystems that people can use in a beneficial way (Haines-Young and Potschin, 2018).

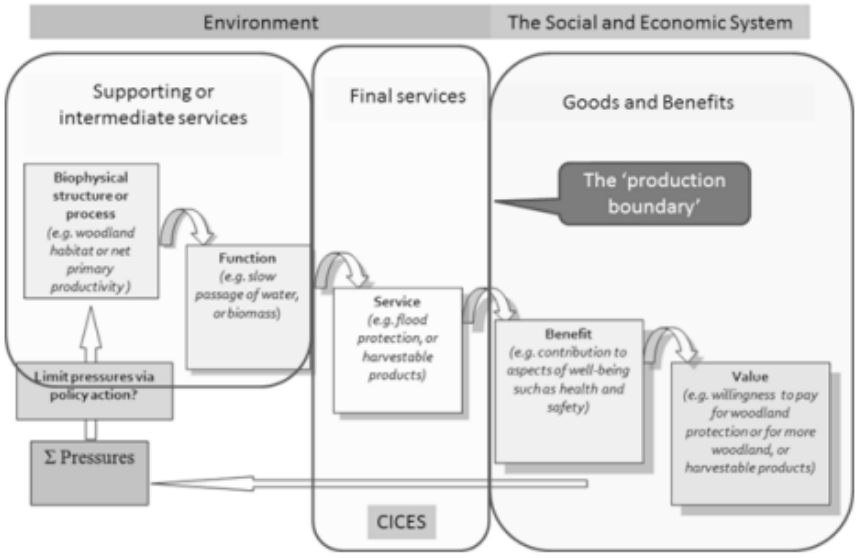


Figure 4-The cascade model (Potschin and Haines-Young, 2016b).

CICES classification describes ecosystem final services using a five-level hierarchy (section>division>group>class>class type), in which each level will be increasingly more detailed and specific than the previous. This five-level hierarchical structure was designed with the aim of allowing users to choose the most appropriate level of detail required for the application in cause as well as to allow for the combination of results when making comparisons or more generalized reports. As one goes down from “Section” through “Division”, “Group”, “Class” and “Class Type”, the specificity of the services will increase but remain dependent of the broader categories above them. In another words, there will be a dependency between the different hierarchical levels, since the characteristics used to define the services at the lower levels are “inherited” from the levels above. It is also relevant to mention that the new version (CICES V5.1**) separates biotic and abiotic factors**, allowing users to select only those ecosystem services that depend on living systems (i.e. biodiversity in its broadest sense) or to

include the non-living parts of ecosystems that can also contribute to human well-being (Adapted from CICES V5.1 guidance report).[37]

Even though CICES facilitates the categorization and the measurement of ecosystems there is still room for improvement. According to the "Revision of the Common International Classification for Ecosystem Services (CICES V5.1): A policy brief", future studies will need to focus on how to link this classification to the characterization of the condition the ecosystems, allowing to better understand what the biophysical underpinnings of ecosystem services are. The deeper description and classification of the benefits and the beneficiaries is also needed, so that we can better draw conclusion on how people depend on and relate to natural ecosystems over time and around the globe (Haines-Young and Potschin, 2018).

The paper published in 2017[38] by Costanza *et. al*. constituted an important landmark regarding the work that still has to be done in ES studies, highlighting the main weaknesses of the mainstream approach to valuation, growth and development and by providing recommendations for the future. Amongst the conclusions of this paper its the need to integrate ES and natural capital into the mainstream economic policy in order to achieve a sustainable future, through a dynamic process that promotes public engagement and that aims to reach a much broader audience (Costanza, 2017).

2.2.1. Approaches to Ecosystem Services mapping

The operationalization of the ecosystem services framework is claimed by a raising number of researchers and practitioners as the way forward to face the increasing territory planning challenges (Baró, 2016). The mapping of ES is a crucial tool to operationalize the concept of ES, since ecosystems and their capacity to provide ecosystem services have a spatial expression. The assessment of ES and their mapping has a broad range of applications: raising awareness about areas of ES supply and demand, environmental education on the importance of functioning ecosystems for human wellbeing, decision making and priority setting instrument (e.g., green infrastructure planning), environmental resource management, land use optimization, portraying trade-offs and synergies for ES, identifying spatial congruence or mismatches between supply, flow and demand of different ES (Burkhard and Maes, 2017; Baró 2016; Maes et al., 2014).

A review of ES mapping approaches shows that there is a wide range of spatial scales, data sources, indicators and methods. However, this wide range of possibilities can also be problematic. According to Crossman et al. (2013) this variety leads to a certain inconsistency in the methodological approaches used in mapping of ES, which will make the comparability of different geographical areas and the

[37] https://cices.eu/content/uploads/sites/8/2018/01/Guidance-V51-01012018.pdf

[38] Constanza et al. (2017): "Twenty years of ecosystem services: How far have we come and how far do we still need to go?" in Ecosystem Services, Volume 28.

development of a robust system of ES indicators at a national and international level much more challenging.

Five main categories for ES mapping approaches can be identified (Burkhard and Maes, 2017):

- **Proxy-based methods**

Proxy-based methods use a single or combined secondary indicators for the definition and mapping of a new proxy layer of ES (Egoh et al., 2012). These approaches usually incorporate the available knowledge on the causal relationship between a certain environmental or social variable and the supply or demand of ES (Baró, 2016; Martínez-Harms and Balvanera, 2012).

An example of a study based on this approach is the one developed by Naidoo et al., (2008) which presented a method for the global mapping and quantification of ecosystem services in biophysical units. In this case study, the limited data availability allowed for the quantification of proxies for global mapping and quantification of four ecosystem services in biophysical units: carbon sequestration, carbon storage, grassland production of livestock and water provision.

- **Look-up tables approach**

The "look-up table" or "value transfer" approach is used when ES values are obtained from empirical data at other places and other spatial scales where data is absent or limited. (Baró, 2016; Martínez-Harms and Balvanera, 2012).

This approach has been mainly applied to regulating ES, e.g., the carbon storage layer (Gibbs, 2006) has been used by Naidoo et al. (2008) and Wendland et al. (2010), giving a single estimate of carbon for each biome. The look-up table approach has been primarily applied at global scales and it has the disadvantage of neglecting spatial differences or habitat land cover types, hence giving very broad estimates of the ES supply (Martínez-Harms and Balvanera, 2012).

- **Participatory and expert-based approach**

Participatory and expert-based approaches appeal to the knowledge or the perceptions of stakeholders and experts in order to value and map ES and are often complemented with information from literature and secondary data (Wolff et al., 2015). This kind of approaches is most usually used in the assessment of ES with a high level of complexity and uncertainty when it is hard to collect empirical data on the natural and societal processes (Baró, 2016).

In this dissertation, one of the most commonly applied expert-based approaches will be used - the ES matrix (e.g., Burkhard et al. 2009, 2012, 2014). For this reason, a full section of this chapter will be dedicated to the mapping of ecosystem services using this approach (see section 2.2.1.). The **ES matrix approach** links ES capacity, flow and demand qualitative scores to the different existing land cover types.

This approach has the advantage of being a relatively fast assessment that pools the knowledge of experts (Martínez-Harms and Balvanera, 2012). However, it has the disadvantage of having high levels of subjectivity in the assessment related to the reliability of the scoring process and it does not provide quantitative estimates of ES (Schröter et al., 2014).

- **Empirical methods**

This type of approach consists of the collection of ES data from empirical methods (e.g. direct observations and field data sources). This empirical ES data can be linked to a given spatial unit (e.g., a land-cover class) or integrated in a more complex process-based model for mapping the distribution of ES in larger areas (Baró, 2016; Martínez-Harms and Balvanera, 2012).

Even though data availability is a clear limitation in this sort of approach, empirical methods present the advantage of generally leading to very accurate ES maps (Baró, 2016). An example in which this approach is frequently used is in the estimates of the ES of food provision, which is normally derived from agricultural census data (Egoh et al., 2012).

- **Process-based models**

This type of approach builds on the theoretical understanding behind the social ecological processes (Baró,2016). Process-based models link delivery, value and trade-offs under scenarios of land cover or socioeconomic changes, allowing for a display of how natural capital or ES flows change in the future. Unlike the previous static maps obtained from the methodologies described above, models are able to show how a given landscape is linked to the supply of the different ES, and therefore able to show how the changes in the landscape will impact the provision of such services (Martínez-Harms and Balvanera, 2012). Process-based models are able to capture the dynamics of ES taking into account the underlying drivers and pressures that induce changes in the socio-ecological system (Wolff et al., 2015).

The disadvantage of this approach is the fact that it requires a comprehensive understanding of the system, and large amounts of time and data and expert knowledge (Maes et al., 2012). Due to this high complexity, this process-based models are usually integrated in larger tools for ES quantification, mapping and valuation (Baró, 2016).

Examples in which this sort of approach has been used are the mapping of the supply and demand of regulating ES through pollination models (Schulp et al., 2014) and through hydrological models (Stürck et al., 2014).

It is also relevant to highlight the fact that **these five methodological approaches are not mutually exclusive and can often be used in a complementary way**, as mentioned above for example in the use of empirical models for the development of process-based models.

In order to choose the most adequate method, one must assess first the ES type being studied, the data availability, the scales (spatial and temporal) and the general desired final goals.

The five approaches presented above are combined in **the tiered approach**. This approach is divided into three different tiers. The different tiers will be defined according to how the considered variables affect ES interactions, ES supply and ES demand related to a specific empirical or policy question under investigation (and that is relevant to the users, policy makers or researchers) with increasing level of detail and complexity from tier 1 to tier 3 (Grêt-Regamey et al., 2015).

At a first stage, the different components of a given human-environment system should be described (including the ES) as well as the beneficiaries and institutions involved and their interactions. After the analysis of the components, the appropriate tier and associated ES mapping method can be selected (Burkhard and Maes, 2017).

A **tier 1 approach** will use available indicators to do the mapping of the ES. The simplest form of an ecosystem services assessment uses data available for most of the European countries (e.g., CORINE). These indicators can come from land use/cover data, national forest inventories, biodiversity monitoring maps, etc. and they represent proxies for a given ecosystem service (Maes et al., 2014).

A **tier 2 approach** will map ES by linking the different indicators with land use data. Finally, a **tier 3 approach** will have the highest level of detail and will further develop the tier 2 approach by modelling biophysical processes (model-based approach) in a GIS or in other software instead of linking indicator data through simple relationships (Maes et al., 2014).

In another words, when the interactions between the system components are relevant and a deeper understanding of processes is needed, a tier 3 approach would be required. If on the other hand, the main purpose of the map is to provide a rough overview of the ES values in a given area or just to highlight their presence or absence, then a tier 1 approach may be sufficient. For example, in regions where the available data is very limited, a tier 1 approach can be the best choice while in the mapping of an urban tissue a tier 3 approach will provide the necessary detailed information (Grêt-Regamey et al., 2015).

2.2.2. Mapping Ecosystem Services with Burkhard's Matrix

As mentioned in 2.2., participatory and expert-based approaches rely on the knowledge of stakeholders and experts for the valuing and mapping of ES and are often supported with information from literature and secondary data (Wolff et al., 2015). These sorts of approaches are more often used in the assessment of ES that present high complexity and uncertainty and/or when it's hard to collect empirical data on the natural and societal processes (Baró,2016). The use of expert knowledge is particularly well-suited for integrative ecosystem service assessments, which address transdisciplinary issues and contain specific data requirements (Jacobs et al., 2015).

One of the most straightforward and therefore most popularized expert-based approach is the ES matrix (Baró,2016). The matrix approach links land cover and/or land use type to ecosystem services by providing a qualitative score for ES capacity, supply, use and/or demand (Burkhard et al. 2009; 2017).

The figure below (fig. 5) schematizes the concept of the ES matrix and provides an overview of the main key components that are usually involved in the process.

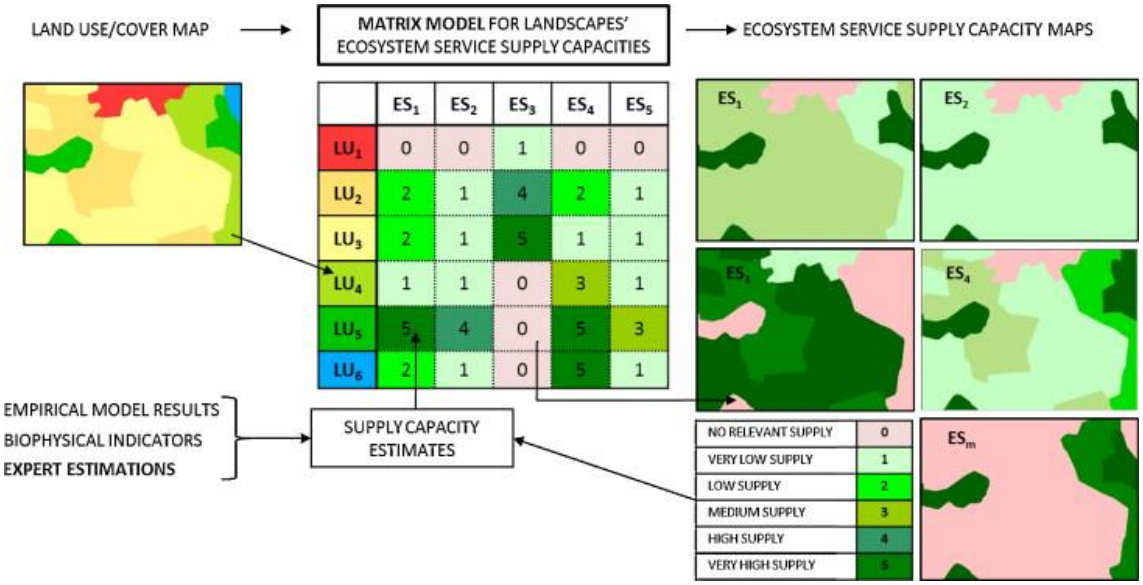


Figure 5- Schematic image displaying the concept of the ES matrix model (Burkhard et al., 2009) retrieved from the article 'The Matrix Reloaded': A review of expert knowledge use for mapping ecosystem services, Ecological Modelling (Jacobs et al. ,2015).

The ES matrix model can use expert-based estimations, physical quantifications or empirical model results to attribute ES supply capacitities to the different land use/land cover classes. The matrix allows the comparison of ecosystem services (columns) as well as land use/land cover classes (lines).

Amongst the **main advantages of the matrix model** are the fact that it is efficient, fast, accessible and adaptable, characteristics that justify its wide popularity. The simple technicality of the matrix model allows for the provision of quick and "mapable " ES data (Jacobs et al., 2015).

The ES matrix approach constitutes an efficient mapping method, linking the different ES to appropriate geophysical spatial units. The matrix provides an extremely flexible tool for ES mapping, and it can be applied to all spatial and temporal scales, for all the ES, for different mapping purposes and for multidisciplinary ES quantification approaches (Burkhard et al., 2017). In the matrix model, estimates are usually put into semi-quantitative units (in the figure we can see the scale used varies from 0-5) in order to allow both the analysis and the comparison across the different ES and LULC (land use and/or landcover) classes. The large flexibility associated to this technique, contributed for its popularization in regional policies (Jacobs et al., 2015).

However, the ES matrix methodology also presents several bottlenecks/constraints. Amongst the main critiques made to this methodology are its often-poor methodological transparency, comparably low reproducibility and lack of appropriate uncertainty acknowledgement. These set of limitations are the reason why the matrix model is sometimes still considered a "risky" tool when it comes to actual decision support, since the uncertainty associated to it can translate into an increased risk of an

unwanted outcome for decision-makers (Jacobs et al., 2015; Burkhard, 2009). Some of these risks, related to the lack of scientific credibility and legitimacy of the results, could be extinct or diminished if special measures of confidence, traceability, reliability and validity were included in the studies (Burkhard and Maes, 2017).

Burkhard (2017) proposed a 10-step ES matrix methodology for ES mapping, based on ES indicators and a collection of suitable spatial data. The basic steps can be seen in the scheme showed in fig. 6 (Burkhard and Maes, 2017).

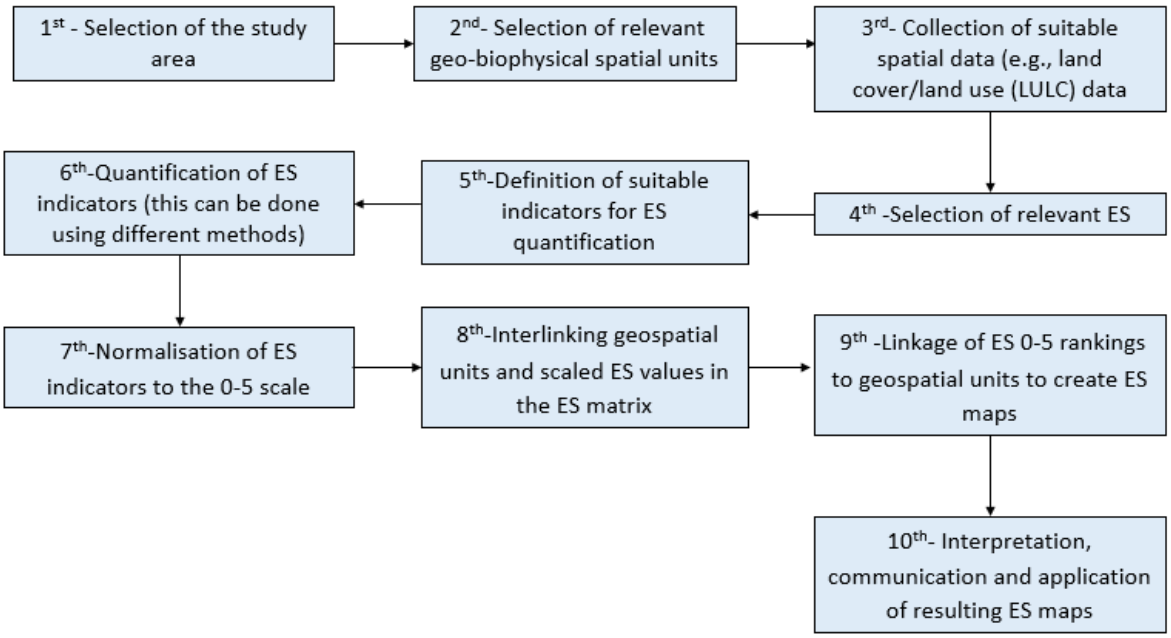


Figure 6-Basic steps for the application of the ES matrix approach (adapted from Burkard et al., 2017, chapter 5.6.4.).

The first 6 steps represented in the scheme relate to the goal of the ES mapping exercise as well to the available mapping tools (data, methods, time etc.). In this process, the inclusion of relevant stakeholders is also very important. Steps 7, 8, and 9 are specific for the ES matrix and each of them is associated to specific uncertainties. Finally, step 10 refers to the communications between the map-maker and the map-user as well as to the multiple applications of the ES maps produced for different purposes (Burkhard and Maes, 2017).

The ES matrix approach is based on a normalization of the ES indicator values to a relative scale that ranges from 0-5 (see step 7th of fig. 6). It is important to note here that the classification “0” doesn’t necessarily mean absolute zero but rather represents that in a given land use/cover there is no relevant supply or demand of a specific ES. This reflects that in natural systems, a lot of ES are supplied in a continuous way, but their supply is not relevant for human well-being. At the opposite end of the scale, the classification “5” represents the maximum value indicator of ES. It will not be useful to use a global maximum reference value (e.g., using tropical forests’ primary productivity as reference for boreal forests) since this would allow no practical application in regional and local studies. For comparative purposes, this maximum value should represent the maximum amount of a given ES supplied in a given region (Burkhard et al., 2017).

Recent studies have presented separate matrices **distinguishing ES potentials from de facto ecosystem service flows** (Burkhard et al., 2014). This differentiation between ES potentials and ES de facto flows is important for ES trade-off analysis as well as for decisions in landscape management, since protected areas may have a wide range of ES potential supply but sometimes, due to their current status, this ES potential is not reached, and in these cases the ES actual flows can be much lower than the ES potential supply (Burkhard et al., 2014; Jacobs et al., 2015). According to Burkhard et al. (2012a) the ES potential is defined as " the hypothetical maximum yield of selected ecosystem services" while the ES flows are described as "de facto used set (bundles) of ecosystem services and other outputs from natural systems in a particular area within a given time period." In the practical case study of this dissertation, the distinction between ES potentials and **de facto ES flows** (these are **referred to as effective ES production** in chapter 3) was frequently discussed and, in the interviews, (see section 3.4. for further detail) an attempt was made to understand the rationale behind the matrix evaluations of the different municipalities, with the aim of understand which perception (potential or effective production) had been used.

Still a challenge in the matrix approach is how to capture and integrate expert knowledge. Campagne and Roche (2018) worked on the development of methodologies on collecting and integrating expert knowledge to address some of the biases and limitations of the expert-based elicitation method. In 2018, Campagne et Roche proposes a methodology with 7 steps for the expert-based matrix approach, which aimed to promote cogency in the methodology as well as coherency in the matrices produced. This methodology will address not only the process of expert scoring but also consider the variabilities and uncertainties as part of the ES assessment.

This 7-step methodology proposed by Campagne and Roche can be considered as complementary to the one proposed by Burkhard (fig. 6), since the 10-steps methodology developed by Burkhard focused mainly on the mapping issues and the use of spatial data, while the methodology presented by Campagne and Roche (2018) aimed to promote a set of practices that would guarantee the production of a reliable ES matrix and an analysis of the main sources of uncertainties and/or variabilities.

In a nutshell, the use of expert knowledge brings with it the advantage of quick and integrative ES scoring, which can be validated for ES assessment and mapping at different scales. However, a clear methodology is needed for collecting and integrating in order to face the biases and limits of this method. The following section (2.2.3.) will address the integration approaches considered for the practical case study of this dissertation.

2.2.3. Burkhard's Matrix - Integration Approaches used in the case-study

Even though the research on ES has been growing significantly in the past years, when it comes to ES integration in the decision-making process, several gaps still subsist and the use of ES in governance frameworks regarding the planning and the management of territory is still very scarce. (Mascarenhas, 2015). Recent changes in the European governance framework will likely contribute to potentially higher degrees of ES integration in the future. In order to overcome the existing gaps, the methodology adopted to apply the ES matrix has to be transparent and should integrate multiple integration approaches and more variability analysis. One of the aims of this dissertation is to promote an ES integration at local and regional policy frameworks (e.g., for spatial planning and for environmental assessment). With this purpose, several integration approaches were used, to try to make the process as holistic as possible.

A **spatial approach** (ponderation per different territorial units) was used in the scoring process to assess the different ES for each of the land cover types of COS 2018. These scores were attributed using a **participatory approach** in which each one of the stakeholders involved in the group project (WG 2.1. of the ROBUST initiative) was given the task to fill an empty matrix with scores varying from 0-5. These scores can be based on or can integrate data from diverse sources of varying quantity and quality. Since transparency in the methodology is crucial, interviews were made in order to collect information on the criteria used by each municipality in the filling of the matrix (e.g., if the filling of the matrix was made individually or with the consultation of other additional documental information and/or help from colleagues working in other sectors). This methodology will be further explained in chapter 3, with a clear description of each of the steps of the process.

Due to the fact that the scoring was made by different stakeholders, it was also considered important to perform **confidence analysis** of the final scores. Reviewing the available literature, one can find that a few studies have already used confidence analysis (e.g., La Bianca et al. 2018, Gorn et al. 2018, Elliott et al. 2019, Geange et al. 2019). Even though the number of studies has increased in recent years, the number of published papers using confidence analysis is still very low. In this paper, the representatives of each one of the municipalities were inquired about their level of confidence when filling in the matrix, with the aim of getting a better perception of the obstacles found during the realization of the exercise and, at the same time, of performing an assessment of the reliability of the results. The confidence analysis performed in the practical case study is carefully detailed in Chapter 3 (Section 3.5.).

Chapter 3. Case Study: Lisbon Metropolitan Area

3.1. Main Objectives of the Case Study

Chapter 3 focuses on this dissertation's case study. In the first sub-section of this chapter (3.1.1) a characterization of the case study area – the Lisbon Metropolitan Area - was performed with the aim of describing the main characteristics of the area being studied.

The second section (3.2.) consisted of an analysis of the revised masterplans from the municipalities that belong to the LMA, with the aim of collecting and categorizing the criteria used for the delimitation of GI. This was done with the purpose of understanding the criteria used for the delimitation of GI and, subsequently, enable an analysis and discussion regarding the main barriers that need to be overcome in the current methodology.

The third and fifth sections of chapter 3 (3.3. and 3.5.) were fully developed within the context of ROBUST project, by the Lisbon Living Lab WG 2.1. Section 3.3. will focus on the analysis of the produced **reclassified land cover maps - which were all produced by members from the WG 2.1 "From the Regional Ecological Network to a Metropolitan Green Infrastructure" steering board (coordination between Setúbal municipality and FCT - NOVA) in order to assess which land cover types, in the Lisbon Metropolitan Area, have a higher capacity of providing the different types of ecosystem services.** These maps were produced in collaboration with the municipalities and other entities engaging in this WG, following an **iterative methodology**: multiple approaches were discussed and experimented along the process with the aim of developing a holistic approach that could be used as a bridge for the creation of a metropolitan green infrastructure. As previously stated in the introduction of this dissertation, the methodology followed uses the matrix developed by Burkhard et. al. (2009) as a basis. In this case study, the matrix prototype used to elaborate the reclassified landcover maps was produced within the context of the work developed by WG 2.1. and this prototype matrix was filled in by the stakeholders from the different municipalities who participated in this project (promoting stakeholder active engagement). The structure of the matrix, as well as the specific methodology used for its filling and subsequent mapping, will be further detailed in section 3.3.

The fourth section of this chapter (3.4.) was developed in parallel to the work developed by the WG. In this section, **several interviews were conducted by me to the stakeholders from the different municipalities with the aim of gathering stakeholders' perspectives regarding the work developed within the WG**, namely the potential and the main limitations associated to the used methodology, as well as future prospects on how this initiative could constitute a tool to progress towards the integration of ES mapping in GI planning at a metropolitan scale. Due to the COVID-19 pandemic situation, all the interviews were conducted online, via zoom. The interview script is displayed in Annex III.

The fifth section (3.5), focused on the statistical treatment of the results obtained in the two previous sections (3.3. and 3.4.). This was done using a set of exploratory approaches for the statistical treatment of the data, with the aim of obtaining a final "uniform" cartography for the LMA.

The final section (3.6.), comprehends an illustration and discussion regarding the final map produced, which identifies the main ES HUBS – the areas where more services overlap – and a map that results from overlaying this ES HUBS map with the Metropolitan Ecological Network[39]. This overlay enabled the analysis of the adherence between these two maps.

3.1.1. Geographical Context of the Region

The Lisbon Metropolitan Area is the region in Portugal with the highest GDP per capita, the greatest diversity of activities, greater density of knowledge activities, greater expression of creative activities and better regional connectivity (PROT-AML, 2009) at a national level. It is the most populated metropolitan area in the country (NUTS III), with 2 870 770 inhabitants (2021[40]), and the second most populated region (NUTS II), after the Northern Region.[41]

Diverse in resources and landscapes, high-density territories exist next to places where rural values and primary sector activities still prevail, creating tensions at times, but also harmony. The Lisbon Metropolitan Area constitutes an historic European capital, with a lot of cultures as well as aesthetic and natural features (e.g. Tagus River and Tagus Estuary Natural Reserve, the largest estuary in western Europe).[42] The LMA territory is “markedly occupied by built-up areas (about 1/3 in 2010), particularly in the core and the immediate surroundings close to it. However, nearly 50% of the region's land has agriculture and forestry as main uses” (Lisbon Living Lab, 2019). [43]

The Decree Law published in 2003[44] states that the Lisbon Great Metropolitan Area is a public collective person of associative nature and with a territorial scope which aims to reach the common public interests of all the 18 municipalities that integrate the AML: Alcochete, Almada, Amadora, Barreiro, Cascais, Lisboa, Loures, Mafra, Moita, Montijo, Odivelas, Oeiras, Palmela, Sesimbra, Setúbal, Seixal, Sintra and Vila Franca de Xira.

In figure 7, a map of the Lisbon Metropolitan Area is represented.

[39] REM – Rede ecológica metropolitana
[40] Resultados Provisórios dos Censos 2021. INE. Consulted on 24/03/2022
[41] Retrieved from: https://www.aml.pt/index.php, consulted on 27/04/2021
[42] Retrieved from: https://rural-urban.eu/living-lab/lisbon, consulted on 27/04/2021
[43] Lisbon Living Lab, Robust, Issue 1 of 3, 01/2019
[44] Decreto-Lei nº 10/2003, de 13 de Maio - Estabelece o regime de criação, o quadro de atribuições e competências das áreas metropolitanas e o funcionamento dos seus órgãos

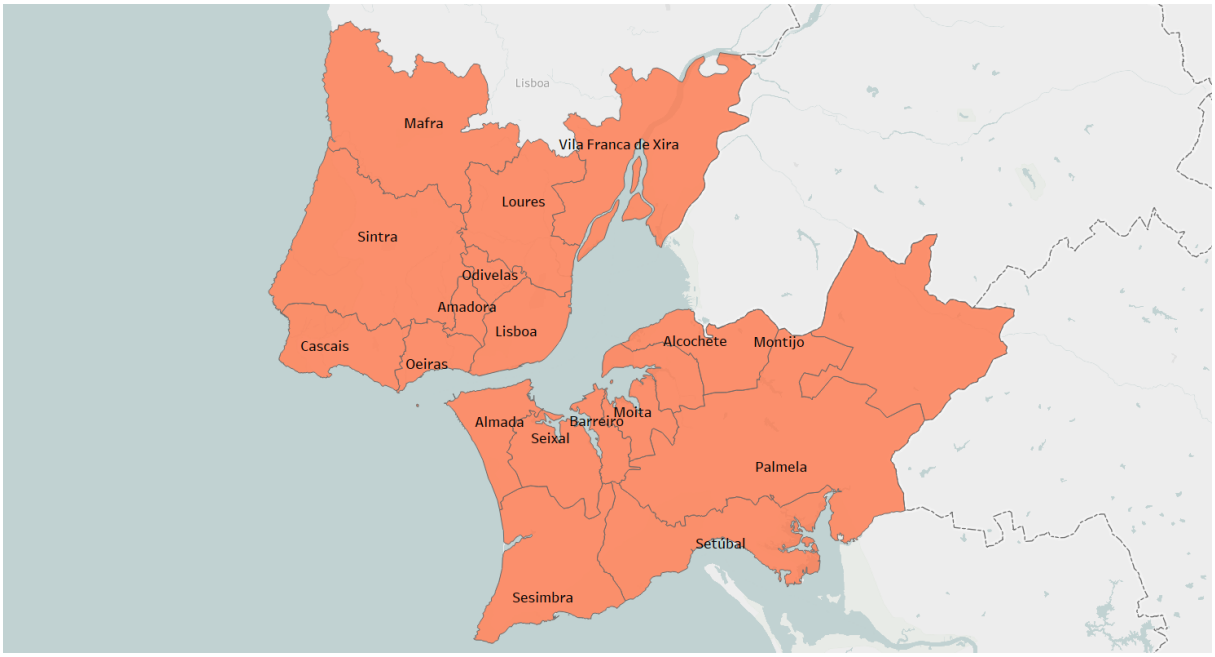


Figure 7- Map of the Metropolitan Lisbon Area. Integrates 9 municipalities north of the River Tejo and 9 municipalities South of River Tejo. Source: https://lxhabidata.iscte-iul.pt/.

The LMA integrates two main distinct sub-regions**: Greater Lisbon and Setubal Peninsula**. These areas are very different from both a demographic, economic and social points of view. The Greater Lisbon Area is organized around the capital - Lisbon - and constitutes one of the largest centers of business services and public services in Portugal. Setubal Peninsula, on the other hand, is characterized by a strong industrial tradition (site CCDR- LVT)[45].

The LMA occupies a very unique position in the region and at the national level. It has a key role since it integrates a large part of the structuring and strategic components of the country's development and its internationalization. The LMA will integrate Portugal's main resources (e.g. scientific and technological development, transport, cultural etc.). These characteristics will constitute a major instrument in the reinforcement of external competitiveness, as well as in the process of improving living standards and territorial cohesion at a national level (therefore contributing for the process of European integration) (site AML).[46]

3.2. GI in the LMA: from the regional strategy to the local land use plans

This section will mainly consist of the analysis of the 10 revised masterplan documents of the municipalities that constitute the Lisbon Metropolitan Area. The map (see fig.8) shows the state of the masterplan's revision in Lisbon Metropolitan Area on 31 January 2021 (retrieved and adapted from the CCDR- LVT site). In this map we can highlight the 10 municipalities which have revised masterplans: Cascais, Lisboa, Loures, Mafra, Moita, Odivelas, Oeiras, Seixal, Sintra, Vila Franca de Xira. An analysis was performed to the masterplan documents (more specifically of the regulations and the reports) of

[45] http://www.ccdr-lvt.pt/pt/ (consulted in 30/04/2021)
[46] https://www.aml.pt/index.php (consulted em 25/04/2021)

these 10 municipalities, in order to obtain a deeper understanding of the approaches used by the municipalities in the definition, integration and legal framing of green infrastructures.

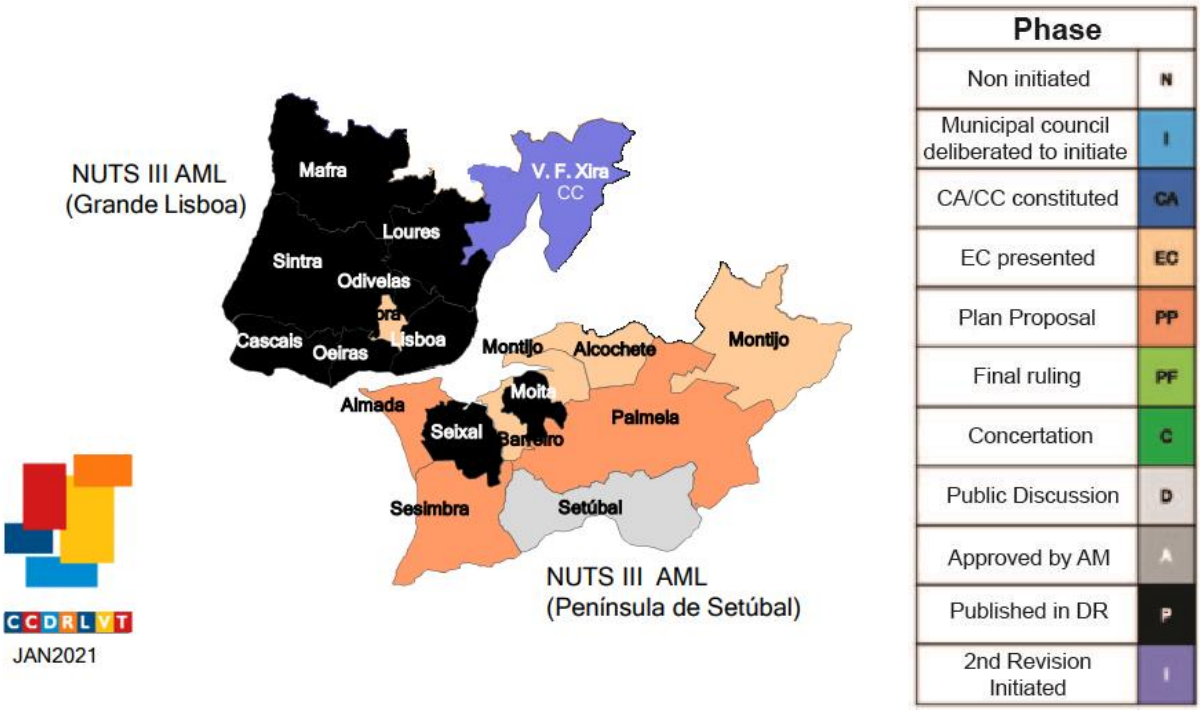


Figure 8-State of the PDM revision in the Lisbon Metropolitan Area on 31 January 2021. Retrieved and adapted from: http://www.ccdr-lvt.pt/pt/ponto-de-situacao-revisao-dos-pdm-da-rlvt-%7C-31-janeiro/10603.htm

3.2.1. Regional Strategy

The Regional Spatial Planning Programs (PROT) are the instruments that "define the regional strategy for territorial development, integrating the options established at the national level and considering the sub-regional and municipal strategies for local development, constituting the reference framework for the preparation of programs and inter-municipal plans and municipal plans"[47].The purpose of the analysis of the Regional Program of the Lisbon Metropolitan Area (PROT-AML) is the understanding of the main guidelines defined for GI at a regional scale.

One must look at territorial policies from a holistic perspective, promoting the continuity of territory and simultaneously a harmonious and multidimensional development that integrates the social, environmental and cultural components. Therefore, the territorial strategy proposed for the LMA in the Regional Program aims to translate the incidence of development strategies and promote a dynamic organization.

[47] Definition retrieved from CCDR-LVT site: http://www.ccdr-lvt.pt/pt/ (consulted in 30/04/2021)

Amongst the four main objectives of the PROT-AML is “the safeguarding of the metropolitan ecological structure, which integrates the most significant natural values of this area, and which performs an essential ecological function for the balanced functioning of the metropolitan urban system”[48].

The Metropolitan Structure of Environmental Protection and Valuation (EMPVA[49]) is a central objective in the PROT-AML. It is concretized in the territorial model through the Metropolitan Ecological Network (REM)[50] and the areas to be stabilized, which are considered structural and decisive elements for the sustainability of the LMA. The ecologic system should work having as a basis an ecological network of support and element of ecologic connectivity. The REM constitutes a “system of areas and connections that integrate, involve and cross the territorial units and the urban system as a whole.” [51]

Considering the different themes addressed - with special focus on the set of protected or classified areas, the elements of green structure and land use patterns, the studies and proposals from the nature conservation, water resources, and soil sectors, among others - a proposal for a hierarchical structure of the REM was elaborated.

The REM (fig.9) currently integrates **primary areas and corridors, secondary areas and corridors** and **vital areas and connections to the metropolitan ecological system.**

In the Lisbon Metropolitan Area, the REM presents the following structure:

- **Primary Network –** Constituted by four main primary structural areas and by their corresponding primary structural corridors:
  1. *Serra de Sintra* and the coast from Colares to Cascais
  2. Tejo Estuary
  3. Sado Estuary
  4. Arrábida/Espichel/ *matas de Sesimbra* / *Lagoa de Albufeira*

- **Secondary Network –** Constituted by the secondary areas and corridors, which have a sufficient dimension to be clearly identified and an important role in the metropolitan and local sustainability of the territorial model.

  In the **Greater Lisbon Area** the most important within the secondary network are the slopes of the valleys of the embedded streams, the forested areas of Sintra, *Serra da Carregueira*, *Vale de Loures* and *matas de Mafra e da Malveira*.

  In the **Setubal Peninsula**, besides the mats and valleys that drain to the estuary, we can highlight other important areas such as *mata dos Medos*, the protected area of *Arriba Fóssil* in

[48] Resolução do Conselho de Ministros nº 68/2002, de 8 de Abril - Aprova o Plano Regional de Ordenamento do Território da Área Metropolitana de Lisboa (PROT-AML)
[49] EMPVA- Estrutura Metropolitana de Protecção e Valorização Ambiental
[50] REM- Rede Ecológica Metropolitana
[51] PROT-AML (Resolução do Conselho de Ministros nº 68/2002, de 8 de Abril): Secção III, 3 — Estrutura metropolitana de protecção e valorização ambiental

Costa da Caparica, *Pinhal das Formas, Pinhal da Marquesa*, *Pinhal das Espanholas* and *mata da Machada*.

- **Vital areas and linkages/corridors**

  In consolidated urban areas, the free non-edified space, is most of the times almost residual (even though in some cases it might have a significant dimension).

  These non-edified areas must be seen as vital for the resolution of problems and existing flaws of the current urban system. In order to promote the functioning and the quality of the urban system these vital areas should represent a space for the concretization of public spaces and areas of leisure and reacreation.

  According to the values and objectives of the PROT-AML, the classification of a given area as a vital area should lead to a revision of the proposals of occupation which are applied over these areas in the municipal masterplans.

For the areas described above, the PROT-AML will establish a set of orientations regarding the uses and activities that should be constrained or restricted as well as recommendations towards the uses and activities that should be promoted in order to enhance and explore the potential of these areas.

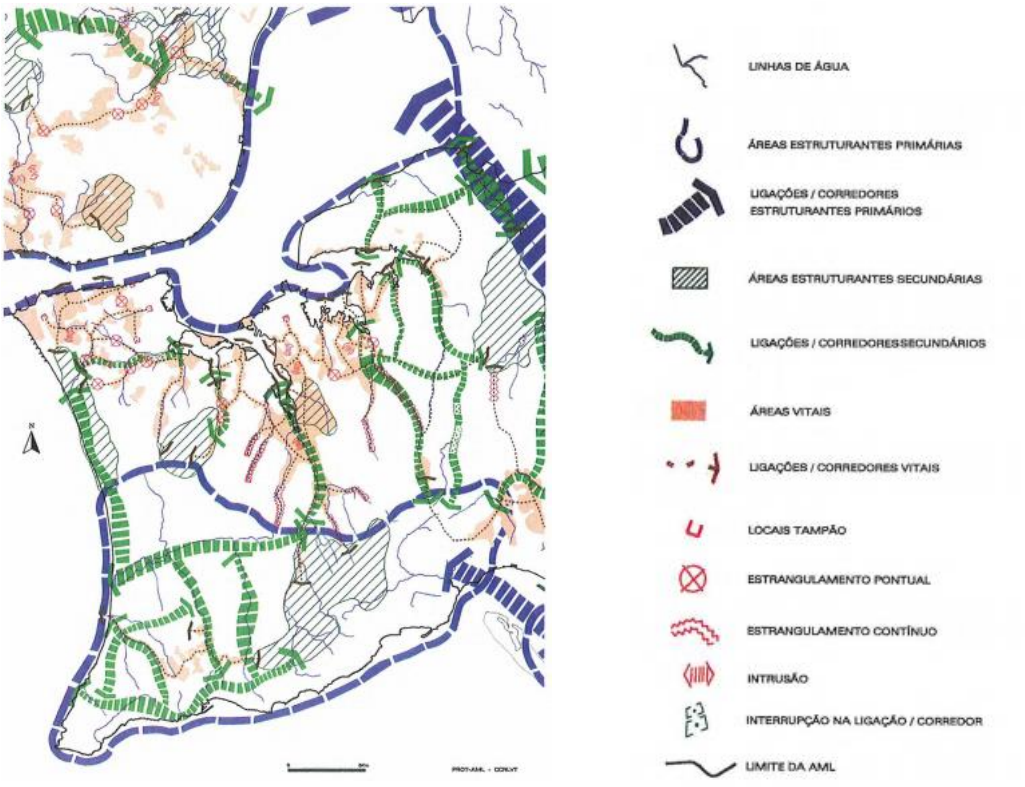


Figure 9 - Metropolitan Ecological Network (REM). Source: PROT- AML 2002

3.2.2. From regional to local scale

As previously stated in section 2.1.1 (which described the legal framework for GI at a national level), it was only in 2009 that the technical concepts in the field of spatial planning and urbanism to be used by the territorial management instruments were established in the Regulatory Decree of 2009, which includes the definition of GI and the elements that it integrates in rural and urban soil.

Figure 10 represents a timeline containing relevant milestones in GI planning since 1999 until 2020 (including the year of publication of all the revised masterplans).

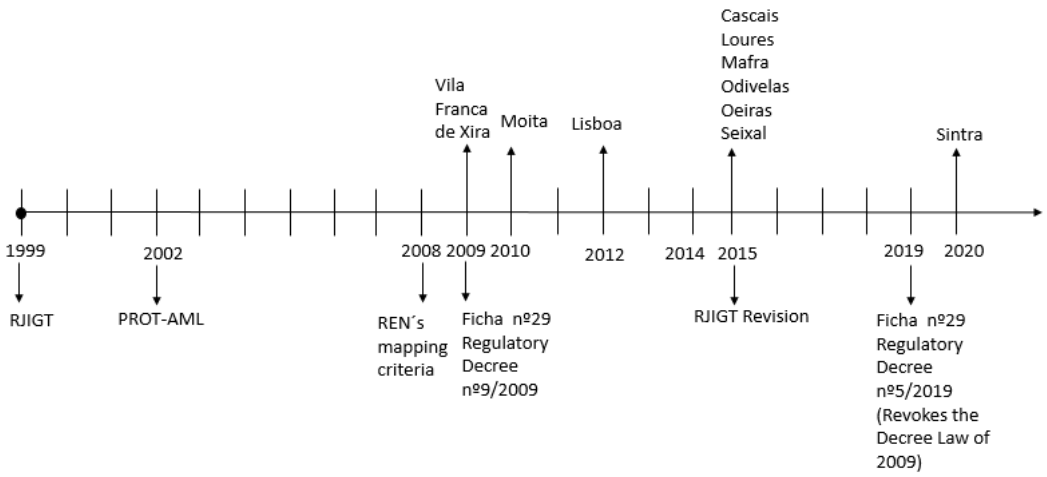


Figure 10- Timeline of publication of the 2nd generation masterplans and other relevant milestones in territory planning and management.

In line with the first objective of this dissertation**, an analysis of the masterplans from the municipalities of the LMA was done** in order to gain a deeper understanding of the GI mapping criteria used at a local level**.** The collected information was subsequently synthesized for the 10 municipalities of the LMA with revised masterplans: Cascais, Lisboa, Loures, Mafra, Moita, Odivelas, Oeiras, Seixal, Sintra, Vila Franca de Xira (fig.8).

For this purpose, the websites of each of these municipalities were consulted in order to analyze their masterplan documents (e.g. regulation and report), following the methodology used by Vaz (2018) in the Alentejo Region. The information retrieved from these documents was then submitted to a categorization process and organized in two tables (Annex I).

The first table elaborated summarizes the following information: the name of the municipality, the year of publication of the masterplan (e.g. notice and date of publication), the definition of Municipal Ecological Structure as defined in the regulation of each municipality's masterplan, the (explicit) inclusion or exclusion of the concept of ecosystem services within the masterplans and/or the reports, and the way their GI is organized (structure used). The general information header of table 1 (Annex I) is represented (see table 1). The second table summarizes the main criteria used for the delimitation of GI in each municipality.

Table 1 - General Information Header of table 1.

Municipalities	Year of Publication	Notice Date	EEM Concept	Inclusion of ES Concept	Structure

• **Municipalities** – Name of each of the municipalities.

• **Year of Publication** – Year of publication of the masterplan.

• **Notice Date**– Legal reference of the publication

• **EEM Concept** – Concept of municipal ecological structure (equivalent to GI) for each of the municipalities, as described in the regulation and/or the report of each of the masterplans.

• **Inclusion of ES Concept**– Whether the masterplan's regulation and/or report explicitly includes the concept of ecosystem services within their definition of municipal ecological structure.

• **Structure** – Main organization levels of the green infrastructure network.

Results: Looking at the collected information it's possible to see that the municipalities address GI planning through distinct approaches. Regarding the organizational structure used by the municipalities, it's visible in the tables (Annex I) **that different types of structures are considered.** Some of the municipalities follow the hierarchical structure defined by the Regional Program (PROT-AML), some use this structure as a foundation but add other layers (e.g. the municipality of Sintra, in which the hierarchization is divided into two main structures: Green Structure and Blue Structure) and others don't comply with this structure at all.

Regarding the explicit mention of the concept of "ecosystem services" in the masterplans and/or reports consulted, it's possible to see that only the municipalities of Cascais (only in the environmental report of the masterplan but not in the regulation), and Sintra include this concept into their legal documents.

Discussion of the results: The analysis of the masterplans highlighted the fact that distinct planning approaches are being used when it comes to the development and implementation of GI. This can be justified by the lack of clear planning guidelines in the Portuguese law regarding GI planning. At the moment, GI are mostly the result of "an overlapping of already established legal regimens that have their own restrictions and management guidelines" (Vaz, 2018). However, this diversity of approaches constitutes an obstacle for the establishment of a methodological framework for GI planning that guarantees the coherency and spatial continuity between the different municipalities and regions. Also, it was possible to see that the majority of the municipalities still don't include the concept of ES within their legal documents. Nowadays, even though ES is a concept familiar to most, it is often very

ambiguous and challenging to put it into practice in territory planning. Nevertheless, the mapping of ES has huge potential in spatial planning to be an active asset in ensuring the sustainable management of natural resources as well as to support the decision-making process.

The diversity of GI criteria used by the different municipalities emphasized the need for a uniform methodological approach for the mapping of GI that could be, in the future, a key tool for the preservation and management of the areas that it aims to protect as well as contribute for the continuity and cohesion of the territory. With this purpose in mind, **a collaborative ecosystem service mapping approach was developed within the context of WG 2.1. of the Lisbon Living Lab**, which will be detailed in the following section of this dissertation (3.3.).

3.3. Linking GI to ES mapping: the ROBUST approach

3.3.1. General Framework of the Case Study: Lisbon Metropolitan Area

The Lisbon Living Lab aimed to reflect on the relevance of addressing the territory as a whole unit as well as to promote synergies between the rural and the urban, with the goal of enhancing the relationship between these dimensions in a complementary (and nonhierarchical) way. WG 2.1., which was coordinated by the municipality of Setúbal, intended to explore the different GI planning perspectives of the municipalities of the Lisbon Metropolitan Area, as well as to start a discussion around ES assessment, with the aim of promoting rural-urban interactions and synergies and **create a metropolitan strategy for the development of a GI network at regional level**. The main objective was to develop a metropolitan GI network, using a bottom-up approach within a transdisciplinary research context.

In line with the 2nd objective of this dissertation, the conceptual model and the iterative methodology followed in the scope of WG 2.1. will be detailed in the present and in the following sections (e.g., 3.3., 3.5., and 3.6.) The participation of stakeholders from the different municipalities of the LMA, from distinct sector fields, was considered a key factor in order to reach a more holistic approach, by promoting an active brainstorming of concepts and visions between the different stakeholders involved**. With this purpose in mind, a group of stakeholders from various institutional backgrounds, whose everyday activities related to GI planning or management, was invited.** The group of stakeholders who engaged in this WG included several municipalities from the LMA, central government entities and decentralized entities of centralized administration.

Several participatory workshops were held virtually (due to the COVID-19 pandemic) with the stakeholders. From the 18 municipalities invited, 16 answered and engaged in multiple meetings. In these workshops a “safe space” for dynamic discussions was created, in which the participants were encouraged to share their experiences as well their doubts and questions throughout the process. Science partners (IST, FCT-NOVA) had a supporting role, assisting leading local stakeholder in suggesting methodologies, organization of sessions on demand, and participating in discussions. All

sessions were held via Zoom, an online platform, and most of the sessions lasted approximately 3 hours each.

Before the 1st official workshop of WG 2.1. (23rd November of 2020), three zoom sessions were held (two during the month of September and one in October) as an introduction to the project, where the municipalities that were part of the group were encouraged to present and share the different methodologies used in the development of their municipality's GI. During the first three introductory sessions held before the 1st workshop, it was possible to see that there were some doubts around the concept of ES amongst the participants. Therefore, it was decided that the **first two sessions of WG 2.1. would be conducted by the science partners (IST and FCT- NOVA) and focus on increasing the literacy of the participants of the WG regarding ES**, in order to create a common language and facilitate the communication. As we can see in the graph below (fig.11), this input of knowledge motivated more participants to adhere to the WG (the number of participants increased from 9 to 35).

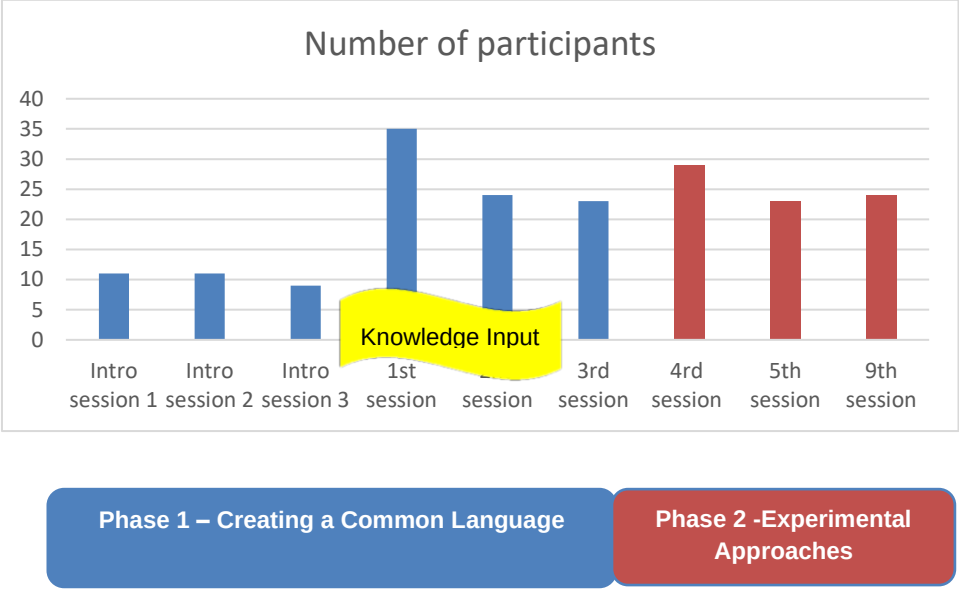


Figure 11 - Number of participants throughout the sessions held online by WG 2.1.

The work developed by the group was divided into two different phases: Phase 1 focused in the creation of a common language amongst the participants of the group; Phase 2 focused on developing and testing different exploratory approaches (see fig.11).

In the table, the timeline of the workshops held via zoom (as well as the content of each work session) is displayed (see table 2).

Table 2 -Table displaying the dates of each workshop held online by the Living Lab Working Group 2.1 . " From the Regional Ecological Network to a Metropolitan Green Infrastructure" as well the respective content addressed in each session.

Session	Date	Number of participants	Objectives
Session 1	23rd November 2020	35	• Ecosystems, ES and the connection between ES provision and land use; • Election of the 5 more relevant ES (using the Mentimeter platform);
Session 2	14th December 2020	24	• ES assessment in the Lisbon Metropolitan Area. • Practical exercise: **ask the present municipalities and entities to fill in a Burkhard inspired matrix;**
Session 3	1st February 2021	23	• Analyzing the ES maps (produced by FCT-NOVA) that resulted from the mapping of the delivered matrixes exercises, for the 5 ES voted as more relevant in the first workshop; • Highlighting geographical discontinuities in the maps produced;
Session 4	10th May 2021	29	
Session 5	28th June 2021	23	• Mapping of ES at the metropolitan scale (statistical and cartographic treatment); • Complementary methodological approach to the valuation of Cultural Services;
Session 6	8th October 2021	24	• Critical analysis of the statistical and cartographic treatment of the results of the matrix; • Discussion on the contribution of the most valued areas in terms of ES to the structuring of a metropolitan green infrastructure; • Discussion regarding the next steps of the project;

Table 2 illustrates **the iterative methodological process followed** throughout the sessions, contributing to the collaborative development of a new methodology in which all the participating stakeholders contributed actively. The working process followed during the workshops was very dynamic since multiple doubts have arisen during the course of this project and in order to try to solve these, different alternative paths were defined and explored. The process followed will be further detailed in the following sections.

3.3.2. ES mapping: methodological approach

Even though several ecosystem services mapping exercises were performed in Portugal over the last two decades, it was only more recently – in 2019 – that the National Program for Spatial Planning Policy (PNPOT) highlighted the importance of ecosystem services as territorial management instruments: "As far as rural-urban cooperation is concerned, it is crucial (…) to develop ecosystem services with links to relevant urban functions (namely in the scope of the food system, labor market, flows of people and goods, of information and investment networks, of water, energy and waste networks, and of services in the areas of tourism, leisure and well-being)" (PNPOT).[52]

The main objective of WG 2.1. was the **mapping of ES at the metropolitan scale in order to explore the potential that this mapping could eventually have for the development of a GI metropolitan network.**

In this section (3.3) , the process and the rationale behind the reclassified landcover maps produced within WG 2.1. will be carefully explained.

The methodology used in order to elaborate these maps was based on the matrix developed by Burkhard et al. (2009)[53]. As previously seen in section 2.2.1., the Burkhard matrix approach uses expert knowledge to illustrate the capacity of each land cover class type to provide each ES. The main goal of these reclassified land cover maps is to display, in a simple and effective way, which land cover classes have a greater capacity of providing each of the ecosystem services.

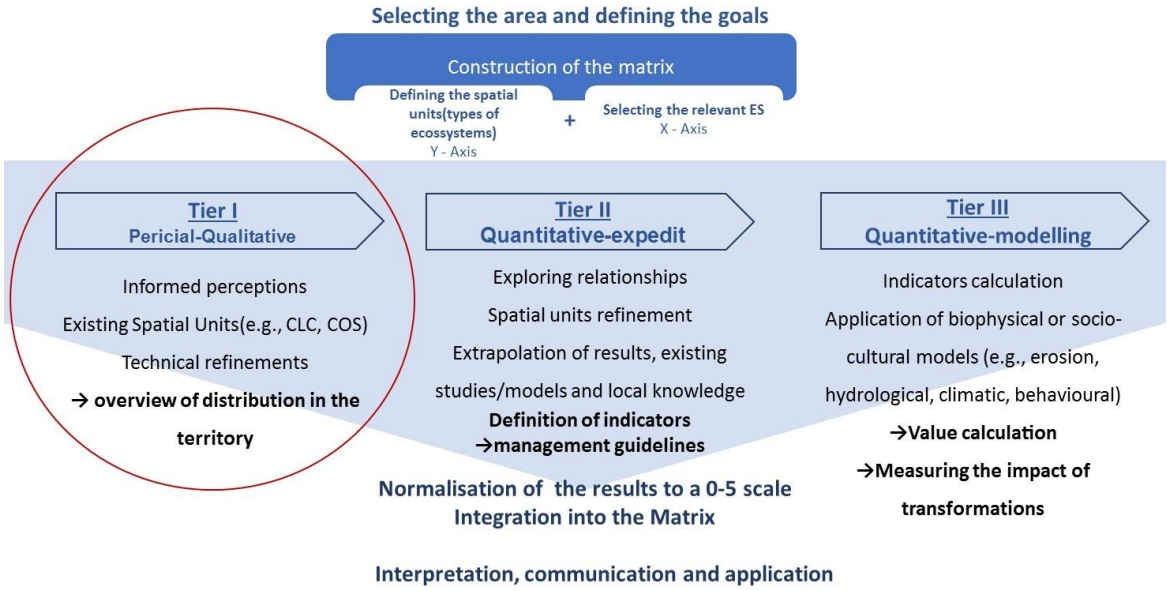


Figure 12 - The different tiered approaches in which the ES matrix could be studied. The red circle highlights the level of complexity in which the work developed in this case-study is inserted (Tier I) (Adapted from Ramos, I.L.).

[52] PNPOT - Primeira Revisão Lei n.º 99/2019 de 5 de setembro Diário da República n.º 170/2019
[53] Burkhard et al; 2009 - Landscapes' Capacities to Provide Ecosystem Services

The figure (fig. 12) represents the different levels of complexity in which the Burkhard inspired matrix can be used. As seen in section in 2.2.1., which addressed the approaches to ES mapping, the tiered approach can be combined with any of the five main approaches to ES mapping. In this case, the figure represents the use of the tiered approach combined with the ES matrix approach. **The work developed by WG 2.1. falls into Tier I, since the study will be qualitative, based on the perceptions of the territorial actors.** A more complex approach could have been adopted but considering the literacy level of the participants around the theme of ES and the fact that the main aim of this WG was to provide a rough overview of the ES values in the case-study-area, the Tier I was deemed to be the most adequate.

In the present case study, all the participants that engaged in the workshops held online, were asked to fill in **a COS[54] 2018 VS. ES matrix** according to the reality of their territories. From these matrixes several **maps were** then **produced by members from FCT – NOVA (who were part of the steering board of WG 2.1. of the Lisbon Living Lab),** with the aim of illustrating the spatial distributions of different ecosystem services in the Metropolitan Area of Lisbon. In order to produce these maps an **iterative process** was followed, which is represented in the diagram (see fig. 13). The maps were produced for both a local and a regional scale. At a first stage each municipality filled the matrix and from these filled matrixes ES maps were produced for their territory (**local scale**). Later on, all the matrixes, from all the municipalities engaging in this project, were aggregated by the WG 2.1. steering board, which lead to the production of ES maps for the whole Lisbon Metropolitan Area (**regional scale**).

[54] COS- Classes de Ocupação do Solo

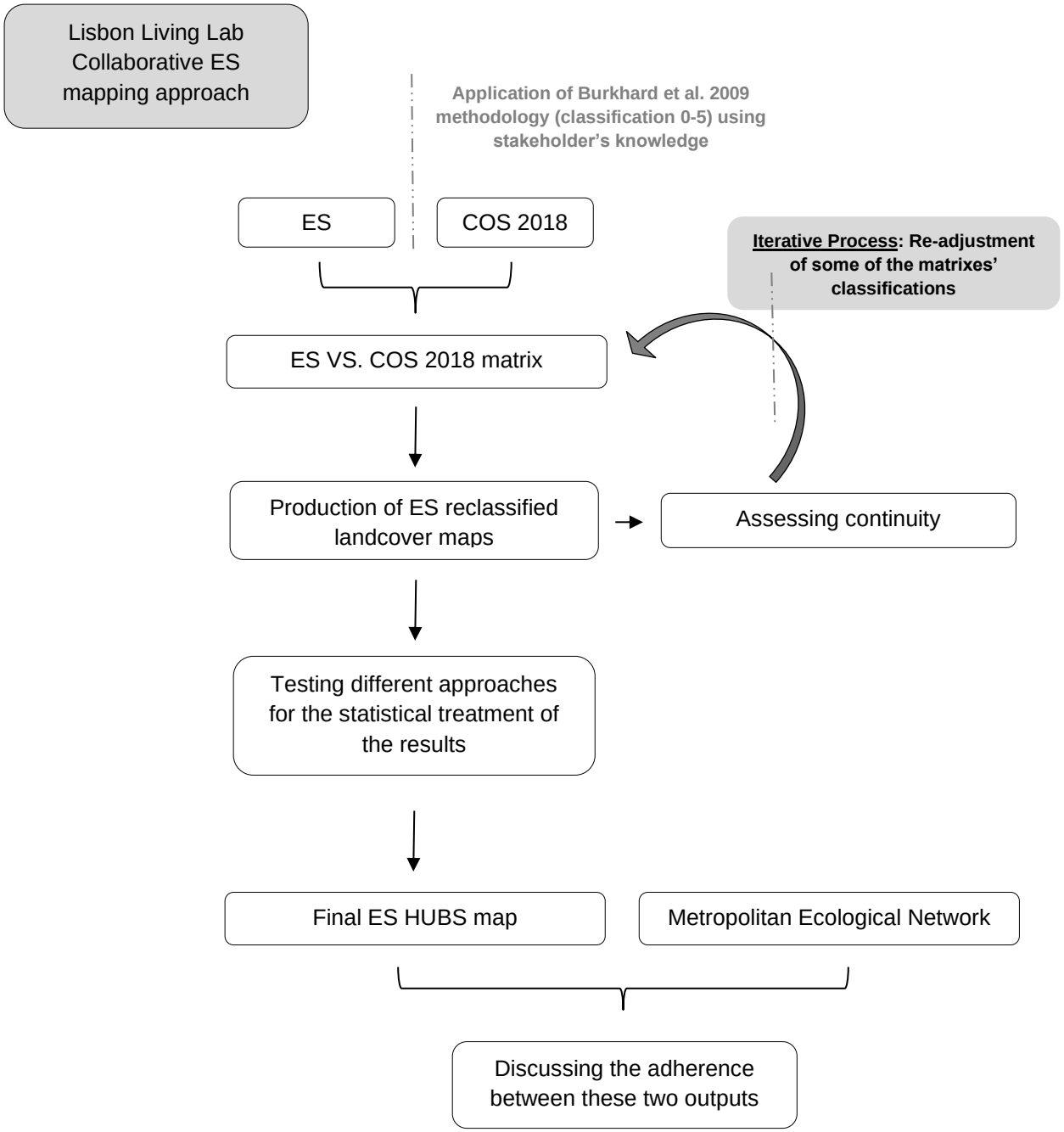


Figure 13 - Diagram outlining the basic methodology followed for the ES mapping approach used in this case study.

3.3.3. Creating the ES reclassified maps

At a first stage, during the workshops of the Lisbon Living Lab Working Group 2.1**., an exercise was proposed to all the municipalities and entities present: to fill in an empty Burkard inspired matrix** (Burkhard, 2009) **prototype,** in which a vertical column displayed all the land cover type classes, and a horizontal column displayed the different types of ecosystem services. The stakeholders from the different municipalities and the entities (e.g., CCDR-LVT) present were asked to fill this matrix, classifying each landcover class, from the perspective of ecosystem service provision.

The landcover base used was the last version of the Portuguese Land Cover map available – **COS[55] 2018, with 1:25000 scale** and a **minimum unit of one hectare**. The nomenclature of the COS was reformulated for the production of COS2018 as part of a working group of the National Commission for the Territory (CNT) coordinated by the DGT and which brought together relevant entities in the fields of land use and land cover. It can be accessed free of charge through its metadata registered in the National Geographic Information System (SNIG[56]).

The new nomenclature includes a total of 83 classes (35 more than the previous version – COS 2015) and it has made a readjustment of the disaggregation levels and a few alterations in some classes' designations and definitions as well as some corrections to the mistakes found in COS 2015.

Table 3 - Excerpt of the empty matrix prototype used for the assessment of the capacity of the different landcover types (vertical axis) to provide the different ES (horizontal axis).

Category (COS2018 Level 1)	Subcategory (COS2018 Level 4)	Provision			
		Food Supply	Water Supply	Raw Materials	Genetic Resources
1. Artificial land	1.1.1.1. Continuous built fabric predominantly vertical				
	1.1.1.2. Continuous built fabric predominantly horizontal				
	1.1.2.1 Discontinuous built fabric				
	1.1.2.2 Sparse discontinuous built fabric				
	1.1.3.1 Parking areas and patios				
	1.1.3.2 Empty spaces without construction				
	1.2.1.1 Industry				
	1.2.2.1 Commerce				
	1.2.3.1 Agricultural installations				
	1.3.1.1 Renewable energy production infrastructures				
	1.3.1.2 Non-renewable energy infrastructures				
	1.3.2.1 Infrastructures for collection, treatment and supply of water for consumption				
	1.3.2.2 Infrastructures for waste and wastewater treatment				
	1.4.1.1 Road Network and related spaces				
	1.4.1.2 Railway network and associated spaces				

In this case-study, the matrix used the landcover classes of **sublevel 4 of COS 2018**. The landcover classes represent the vertical axis of the matrix. Three of the landcover classes of COS 2018 were intentionally not represented in the matrix, due to the fact that they don't exist or exist in a very irrelevant proportion in the case study area, and they were: Temporary crops and/or improved pastures associated with vineyards, other OAKS AFS and chestnut forests.

[55] COS- Carta de Ocupação do Solo
[56] Available at: https://snig.dgterritorio.gov.pt

Table 4- List of non- existents (and therefore not represented in the matrix) landcover classes.

2.3.1.1.	Temporary crops and/or improved pastures associated with vineyards
4.1.1.3	Other OAKS AFS
5.1.1.4	Chestnut forests

Therefore, in the matrix a total of 80 landcover classes were considered (vertical axis of the matrix) which are displayed in the Annex Section (see Annex II).

As for the horizontal axis of the matrix, **a total of 23 ecosystem services of were considered (table 5)**.

Table 5- List of the 23 ES used in the prototype Burkhard inspired matrix, which are placed in the horizontal axis of the matrix.

Provisioning Services	**Regulating Services**	**Cultural Services**	**Supporting Services**
- Food supply - Water supply - Raw materials - Genetic Resources - Medicinal Resources - Ornament resources	- Air regulation - Noise Reduction - Climate Regulation - Moderation of extreme events - Regulation of water flows - Waste treatment - Erosion control - Fertility of the soil and cycle of nutrients maintenance - Pollination - Biologic control	- Aesthetic - Tourism and recreative activities opportunities - Inspiration for culture, art and design - Spiritual experience - Information for cognitive development	- Life cycles maintenance - Genetic diversity maintenance

These 23 ES were retrieved from the literature and follow the Millennium Ecosystem Assessment[57] classification: provision, regulation, supporting, and cultural.

Regarding the process of filling out the matrix, the stakeholders engaging in the WG were designated the task of filling the matrix, classifying each landcover class, from the perspective of ecosystem service provision.

[57] https://www.millenniumassessment.org/

The classification used was the same as the one used by Burkhard (2009):

0= no relevant capacity
1=low relevant capacity
2= relevant capacity
3=medium relevant capacity
4=high relevant capacity
5= very high relevant capacity

It is also relevant to mention that the municipalities were instructed to fill in with "-" all the lines corresponding to the landcover classes that did not exist or were not relevant in their territories.

In this process of filling in the empty matrix, the stakeholders representing the different municipalities were steered in the direction of attributing the classifications according to the "**effective provision of services**" verified in their territories rather than considering the "**potential provision**" of a given services (the distinction between effective and potential provision of ES was addressed previously in 2.2.2.). This guidance was given during the held online workshops, with the aim of trying to guarantee that the results obtained translated the reality of each of municipality's territory as much as possible.

The methodology followed by each municipality for filling in the matrix will be further detailed in the following sub-chapter (3.4.), which contains a collection of the results gathered from the interviews made to the municipalities.

The proposal to perform this exercise was done to all the participants of the project. From the municipalities engaging in the workshops, the following presented results: **Alcochete, Barreiro, Lisboa, Loures, Mafra, Odivelas, Palmela, Seixal, Setúbal, Vila Franca de Xira and CCDR-LVT**[58].

As previously stated, the matrixes which were filled out by the municipalities contained a total of 23 ES. Due to the fact that the mapping of each of these 23 services would be a nearly impossible task, the **next step was to choose which ES were more relevant to map**. In order to do this, the interactive presentation software of "Mentimeter" was used, during one the 1st workshop (which took place on the 23rd of November of 2020) , to see which were the ES that the participants considered more relevant.

[58] CCDR-LVT- Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo

The results showed that **the five ES that were considered to be more relevant** (by the present municipalities and entities) were:

1. Food Supply

2. Water supply

3. Climate regulation

4. Water flow regulation

5. Recreation and tourism

At first, for operational reasons, these 5 ES were the only ones mapped. In order to facilitate the analysis of the maps produced, the definitions of the latest version of CICES V5.1[59] were consulted. For each of the 5 elected ES, the following items (retrieved from CICES V5.1.) were considered:

1. **Food Supply - Nutrition (V5.1):**
    - Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes
    - Plants cultivated by in- situ aquaculture grown for nutritional purposes
    - Animals reared for nutritional purposes
    - Animals reared by in-situ aquaculture for nutritional purposes
    - Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition
    - Wild animals (terrestrial and aquatic) used for nutritional purposes
    - Mineral substances used for nutritional purposes

2. **Water Supply - Water (V5.1):**
    - Surface water for drinking
    - Ground (and subsurface) water for drinking

3. **Climate Regulation (referred to as " atmospheric composition and conditions" in V5.1):**
    - Regulation of temperature and humidity, including ventilation and transpiration

4. **Water Flow Regulation (V5.1):**
    - Hydrological cycle and water flow regulation (Including flood control, and coastal protection)

5. **Recreation and Tourism (V5.1)**:
    - Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through active or immersive interactions
    - Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions
    - Elements of living systems used for entertainment or representation

[59]Available at: https://cices.eu/resources/

- Natural, abiotic characteristics of nature that enable active or passive physical and experiential interactions

The mapping of these 5 ES was performed by FCT-NOVA using software of ArcGIS. A total of 10 maps were produced, two maps for each of the 5 ES which were voted as more relevant:

- One map that resulted in mapping the aggregated scores of all the matrixes delivered by the municipalities;

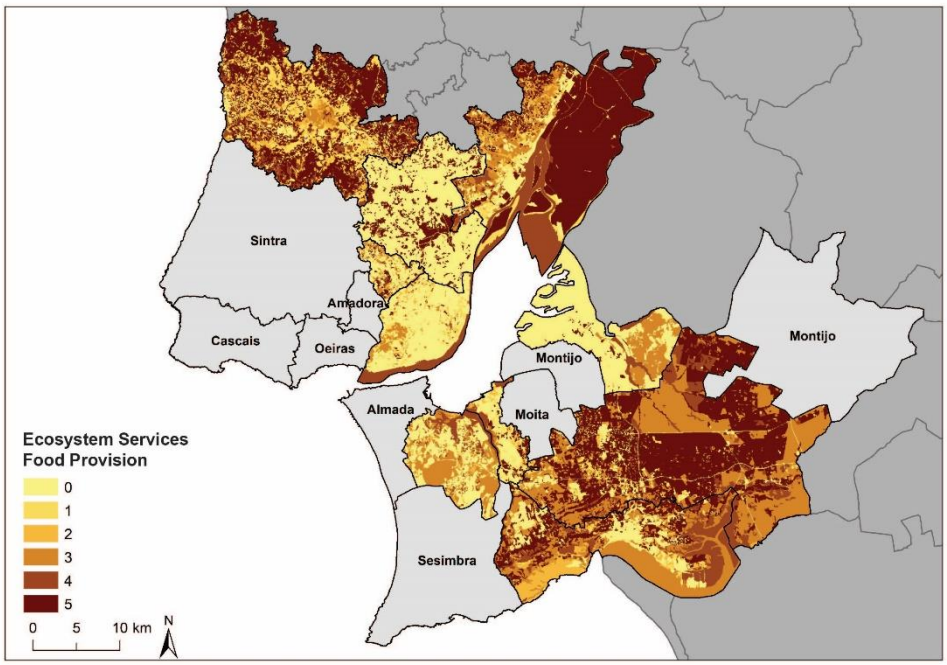
- Another map that resulted from mapping the scores of the matrix delivered by CCDR-LVT;

The mapping (done only for each of the 5 ES voted as more relevant for operational reasons) of the matrix that resulted from the aggregation of all the exercises from the municipalities was done separately to the mapping of the matrix delivered by CCDR-LVT in order to facilitate the comparation between the classifications attributed and, at the same time, verify the existence/absence of discontinuities in these two cases. **This approach was useful by allowing for a visual comparation of possible different perspectives from the municipalities and CCDR-LVT regarding ES provision in the territory of the Metropolitan Area of Lisbon.**

3.3.4. Analyzing the ES reclassified maps

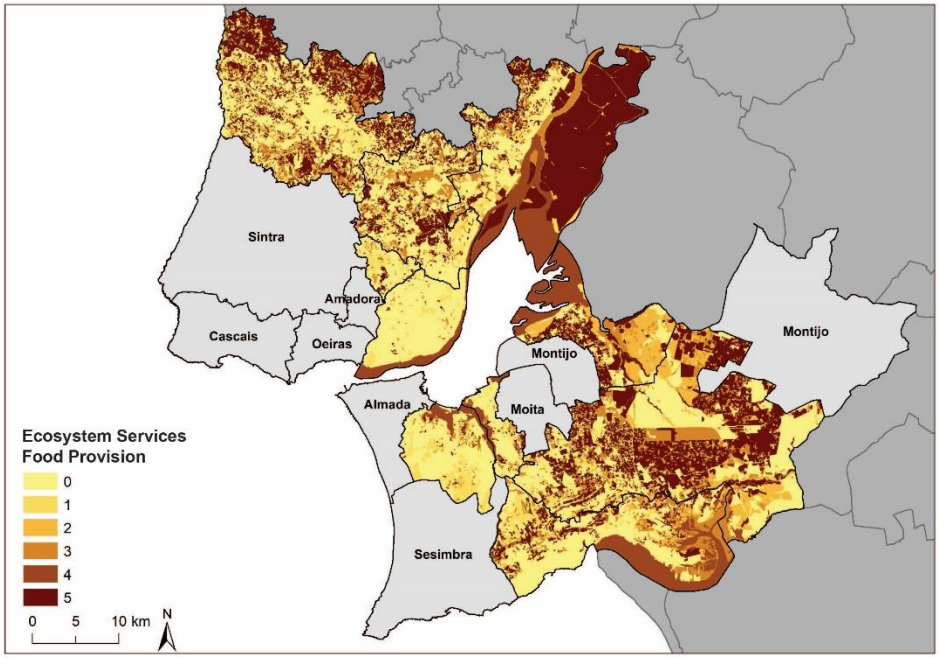
The maps produced from the matrixes that were filled in by the municipalities and CCDR-LVT, illustrating the 5 ES voted as more relevant, were presented and analyzed during the workshop that took place on the 10th of May of 2021. As previously stated, the maps were produced by members of the steering board (FCT-NOVA). During this workshop, **the 10 maps produced were analyzed** with the aim of **highlighting the main geographical discontinuities found** as well as **interpretating the causes that could be behind them.**

This sub-section of Chapter 3 will be dedicated to **the analysis of the elaborated maps that illustrate the ecosystem service of "food provision"** (both the map that resulted from mapping the matrix that aggregated all the results delivered by the municipalities as well as the map that resulted from mapping the matrix delivered by CCDR-LVT). The remaining 8 maps – regarding the ecosystem services of "water supply", "climate regulation", "water flow regulation" and "recreation and tourism" were also produced but were not included in the present dissertation. The **2 generated maps for the ecosystem service of "food provision"** are displayed in the following page (figure 14 and 15).



→ **Municipalities Map**

Figure 14 - Map generated for the ecosystem service of "food provision" that resulted from the mapping of the aggregated results from the municipalities. Source: WG. 2.1. (FCT-NOVA)



→ **CCDR-LVT Map**

Figure 15 - Map generated for the ecosystem service of "food provision" that resulted from the mapping of the matrix delivered by CCDR-LVT. Source: WG. 2.1. (FCT-NOVA)

During the online workshop held in May, **both the municipalities and the entity of CCDR-LVT were inquired on the rationale used while filling in the matrix.** This was a crutial step to perform a

comparation between the maps produced for the municipalities and for CCDR-LVT as well as for understanding the reasoning for the main discontinuities found.

It's also relevant to highlight the fact that the maps produced are non-uniformized maps. A patchwork has been done, in a deliberate way, in order to understand how to progress to a proper integration methodology for creating continuity (the integration of the results will be addressed in 3.5.). Hence the importance of understanding the thinking behind the classifications.

Looking at figure 14, which represents the mapping of the matrix that resulted from the aggregation of all the results presented by the municipalities for the ES of "food provision", it's possible to observe that this map presents more discontinuities and is, from an overall perspective, less homogeneous than the map below (figure 15), which illustrates the generated map for the matrix delivered by the entity of CCDR-LVT.

Looking at the boundaries between the municipalities in the map represented in figure 14, it is possible to highlight three main discontinuities (see fig.16):

- Between the municipalities of Alcochete and Palmela
- Between the municipalities of Vila Franca de Xira and Loures
- Between the municipalities of Mafra and Loures

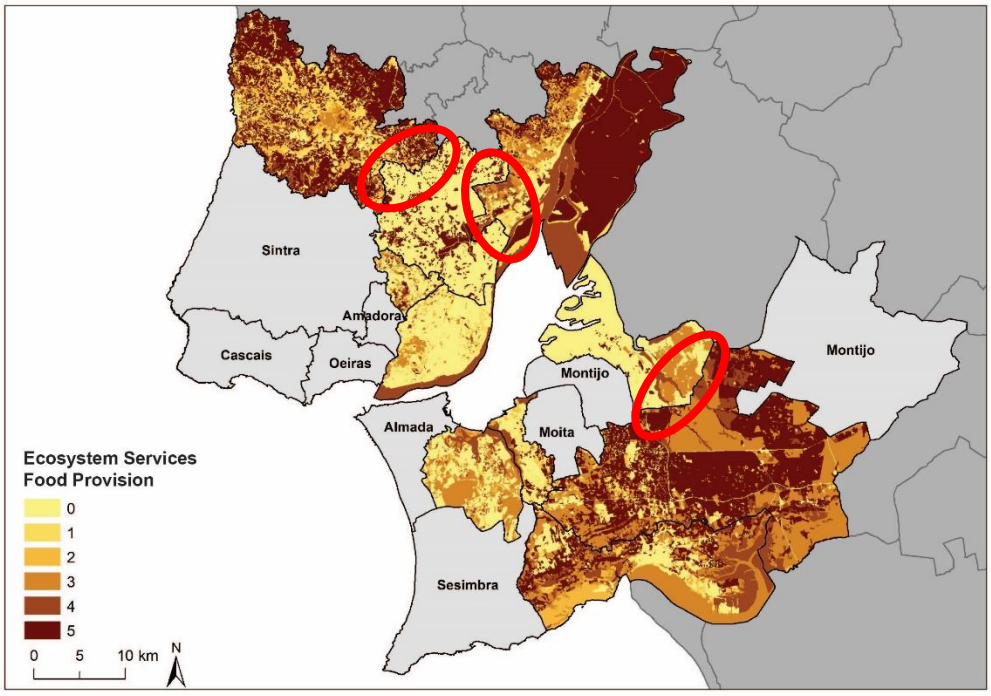


Figure 16 - Map generated for the ecosystem service of food provision resulting from the aggregation of the matrixes results from the municipalities, with the three main discontinuities between the municipalities' boundaries highlighted by the red circles. Source: WG. 2.1. (FCT-NOVA)

Regarding the main discontinuities found, the municipalities of Loures, Mafra, Palmela and Vila Franca de Xira were asked to confront and compare their results with the aim of understanding why these visible gaps between their boundaries were showing in the map (the municipality of Alcochete was not present in the workshop on the 10th of May 2021, and therefore couldn't participate in this discussion).

This way, the ES maps produced worked as a tool to promote a reflection on the criteria and perspectives used by each of the municipalities for the attribution of classifications.

The municipality of Mafra stated that the **darker spots (which correspond to a higher capacity to provide the ecosystem service in question)** in the *Milharado* area corresponded mostly to agro-forestry areas. The stakeholders of the municipality of Mafra who filled in the matrix attributed a relevant classification to these territories, even though they recognized that these territories were more cultivated in the past than in the present. The area that slopes to the north (*Santo Estevão das Galés* area) is a very steep slope area and therefore may have been erroneously overvalued since this area from the agricultural point of view is not so highly valued. Therefore the classification of these areas was made more from a perspective of the potential they had to provide the ES of food provision, which could be a possible explanation for the discontinuity found between the municipalities of Mafra and Loures, since Loures filled the matrix considering the effective production of ES in their territory. Another possible explanation for the visible discontinuity between the parish of *Milharado* (in Mafra) and the municipality of Loures may be the fact that Loures did not consider the contribution of any forests for the provision of food (with the exception of the forest of cork oak, which was classified). If these had been considered, the transition from the Northern part of Loures to the municipality of Mafra would probably be smoother, as well as the transition from Loures to Vila Franca de Xira.

Regarding the discontinuity between Palmela and Alcochete it was not possible to confront the results of these municipalities since the municipality of Alcochete did not attend the workshop. However, it was still possible to analyze the criteria used by Palmela for filling the matrix. The municipality of Palmela assigned maximum value to the classes of COS respective to orchards, vineyards, to SAF (because they considered them to have the greatest potential to provide food, even if some are not being used at the moment). On the other hand, classes with more impermeable surfaces were assigned with lower ratings (“0”,”1” or “2”). The sparse built fabric was classified with a medium valuation (“3”) due to the fact that Palmela has a lot of scattered buildings and associated to these areas are often vegetable gardens and agriculture. Also relevant to note that maximum classification (“5”) was attributed to agricultural facilities, because the stakeholders from Palmela who filled in the matrix considered that greenhouses were included in this landcover class and could be considered an ecosystem.

Comparing the map of the municipalities with the map of CCDR-LVT (represented in fig.15) it’s possible to see that the map from CCDR-LVT is, from an overall point of view, more homogenous and doesn’t present any drastic discontinuities unlike the one generated for the municipalities. The explanation for this, as previously said, lays within the fact that municipalities used different criteria while filling the matrixes, which resulted in more visible discontinuities.

The entity of CCDR-LVT stated that for filling in the matrix it considered a regional perspective for all the Metropolitan Area of Lisbon, not overvaluing any particular territory or municipality and taking to consideration the technical terms of COS 2018 and of CICES 5.1. Analyzing the matrix results delivered by CCDR-LVT it was possible to observe that, unlike most of the municipalities, CCDR-LVT didn’t

consider the florests for the ecosystem service of food provision (it only considered the SAF[60] landcover classes). Discontinuous or sparce built-up spaces were classified with existing but low valuation (they were classified with “1”) due to the possible existence of some vegetable gardens in these areas. Agriculture classes were classified between the range 3-5 (most with 5, those with grasslands with 3 or 4 due to the fact that in grasslands human food production is lower). Agro-forestry areas also considered, but with lower capacity – they were classified with “2”(activities like hunting, cereal production, animal feed, and extensive livestock production were considered to evaluate these areas with this classification.)

After this workshop, some of the municipalities rectified their initial matrix classifications, in order to try to smooth the transitions between the borders of the different territories and obtain a more uniformized map.

During the workshop (which occurred on the 10th of May of 2021), the 10 maps produced were shown and briefly analyzed, allowing for the municipalities and the entity of CCDR-LVT to confront different perspectives and criteria used to perform the matrix exercise. In this dissertation, however, **the remaining 8 maps (the ones regarding “water supply”, “climate regulation”, “water flow regulation” and “tourism and recreation”) will not be illustrated, in order to keep the discussion succinct and to avoid repetition, since the reasoning behind the discontinuities existing in these 8 maps is similar to the reasoning presented and discussed for the ecosystem service of “food provision” (e.g., the different criteria used by the different municipalities).**

[60] SAF- Sistemas Agroflorestais

3.4. ES map to progress towards GI planning in the Lisbon Metropolitan Area: Collecting stakeholder's perspectives

3.4.1. Collecting Stakeholder's perspectives: Methodology

This section of Chapter 3 will focus on collecting stakeholders' perspectives on the path towards a metropolitan network of GI and on how the use of the ecosystem service-based approach adopted in this group work could constitute a tool to reach this goal.

In line with the 4th objective of this dissertation (Chapter 1.2.), a questionnaire with the same structure and content was formulated and used as a guideline for the interviews conducted to the municipalities. From the municipalities who participated in the workshop, and who delivered the matrix exercise, stakeholders from **the following municipalities were interviewed: Cascais, Mafra, Odivelas, Seixal, Setúbal, Palmela and Vila Franca de Xira.** The stakeholders of the municipalities were experts from different fields and disciplinary areas. These stakeholders were considered a relevant sample for this study, since the main theme of this case-study regards the development of a metropolitan green infrastructure network in the LMA, and the development of such structure depends heavily on the participation and active collaboration of the parts that constitute it (e.g., the municipalities).

To schedule the interviews, the municipalities of the LMA were contacted by email, requesting the technical members who represented the different municipalities in WG 2.1. to collaborate in the study of this dissertation. At a first stage, emails were sent by the Living Lab Group WG 2.1. workshop's organizer, Vasco Raminhas Silva (Head of the Urban Planning Division in Setubal city hall), in order to inform the municipalities that I would be contacting them with the aim of scheduling an interview. This way, the municipalities who responded to this email and confirmed their availability were the first ones I scheduled an interview with. All the interviews were conducted via Zoom due to the pandemic situation (with the exception of Mafra which was conducted by telephone), between the months of April and July of 2021, and had an approximate duration of 45 min to 1 hour. **The guideline used as basis for all the interviews can be seen in Annex III.** Even though the questions formulated worked as a guide during the interviews, total freedom was given to the respondents to share their views on the multiple topics addressed, as well as to add any information they considered relevant.

The **structure of the interview was mainly divided with the aim of exploring 4 main themes**:

-Motivation to adhere to this group work

-Exploration of the rationale behind the filling of the matrix

-Integration of this methodology in territory planning

-Governance measures needed to put this initiative into practice

For this reason, the following section (3.4.2.) will be divided into these 4 issues, and for each of these topics, the reasoning beyond the questions and subjects addressed during the interviews will be explained, followed by a categorized organization of excerpts from the answers given by the different municipalities.[61]

3.4.2. Results

3.4.2.1. Motivation to adhere to Lisbon Living Lab WG 2.1.

The first question addressed in the interviews regarded the **motivation of the municipalities to join the ROBUST project Living Lab WG 2.1. workshops** and why they maintained their interest throughout the several working sessions. This question was done with the aim of deepening the understanding of the reasons that drove the municipalities to participate in this project as well as to highlight the different perspective of the stakeholders regarding the importance of the theme addressed in this group work: **the development of a metropolitan green infrastructure network, using ecosystem services** as a key tool.

Analyzing the transcripts of the interviews it was possible to see that the main reason given by the municipalities for participating in this group work had to do with the fact that the city hall of their municipality had received an invitation to join this project and also that the thematic of ecosystem services and of their valuation was particularly interesting to them and, in their opinion, had alot of potential to explore.

In the interviews conducted to Palmela and to Setúbal, another reason mentioned for participating actively throughout the sessions (besides the invitation made and the interest on the thematic itself) was the fact that they were in the revision phase of their masterplans and found that this ES approach could be a helpful tool to solve the current issues related to the definition of the Municipal Ecological Structure.

In the specific case of the municipality of **Setúbal**, their municipality **was challenged to lead this group work (WG 2.1) which concerns the development of a GI metropolitan network.** This request (which was accepted) was addressed to Setúbal due to the fact that during their masterplan revision process the municipality of Setúbal started developing a relatively innovative methodology regarding the definition of Municipal Ecological Structures which included the theme of ecosystem services in it, with the aim of transforming this structure into a real municipal green infrastructure.

Table 6 illustrates the reasons given by the stakeholders from the different municipalities for adhering to WG 2.1.

[61] Even though all the interviews were conducted in Portuguese, all the transcript excerpts from the interviews, used for illustration purposes, were translated to English.

Table 6 -Overview of the answers given by the stakeholders on their motivation to participate in this group work.

Motivation / Municipalities	Invitation to participate	Interest in the thematic	Masterplan's Revision in process
Cascais	X		X
Mafra	X	X	
Odivelas	X		
Palmela	X	X	X
Seixal	X	X	
Setúbal	X	X	X
Vila Franca de Xira	X	X	

The following question addressed to the representatives of the municipalities regarded their perspective on **what was the potential/interest of developing a metropolitan GI network**. To justify the importance of the efforts developed within this group work it was considered relevant to highlight all the diverse potential advantages associated to the development of a metropolitan GI network, hence the importance of integrating this question in the interview guideline.

Most of the municipalities interviewed listed the promotion of the continuity of the territory as the main interest in the development of a GI metropolitan network. The following excerpts retrieved from the interviews illustrate the significance attributed to the promotion of continuity by the different municipalities:

"The interest of a metropolitan scope is related to the fact that GI are systems that do not have, in fact, municipal boundaries, so we consider that it makes sense to look at the work from a metropolitan perspective (often in a broader sense than the geographical limit of the metropolitan area in question). The systems should be seen in an integrated logic." –Câmara Municipal de Palmela

"(…)The main interest, according to my point of view, is the promotion of the continuity between the territories. It is necessary to have this connection between the parts, because in the absence of this territorial continuity - the main objective of the Municipal Ecological Structures - is lost.(…)" – Câmara Municipal de Vila Franca de Xira

"(…)On the other hand, many times we work within the borders of our municipality (our administrative boundaries) and from the point of view of ecosystems this is not so, that is, ecosystems are continuous.(…)" – Câmara Municipal de Mafra

"(…)The territory is not finite, and despite our municipality's limits, it is crucial to take into account all the interactions with everything around us. From my point of view, the interest lies mainly in this.(…)" – Câmara Municipal de Odivelas

"(…) In this project the methodologies used could later be incorporated into spatial planning and land management plans, which could help operationalize the whole theoretical part and promote continuity.(…)" – Câmara Municipal do Seixal

Besides the promotion of territory continuity, other advantages/benefits regarding the development of a metropolitan GI network were mentioned by the municipalities and are graphically displayed in the diagram below (see fig. 17).

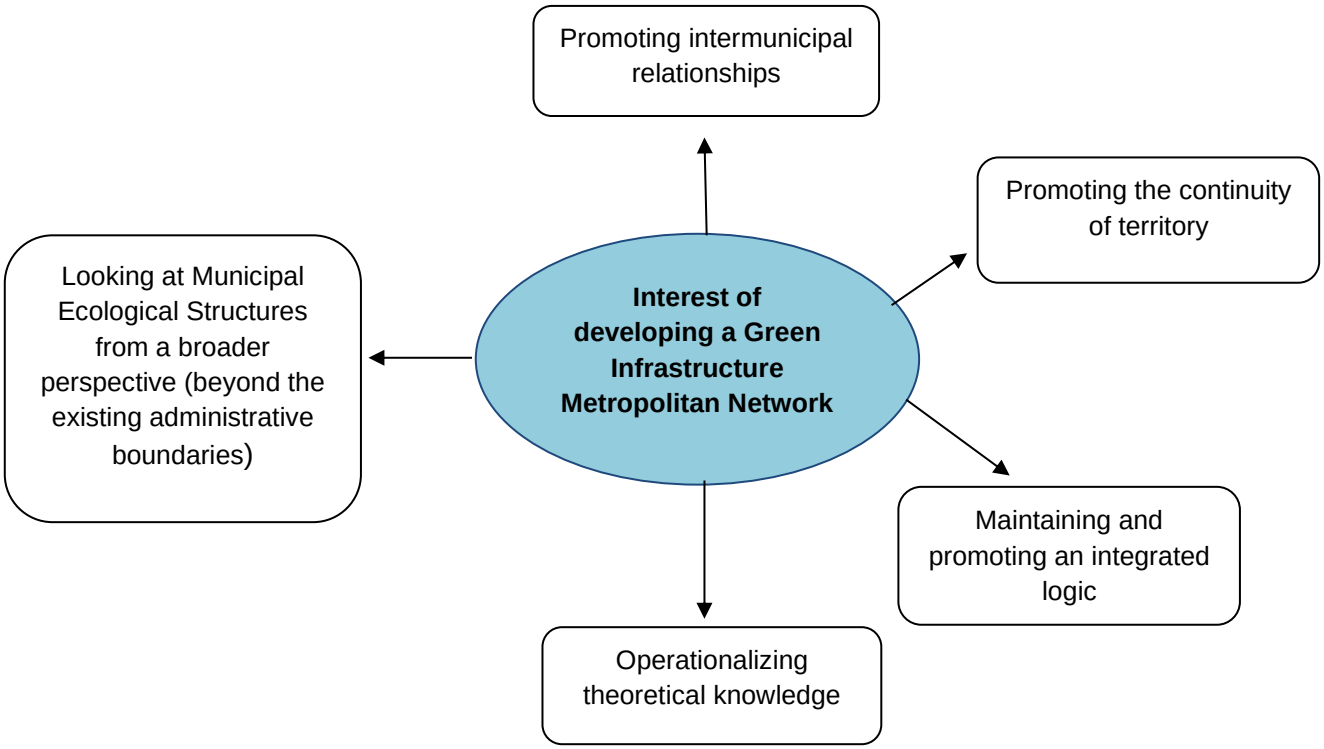


Figure 17 - Diagram displaying the answers given by the municipalities when inquired about the importance of developing a GI metropolitan network.

3.4.2.2. Filling in the ES matrix

The following subject addressed in the interviews **regarded the process of filling in the matrix**. This part of the interview was conducted in an effort to **understand the reasoning behind the classifications** made and also in order to **understand** what were **the main challenges/difficulties found in the use of this methodology**. Understanding the rationale behind the attribution of the different classifications is an essential step to perform an analysis of the multiplicity of criteria used by the different municipalities while performing this exercise.

In order to perform this assessment, the first question that was asked to the stakeholders was if they had ever previously worked with the concept of ecosystem services and/or with the specific methodology used in the group work (Burkhard inspired matrix). The response obtained was mostly uniform: with the

exception of the municipality of Setúbal, none of the remaining municipalities interviewed had worked with the concept of ecosystem services nor with Burkhard's methodology before. For the interviewed stakeholders of these municipalities (with the exception of Setúbal), the work developed within this project was their first contact with this methodology. Although most of the stakeholders were already familiarized with the concept of ecosystem service, they stated that they had never developed any work related to this thematic.

Regarding the process of filling in the matrix, the stakeholders were inquired on if they felt the necessity to perform this matrix exercise with the help from colleagues from other areas (in another words, it was questioned if they felt that the filling of the matrix required a cross-sectorial joint work). The aim of this question consisted mainly in understanding if this type of methodology should use a multidisciplinary approach (that is, if it should be performed by a team of technicians from different areas), as well as understanding the main tools necessary to fill the matrix with a relevantly high level of confidence.

In response to this question, all the municipalities manifested **the need to communicate with different sectors** in order **to be able to do the scoring of the ecosystem services with a higher confidence level**. The following excerpts from the interviews illustrate the need felt to fill the matrix using a multidisciplinary approach:

"(…)The filling of the matrix covers very specific issues and ideally should be done by a multidisciplinary team, because there are several specific issues that are not easy to understand.(…)" – Câmara Municipal de Palmela

"(…) I also felt the need to articulate with some colleagues, particularly in the area of planning and the environment in order to understand what their sensitivity was to certain specific issues. (…)" – Câmara Municipal de Vila Franca de Xira

"(…)The first time we came across with what was involved in filling out the matrix, I (a territorial engineer) was doing the work with two other colleagues: an anthropologist and a geographer. From the start, the 3 of us felt the need to have someone to help us with everything related to environmental and natural issues, since it was beyond our competence. (…) Thus, a Landscape Architect and a Forest Engineer were also involved in this work. (…)" – Câmara Municipal de Odivelas

Following this, interviewees were inquired about the necessity to consult additional documental information. The municipalities mentioned the need to consult the definitions of the COS 2018 and also information about the methodology used (although some considered that the article of Burkhard[62] provided by the group work was sufficient) and the use of spatial information (mentioned by the municipality of Odivelas, specifically the use of Google Maps). Besides these, no specific additional documental information was mentioned by the stakeholders. However, the municipality of Odivelas manifested that extra scientific information would have been helpful for attributing scores with a higher confidence level, but also noticed that the use of too much information could at the same time have the

[62]Burkhard, 2009. Landscapes' Capacities to Provide Ecosystem Services – a Concept for Land-Cover Based Assessments.

drawback of slowing down the process of filling in the matrix. The following excerpt illustrates this statement:

"(…) In terms of documental information we used the Burkhard article available to us and the COS definitions. While filling in the matrix we felt that in some cells of the matrix we might need to have more scientific background information to help us answer more correctly. (…)On the other hand, I don't know if using too much information could make the classification too complex and time consuming. (…)" – Câmara Municipal de Odivelas

The municipalities of Palmela and Cascais highlighted that another difficulty found while attributing classifications in the matrix was the fact that this process was limited to the classes of the COS2018, which in many cases did not really coincide with the reality of their municipality (they felt that there were some misrepresented classes):

"(…)Our main obstacle in filling in the matrix was the fact that COS2018 has some errors in the classification (sometimes it doesn't match the reality of our territory). (…) It would be important that the COS had this rigor and a discussion with the municipalities in order to detect these errors." –Câmara Municipal de Cascais

With the aim of assessing the level of confidence of the classifications made, during the interview the municipalities were also asked to specify in **which classifications they had felt a lower/higher level of confidence.** Subsequently, with the responses collected a confidence matrix was elaborated, in order to illustrate which classifications were easier or harder to perform (the confidence matrix elaborated will be addressed in the following section). The answers given by the municipalities **highlighted the following classifications** as being particularly challenging to attribute (and therefore associated **to lower confidence levels**):

*"(…)**Cultural services** (namely those related to **aesthetic issues** or **spiritual appreciation**) were particularly difficult to fill in, due to the high subjectivity (it depends a lot on the perspective of the person filling in the matrix).(…)" – Câmara Municipal de Palmela*

*"Some biophysical services (namely the ecosystem service **Maintenance of soil fertility and nutrient cycling**) were also a bit out of our formation. (…)" – Câmara Municipal de Palmela*

*"(…) At the level of cultural services I didn't feel any particular difficulty, except in the service "**Information for cognitive development**" which raised some questions. In terms of regulatory services, there were some that I found particularly difficult to evaluate, namely the "**Noise Reduction**" service, or when the services are more descriptive that also raised some doubts for me, for example in the difference between "**medicinal resources**" and "**genetic resources**". – Câmara Municipal de Mafra*

*"I remember having some doubts regarding the class "**Parking areas and** **courtyards.** Initially I thought that courtyards could be spaces where there was vegetation and/or where there was no impermeabilization, but as we reviewed the COS concepts, we corrected these initial perceptions that did not coincide with the COS definitions.(…)Also, for example, on the **specific differences between***

cork oak, holm oak or oak forests *it would have been useful to have more detailed information. (…)" – Câmara Municipal de Odivelas*

"(…) the classifications concerning the class of ***oceans****, and water bodies in general, raised some doubts for us and we felt that there was insufficient knowledge on our part to make these classifications.(…)" – Câmara Municipal de Odivelas*

"In the cross-referencing of ecosystem services *with land cover classes where we felt the most difficulty and* ***where the most doubts arose was in the classification of artificial land,*** *because my two colleagues had much more confidence in attributing classifications when it came to natural territories" – Câmara Municipal de Odivelas*

"Regarding the evaluations in which we felt a lower degree of confidence, we ***highlight cultural services*** *due to their greater subjectivity and also* ***some services perhaps due to their greater biotic component*** *(…)We would often do the filling with the knowledge that we might not be in the realm of all the information we should have, hence the need to have a wide range of experts participating in this process" – Câmara Municipal de Setúbal*

To finish the questions regarding the process of filling in the matrix, the technical members of the municipalities were inquired on what perspective they used for attributing the classifications in the matrix: if they had considered the **effective production of services** (according to the reality of their territory) **or** if instead they considered **the potential** that those given classes had to provide the ES. In the workshops of the WG 2.1. the orientation given to the municipalities was to consider the reality of their territory and to leave in blank the classes of occupation that didn't exist or that weren't relevant in their territories. However, by analyzing the responses given on the interviews, it was possible to see that different approaches were used by the different municipalities (some filled the matrix considering the effective production of ES while others considered the potential the different landcover classes had to provide those ES).

In the cases of Cascais, Odivelas, Palmela and Vila Franca de Xira, the two approaches were performed. Initially they filled in the matrix according to the potential of providing ES, and in this case, considered the totality of the Metropolitan Area of Lisbon while attributing the classifications. However, after orientations were given in the group workshop towards attributing the scores according to the characteristics of their own territory, they "corrected" the first matrix and filled it again but this time considering the effective production. Since these matrixes were later readjusted to the reality of each municipality, we assumed that these 4 municipalities considered the effective production of ES for the classification process (see fig. 18).

The municipality of Setúbal considered the effective production of ecosystem services for the attribution of all the classifications since the beginning of the process.

The municipalities of Mafra and Seixal attributed all the classifications considering the potential of the landcover classes to provide each ES.

The graph below (fig. 18) sums up the results from the interviews regarding the approach used for the attribution of classifications. As displayed in the graph, from the totality of 7 municipalities interviewed, 5 of them considered the effective production (Cascais, Odivelas, Palmela, Setúbal and Vila Franca de Xira) and 2 considered the potential (Mafra and Seixal).

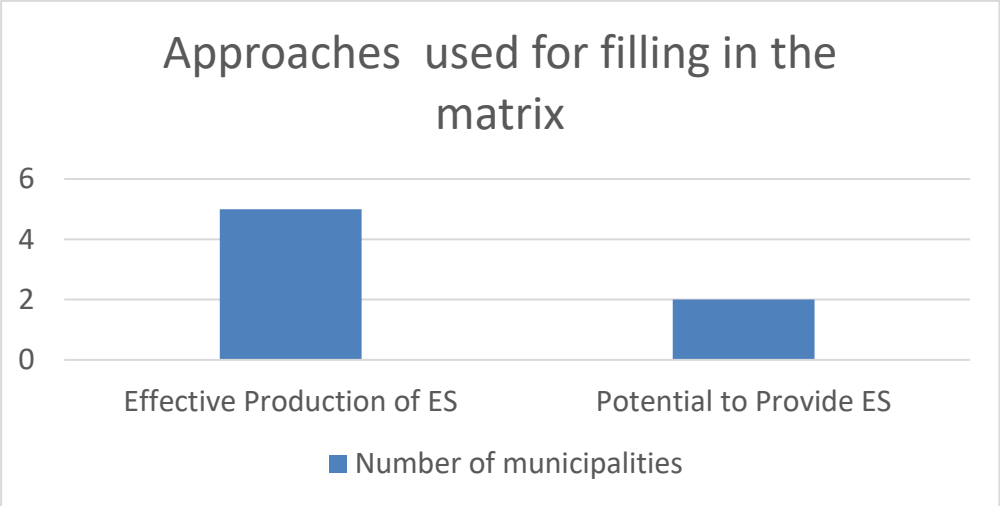


Figure 18 - Graphical display of the number of municipalities that considered each of the two approaches: Effective ES Production VS. Potential ES Production.

3.4.2.3. Integration in Territory Planning

The following theme discussed in the interviews regarded the process of integration of this ecosystem service approach within the instruments of urban territory planning. The first question made regarded **the potential and the limitations that the mapping of ES could have in the municipalities' territories**, specifically when it came to the integration of this methodology into spatial planning. Analyzing the answers, from an overall point of view, the stakeholders highlighted the fact that this ES mapping approach could complement the current delimitations used for the integration of green infrastructures (e.g., RAN, REN etc.) and, could be an effective tool to achieve a more articulated network that makes the most of the multiple potentials provided by the ES as well as constituting an effective way of valuing the unbuilt territories (which are often neglected).

The following excerpts from the interviews illustrate the perspective of the interviewed stakeholders from each municipality regarding this subject:

"(…) In the specific case at hand - the development of a metropolitan green infrastructure - we consider that this mapping with ES allows a greater knowledge and the possibility of valuing ES, allowing for a transition to important issues, namely the ones regarding the remuneration of services. (…) The Municipal Ecological structure has diverse values and mapping with ES is an effective way to enhance this multiplicity of values." – Câmara Municipal de Palmela

"(…) I see that there is a lot of potential in mapping ecosystem services in order to give more value to the territory that is not built, in a municipality like Odivelas, in which what is built or what has potential for construction is highly valued whilst all the other territories are often totally devalued (…)" – Câmara Municipal de Odivelas

"(…) This mapping of ecosystem services could even be important to justify in the PDM itself why there are undeveloped areas that have intrinsic value and should therefore be protected and not used for construction. (…)" – Câmara Municipal de Odivelas

"Seeing the results on the map we can demonstrate more easily (more than the matrix itself) to those outside where are those territories that in this perspective of ecosystem service provision have greater potential. ***These ES maps transmit even more clearly this potential of the territories than the National Ecological Reserve (REN****), that is, if this methodology of mapping ecosystem services was further developed in the future and integrated into spatial planning, it could be a better "advertising" of what we want to protect than the current instruments used (…)" – Câmara Municipal de Mafra*

"(…)It is important to understand that the territory has different characteristics, and that each ecosystem is a provider of services, thus increasing awareness of the potential associated with that same ecosystem. From the point of view of defining land uses and defining the planning model, it is essential to keep these issues in mind.(…)" – Câmara Municipal de Setúbal

"(…)It is essential to have a coherent ecological structure. It is necessary to articulate this new knowledge with the legal constraints that are currently in practice."- Câmara Municipal de Cascais

The potential of this ES mapping approach was also mentioned as an effective tool to use in current issues, namely in the thematic of **climatic change**:

"For example, now on the big issue of climate change, I see enormous potential. We have attempted to integrate tree plantations, ecological corridors (for example) etc., and when we can leverage these efforts with ecosystem services and make numerous contributions, all the better. (…)" – Câmara Municipal de Vila Franca de Xira

The diagram (see fig.19) displays the potential of using an ES mapping approach according to the responses given during the interviews.

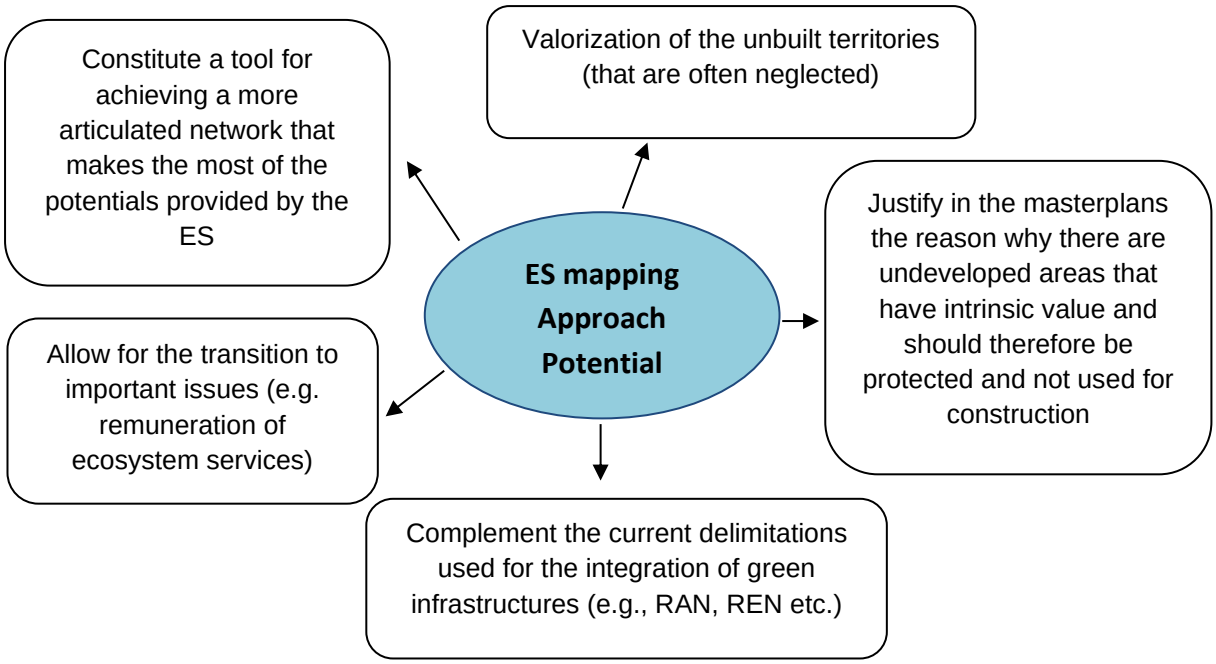


Figure 19 - Diagram displaying the potential of using an ES mapping approach according to the answers given by the interviewed stakeholders.

As for the **limitations that could be associated to this methodology**, the difficulties mentioned by the stakeholders in the interviews mainly had to do with the doubts that arose from filling in the matrix and with making these results/maps coincide with the reality of their territory:

"(…) In terms of the obstacles/limitations of this methodology, I would say that the first one will be the impact of this new knowledge, that is, trying to explain these new concepts and methodologies to the decision makers and technicians. After this conquest, I think that the operational part will be easier. (…)" – Câmara Municipal do Seixal

"(…) I would say that the limitations are often related to filling in the matrix and to the fact that the result on the map sometimes may not seem very correct, which requires a new correction in of some cells of the matrix. But maybe this tentative error method is also an inherent step of the methodology itself. (…)" – Câmara Municipal de Mafra

"(…)Within the limitations, I would say that many times these have to do with the occupation of the territory itself and with other types of instruments that may exist for management and planning. It is always necessary to balance this methodology with the municipality's existing planning. (…) – Câmara Municipal de Vila Franca de Xira

"(…)As far as limitations are concerned, this methodology also has its weaknesses, starting with the fact that it is fundamentally based on land cover cartography (COS), which has some problems, but at the same time has the potential to be easier to apply. In addition, this Burkhard methodology has a strong

subjective component, since the classifications attributed will always depend very much on the person who is filling the matrix. (…)" – Câmara Municipal de Setúbal

Following this, the municipalities were inquired on **how ES could constitute an instrument for the improvement and operationalization of Municipal Ecological Structures**. The answers collected from the interviews highlighted the integration of the concept of ecosystem services into the existing planning figures (both at a local and regional level) as being a crucial step for the operationalization process, as the following excerpts illustrate:

"(…)The linking of ES to the Municipal Ecological Structure, in my view, would be the best option since there are already some legal figures that oblige the inclusion of these structures and guide their planning, and the inclusion of ecosystem services would be an added value. In a nutshell, ***ecosystem services would have to become one more element integrated in the planning figures at the level of our municipality in order to make this operational.*** *(…)" – Câmara Municipal de Vila Franca de Xira*

"(…) the ecosystem services represent an evolution of the Municipal Ecological Structure because they transmit to the population the idea that this structure provides numerous services. In addition, ***it is necessary that there is some articulation in the regulations (namely in the PDM and in the green spaces and building regulations) that is associated in the licensing itself,*** *i.e., it is important that later there is this bridge to make it operational. The part regarding the filling in of the matrix constitutes the analytical part, but the proposal will then have to be linked to a regulation to be effective. (…)" – Câmara Municipal de Mafra*

3.4.2.4. Governance

The final theme addressed in the interviews regarded the organizational tools and the hierarchical political figures that would be required to implement this initiative. In order to collect information on this thematic, the representatives of the interviewed municipalities were inquired on their perspectives for the future, that is, **how could this initiative for the development of a green infrastructure network be followed up from an organizational point of view**. Following this, they were inquired on their thoughts regarding the roles that both the municipalities and the existing entities should have in this process of developing a green infrastructure.

Analyzing the responses given by the stakeholders, it was possible to see **that there was an overall consensus in the fact that the management of this green infrastructure network should be attributed to a regional entity** (CCDR-LVT and AML were the entities referred in the answers) and that **this organization task should work more in the form of guiding and collaborating with the municipalities, rather than imposing terms.** The need to come up with solutions that promote intermunicipal relationships and for the existence of an entity responsible from bringing all the municipalities together were highlighted as being key factors to make sure that all the municipalities are

active participants in this project of developing a green infrastructure network. The following excerpts from the interviews sum up the feedback given by the municipalities on this thematic:

"(…) it seems to us that this work developed by the ROBUST project can contribute to promote the involvement and articulation with municipalities, so that the definition and delimitation of the green infrastructure is seen from a more strategic and regional perspective, instead of being imposed by a hierarchy of instruments. The role of the municipalities in the process is to contribute actively, and these contributions should be important in the definition of a more metropolitan GI and included in the binding instruments of the entities themselves and of the private sectors. (…)" – Câmara Municipal de Palmela

"(…)The organizational level must always be a regional entity, but it shouldn't be in imposing terms, but in guiding and collaborating with the municipalities. The measures are usually very imposing and prohibitive, not giving municipalities the capacity to defend other values that in regional terms may not be very important, but that at the municipal level are very relevant.(…)" – Câmara Municipal de Palmela

"(…)At a first stage this responsibility has to land on the institutions (such as CCDR and AML), i.e. figures higher than the municipalities, that can manage and integrate all the participants, because each municipality individually would be very difficult. (…) ***The role of municipalities is always in their representativeness****, that is, in an effort to be present and in fact share their experiences, their projects(…)." –Câmara Municipal de Vila Franca de Xira*

"(…)Besides the need for technicians to mature (in terms of assimilating these new concepts), it is also necessary to involve the political component, because they will ultimately be the ones responsible for making these decisions. For example, the climate change project, even from the regulatory point of view, is already having a more significant impact, and in the case of the green infrastructure this is not happening yet. ***(…) the role of the municipalities should not be limited to enforcement****, but should involve the development of proposals (…)" – Câmara Municipal de Mafra*

*"(…)It would be necessary to work towards joint management of this infrastructure network. In my opinion, just the fact that this initiative could promote a co-management of the GI network, justifies its continuity (…)****There should be an entity promoting inter-municipal collaboration, but ultimately the management of this network should be a responsibility shared by all.****(…)" – Câmara Municipal de Odivelas*

"(…) It is important to leave this fragmented view of green infrastructure and think ***that the ecosystem services that exist in a municipality will have an impact beyond the limits of those municipalities.*** *The very issue of water supply, food, water regulation services, etc. should constitute a complementary network that is visible on maps, for example. (…)" – Câmara Municipal de Odivelas*

"(…) In my opinion I would like a regional or central entity (in this case I don't know if it would come from the CCDR or the AML, for example) to elaborate work instructions and good practice guides that make sense and are in line with the legislation. This would perhaps be the first big step to follow up on this initiative. (…)" – Câmara Municipal do Seixal

The municipality of Setúbal also highlighted the importance of involving the private sector in this process:

*"(…)**this governance model will have to be an inter-layer model**, that is, **there will be a regional level (in which CCDR-LVT or AML will play a very important role in regional coordination) and also a municipal level**, where the municipalities will play a crucial role as well as the private sector, since a large part of the territory constitutes private property and should therefore be involved in defining and participating in this governance model. (…)*

3.5. Statistical and cartographic treatment of the results

The following step of this project was to **define a set of exploratory approaches for the statistical treatment of the results** in order to obtain a "uniform" cartography for the whole metropolitan area. The initial discussion concerning the possible methodologies that could be used for the statistical treatment took place in the online workshop of the 28th of June 2021, after the presentation and discussion of the maps that resulted from the matrixes delivered by each of the municipalities. An assessment was then made by the steering board regarding which statistical methods would be the most appropriate.

A zoom meeting was held with Prof. Manuel Ribeiro, lecturer of statistical subjects in Instituto Superior Técnico. In this meeting, the conclusion reached was that **the median would possibly be the more adequate measure for the statistical treatment of the data.** The arithmetic mean, on the other hand, would have the problem of being influenced by extreme values and of blurring the values (which goes against the main objective of this case-study, which is the enhancing the areas with particular value regarding the provision of ES and which should eventually integrate the metropolitan green infrastructure network).

In parallel, after the interviews **a confidence matrix was elaborated based on the confidence demonstrated by the stakeholders in the attribution of the classifications.** In section 2.2. of this dissertation, the importance of performing a confidence analysis of the final scores was discussed as well as the mention of several studies which performed confidence analysis (e.g., La Bianca et al. 2018, Gorn et al. 2018, Elliott et al. 2019, Geange et al. 2019). In this dissertation, **an exploratory confidence analysis was developed using as a basis the answers given in the interviews to question 4** (see interview guideline in annex III). The rationale behind this confidence matrix will be further explained in this section of Chapter 3.

After carefully discussing the possible ways to integrate the results, the steering board of the Lisbon Living Lab WG 2.1. decided to perform the **statistical treatment of the results using 3 different approaches**:

I. Area-weighted average

It was considered relevant to perform an area-weighted average, according to the representativeness of each of the landcover classes in each municipality in relation to the total occupation area of each landcover class in the LMA. In this approach, **the municipalities with a larger area of a given**

landcover class are considered as having more knowledge/expertise in these areas and subsequently, in the ecosystems and ES associated to them.

In this exercise, the answers of the CCDR-LVT were not considered, since it's an entity and not a municipality, and therefore these criteria cannot be applied.

Methodology: Using the ArcGIS software, the total area (in km²) corresponding to each landcover class in the LMA was extracted, as well as the area that each municipality had of each landcover class. In order to see the representativeness that each of the landcover classes in the municipalities had in relation to the total area of that landcover class in the LMA, a percentage was calculated ($\frac{Area\ of\ the\ landcover\ class\ in\ each\ municipality}{Area\ of\ the\ landcover\ class\ in\ the\ whole\ LMA} \times 100$).

Posteriorly, these percentages were transformed into 5 classes. Initially a test was made using only 3 classes, but in this case a problem similar to the arithmetic mean would arise (resulting in a very "blurred" map which goes against the main goal which is to highlight the areas with more capacity to provide ES).

This way, for each landcover class, the maximum and the minimum percentages[63] were identified, and the difference between these two values was calculated. This difference was then divided by 5 (to obtain the 5 classes). After this, a matrix was done with the class values (from 1 to 5) attributed for each municipality and each landcover type (from here on this matrix will be designated as the "weighting matrix"). This value of the weightings was then multiplied by the scores of the ES matrixes and a new matrix was obtained (with the multiplication of the weighting value of each municipality for each category). This was done only for the 5 ES voted as more relevant. For each of these 5 ES, a matrix was elaborated which resulted from the multiplication of the weighting matrix with the matrix filled by the municipalities. In the end an average was made, for each of the 5 ES, in which the sum of the values of the all the municipalities for each landcover class was divided by the total sum of the weights for each landcover class.

The image displayed in the following page (see fig.20) represents the area-weighted average for the ES of **food provision**.

[63] The percentages calculated using the formula $\frac{Area\ of\ the\ landcover\ class\ in\ each\ municipality}{Area\ of\ the\ landcover\ class\ in\ the\ whole\ LMA} \times 100$.

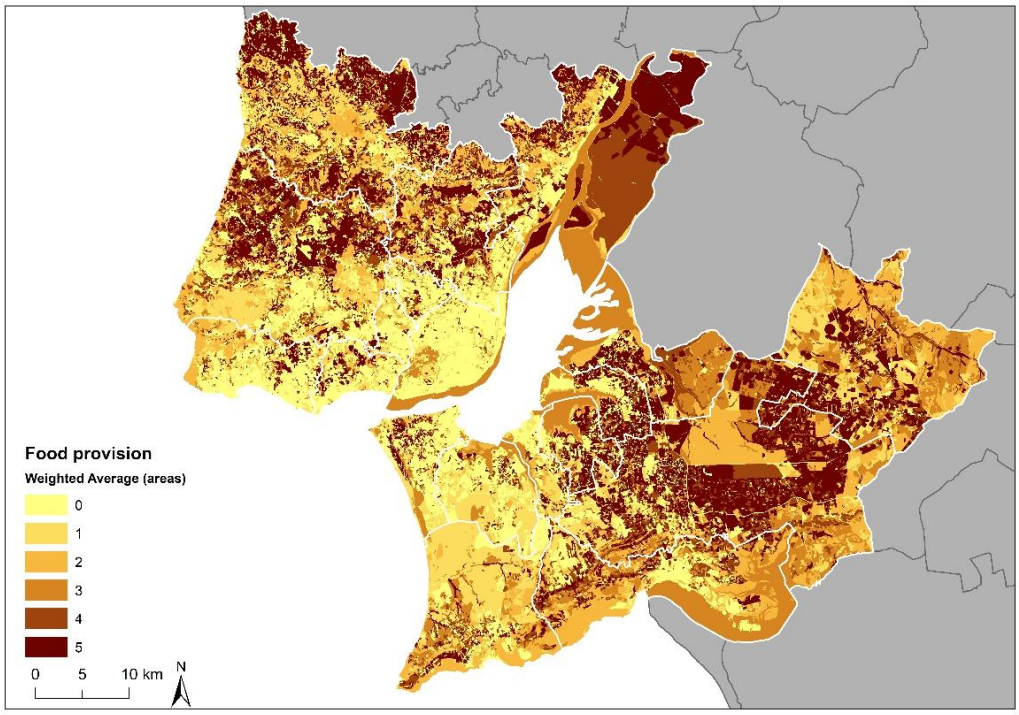


Figure 20 - Map obtained after applying the area-weighted average, for the ES of food provision. Source: WG 2.1. (FCT-NOVA).

These maps (produced by FCT-NOVA) were presented and analyzed in the online workshop which occurred on October 8th of 2021. During this workshop the municipalities were asked to critically assess the maps produced and at the same time **evaluate if they felt that these new maps obtained after the statistical treatment represented the reality of their territories in an accurate way** (similar to their perception of their territories).

One of the critics made to the approach of the area-weighted average as a way to integrate to the results was the fact the smaller municipalities would be less representative, since the proportions of their areas of each landcover class in relation to the total area of that class in the Lisbon Metropolitan Area would be less significant. A possible solution to solve this would be to perform an area-weighted average that considered both the proportion of each landcover class areas in relation to the LMA but also in relation to the area of each municipality. This could allow for an analysis of the significance of each landcover classes within the area of each municipality.

II. Median Value

Median was considered by the steering board to be the most appropriate measure of statistical integration as it is less influenced by extreme values.

Methodology: The ecosystem services matrixes delivered by the municipalities were aggregated in excel. For each of the 5 ES (food provision, water provision, water regulation, climate regulation and tourism and recreation) the values from all the matrixes were selected and then the median for each of

the 5 ES and for each landcover class was calculated in Excel. In this case the CCDR-LVT matrix was already included.

The image below (fig.21) represents the median applied to the ES of **food provision**.

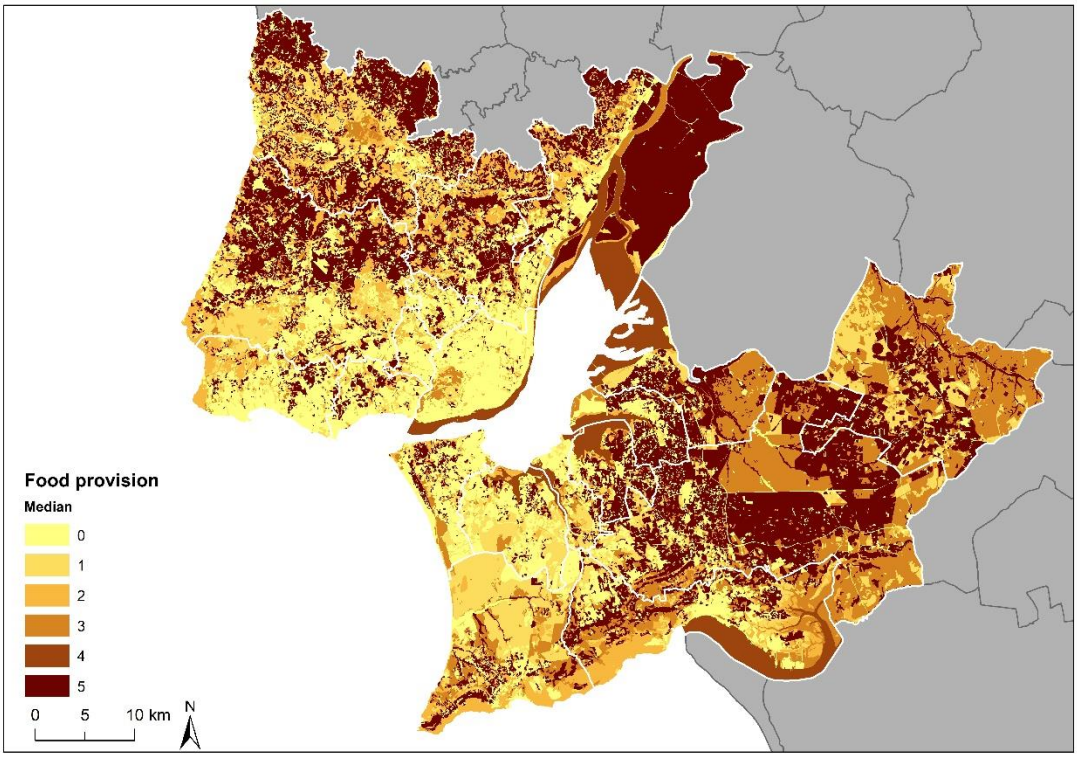


Figure 21 - Map obtained after applying the median, for the ES of food provision. Source: WG 2.1. (FCT-NOVA).

III. Confidence Matrix

An exploratory confidence analysis approach was developed using the answers of the interviews as a basis. Therefore, the sample used for the development of this approach uses only the contributes of the 7 municipalities which were interviewed: Cascais, Mafra, Odivelas, Palmela, Vila Franca de Xira, Seixal and Setúbal. The answers to the second question of the 5th item of the interview guideline (see Annex III), which regarded the level of confidence felt by the stakeholders while filling in the matrix as well as inquired them to highlight in which classifications they felt less confidence, were the ones I used in order to develop this exploratory approach.

The main goal of trying to apply a confidence analysis is to assess the level of uncertainty of the methodology used and at the same time understand which are the landcover classes and the ES associated to higher levels of uncertainty and discuss possible ways to overcome this uncertainty in future studies. The confidence matrix created in this dissertation was therefore an innovative attempt developed to process the data retrieved from the interviews in a useful way, allowing for a subjective analysis of the uncertainty associated to the valuations of the Burkhard inspired matrix. The rationale behind this confidence matrix will be further explained in the following section.

Methodology

The first step was to define a set of arbitrary values that would be associated to the different confidence levels regarding the filling of the different cells of the matrix. Initially, it was arbitrarily defined that the landcover classes and/or ES that were highlighted by the municipalities (during the interviews) as the ones associated to more uncertainty/ harder to evaluate were classified in the matrix with the value "-1"; the landcover classes that were not mentioned "0"; and finally the landcover classes and/or ES which were highlighted as the ones associated to the lower level of uncertainty/easier to evaluate were attributed the valuation "1" in the matrix. This valuation was considered as being visually attractive since the negative values in the matrix would instantly highlight the landcover classes and/or ES which were associated to lower levels of confidence and the positive values would highlight the landcover classes and/or ES which were associated to higher levels of confidence. The non-mentioned landcover classes and/or ES classes were attributed the neutral value of "0".

The table below (table 7) illustrates the arbitrary chosen classification.

Table 7-Table illustrating the valuation of the level of confidence used for the production of the confidence matrix.

Level of Confidence	Value Inserted in the Confidence Matrix
Low Confidence Level	"-1"
Not Mentioned	"0"
High Confidence Level	"1"

Using Excel several confidence matrices were created, one for each interviewed municipality. In the figure below (see table 8) an excerpt of the confidence matrix produced for the municipality of Mafra is represented.

Table 8 - Excerpt of the confidence matrix elaborated for the municipality of Mafra, based on their interview answers regarding the level of confidence associated to their classifications.

		Provision				
		Food Provision	Water	Raw Materials	Genetical Resources	Medicinal Resources
Category (COS Level 1)	**Subcategory (COS Level 4)**					
Artificialised Territories	Continuous built fabric predominantly vertical	0	0	0	-1	-1
	Continuous built fabric predominantly horizontal	0	0	0	-1	-1
	Discontinuous built fabric	0	0	0	-1	-1
	Sparse discontinuous built fabric	0	0	0	-1	-1
	Parking areas and patios	0	0	0	-1	-1
	Empty spaces without construction	0	0	0	-1	-1
	Industry	0	0	0	-1	-1
	Commerce	0	0	0	-1	-1
	Agricultural installations	0	0	0	-1	-1

Analyzing the excerpt of the confidence matrix in table 8, it's possible to see that in this case the ES of **"Genetic Resources" and "Medicinal Resources" were highlighted as being associated to a higher level of uncertainty,** during the interview conducted to the stakeholder of the Mafra municipality. In this particular example, only ES were associated to a low level of confidence, and therefore it's possible to observe the two columns of "-1" in the table. However, in some cases the municipalities associated certain landcover classes to higher/ lower confidence levels, and in those cases, we have

lines with the values “1” or “-1” instead of columns. An example of this is illustrated in the figure below, which displays the confidence matrix created for the municipality of Odivelas (see table 9).

Table 9 - Excerpt of the confidence matrix elaborated for the municipality of Odivelas, based on their interview answers regarding the level of confidence associated to their classifications.

		Provision				
		Food Provision	Water	Raw Materials	Genetical Resources	Medicinal Resources
Category (COS Level 1)	**Subcategory (COS Level 4)**					
Artificialised Territories	Continuous built fabric predominantly vertical	-1	-1	-1	-1	-1
	Continuous built fabric predominantly horizontal	-1	-1	-1	-1	-1
	Discontinuous built fabric	-1	-1	-1	-1	-1
	Sparse discontinuous built fabric	-1	-1	-1	-1	-1
	Parking areas and patios	-1	-1	-1	-1	-1
	Empty spaces without construction	-1	-1	-1	-1	-1
	Industry	-1	-1	-1	-1	-1
	Commerce	-1	-1	-1	-1	-1
	Agricultural installations	-1	-1	-1	-1	-1

The municipality of Odivelas stated during the interview that they felt, from an overall point of view, that the artificial landcover classes were harder to classify, since the stakeholders who filled in the matrix were more used to work with more “natural” land cover classes. Due to this, the confidence matrix elaborated for this municipality illustrates lines of “-1”, which correspond to all the landcover classes that belong to the category of “artificial territories”, which are therefore associated to a higher level of uncertainty.

At a first stage, a confidence matrix was created for each of the interviewed municipalities. Following this, all the matrixes were added with the aim of producing one final confidence matrix (see Annex IV). Looking at the final matrix, which resulted from the sum of all the matrixes produced for each municipality, **it stands out that the most** negative **values (“-5” and “-6”) are associated to the cultural services**. This highlights that this category of services was the one associated to a higher level of uncertainty, which is most likely associated to the subjectivity inherent to the classification of cultural services. The development of new complementary methodologies to evaluate cultural services could be a way to overcome this uncertainty and was discussed in the workshop that took place on the 28th of June of 2021.

Later on, in order to perform the mapping of the confidence matrix, the steering board decided to change the values of the confidence matrix, which were initially from -1 to +1, to values from 0 to +2. This was done in order to avoid mapping a matrix with negative values. Therefore the classification used initially was changed for the one illustrated in Table 10.

Table 10 - Table illustrating the altered valuation of the level of confidence used for the production of the final confidence matrix.

Level of Confidence	**Value Inserted in the Confidence Matrix**
Low Confidence Level	“0”
Not Mentioned	“1”
High Confidence Level	“2”

The values of the confidence matrixes were multiplied by the corresponding weighting factors, and after this an average similar to the average done for the area-weighted average was done. The resulting matrix was mapped by FCT-NOVA and the map, for the ES of food provision, is shown below (in fig. 22).

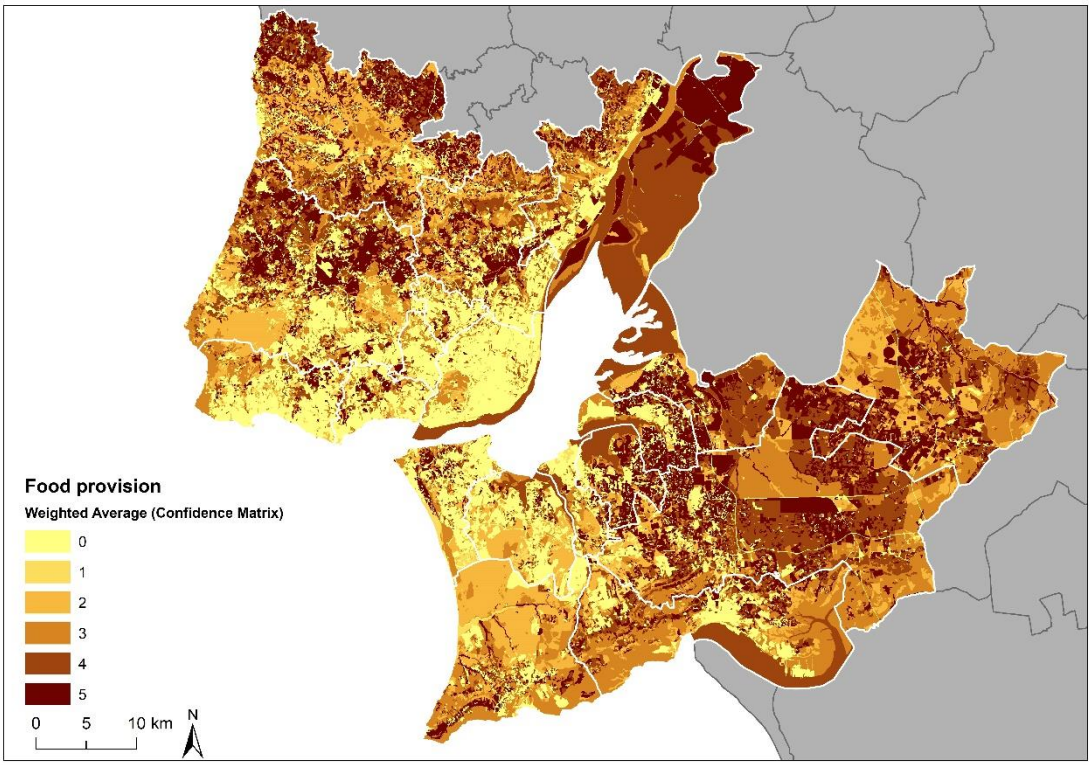


Figure 22 - Map obtained for the confidence matrix, for the ES of food provision. Source: WG 2.1. (FCT-NOVA).

3.6. Final Results

At the end of the last workshop, which occurred on October 8th of 2021, six maps were presented. Four of these represented the mapping of each of the categories of services: provision, regulation, support and cultural. These maps were later added in order to reach a final map that identifies ES HUBS – the areas where various services overlap, and which therefore constitute the “nodes” of the possible green infrastructure network that could be developed in a future scenario. Finally, the last map presented illustrates the overlaying of the ES HUBS map with the REM, which enabled the analysis of the adherence of these two maps.

3.6.1. Methodology

As previously stated in section 3.3.1., the 5 ES which were elected more relevant were: food provision, climate regulation, water provision, water regulation and tourism and recreation. Bearing this in mind, the steering board decided **to valuate these 5 ES by attributing them a weighting factor of “2”**. This value was chosen arbitrarily, but other weighting factors could have been tested. The main goal of

attributing this weighting factor was merely to value the 5 ES voted as more relevant more than the remaining ES.

Having as basis the aggregated matrix already with the application of this weighting factor for these 5 ES, the median (which was considered the most adequate integration statistical measure) was then calculated for each of the services. A sum of the median values was then performed for each of the service categories (provision, regulation, support and cultural).

The COS2018 shapefiles were then crossed with the matrix scores in ArcGIS. In order to facilitate the analysis, a raster conversion was made at the same resolution as the COS (1 hectare pixel) and the results were normalized by reclassifying the information to intervals with the same dimension from 1-5. This way, **four maps were produced by the steering board, for each of the ES categories – provision, regulation, support and cultural**. The figure below (fig. 23) illustrates the map that resulted from the aggregation of all the ES that belong to the category of "Provision". The remaining three maps regarding the ES categories of regulation, support and cultural are illustrated in Annex V.

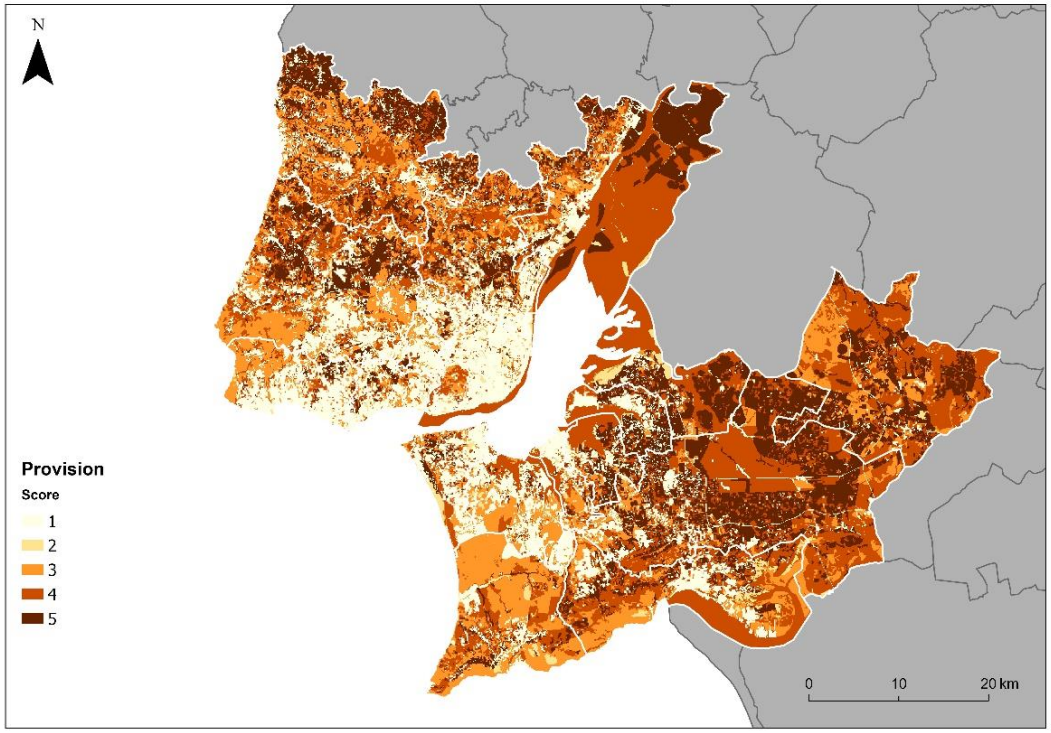


Figure 23 - Map obtained for the ES category of provision, considering a weighting factor of "2" for the ES of food provision and water provision (which belong to the 5 ES voted as more relevant). Source: WG 2.1. (FCT-NOVA).

In order to obtain **a final HUBS map**, that highlighted the areas which provided more ES**, the next step was to export the maximum classification classes** (that is, to export all class "5" valuations).

The use of the weighting factor "2" for the 5 services considered most relevant was still maintained in the exportation of class "5" for the mapping of HUBS. Initially, four HUBS maps were made, which

resulted from the exportation of the maximum classification areas for each category of ES (provision, regulation, support and cultural). These maps were subsequently added together to obtain the final map.

The image below illustrates the **final ES HUBS** map (see fig. 24).

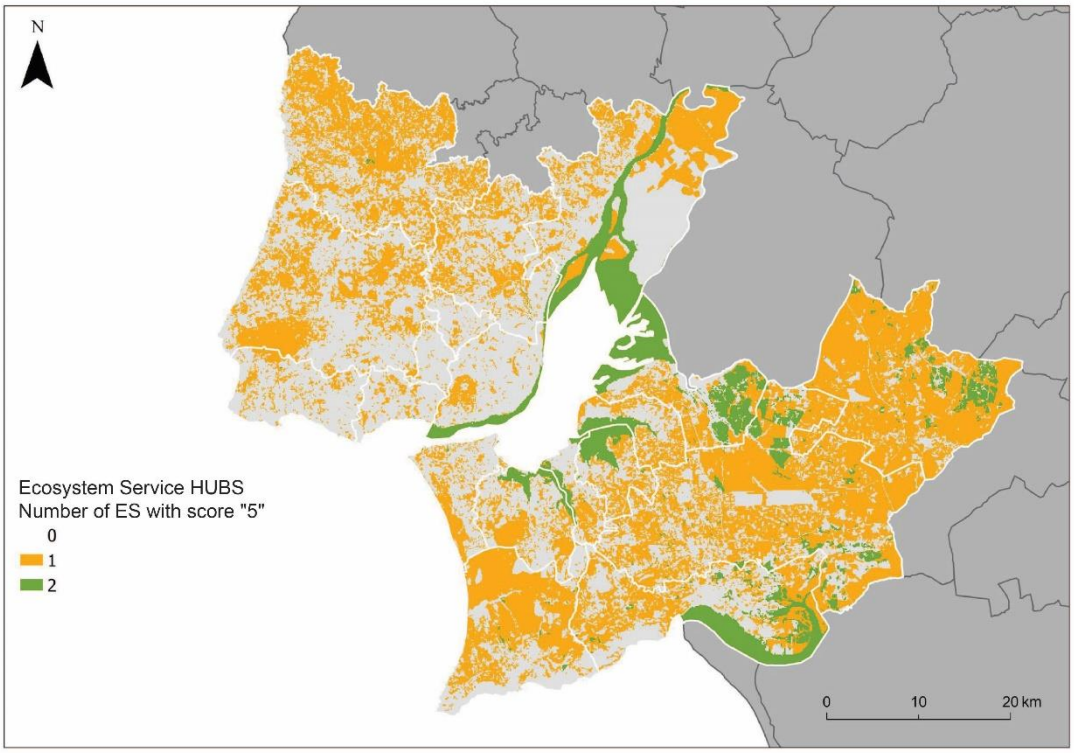


Figure 24 - Ecosystem Service final HUBS map. Source: WG 2.1. (FCT-NOVA).

This final map shows scores varying from 0 to 2, which are relative to the number of ES categories (provision, regulation, cultural and support) which have a score of "5". This means that the green area visible in the map, for example, corresponds to areas in which two ES categories had a classification of "5". If we analyze the maps in Annex V, we see that the maps regarding the categories of support and cultural ES both have this corresponding area with the maximum classification ("5"), which explains why the ES HUBS map shows this area in green.

Analyzing the HUBS map we can see that the estuary zones stand out as having the greatest importance from the point of view of the provision of ES (they are represented in green which means that they have 2 of the 4 ES categories with the maximum classification).

This final ES HUBS identifies the areas where various ecosystem services overlap, and which therefore could work as "nodes" of the green infrastructure network. This map was subsequently overlaid with the Metropolitan Ecological Network (REM)[64] in order to check the adherence between these two maps as well as to highlight the main differences between them.

[64] REM – Rede Ecológica Metropolitana

The figure below (see fig. 25) illustrates the map that resulted from the overlapping of the ES HUBS map with the REM.

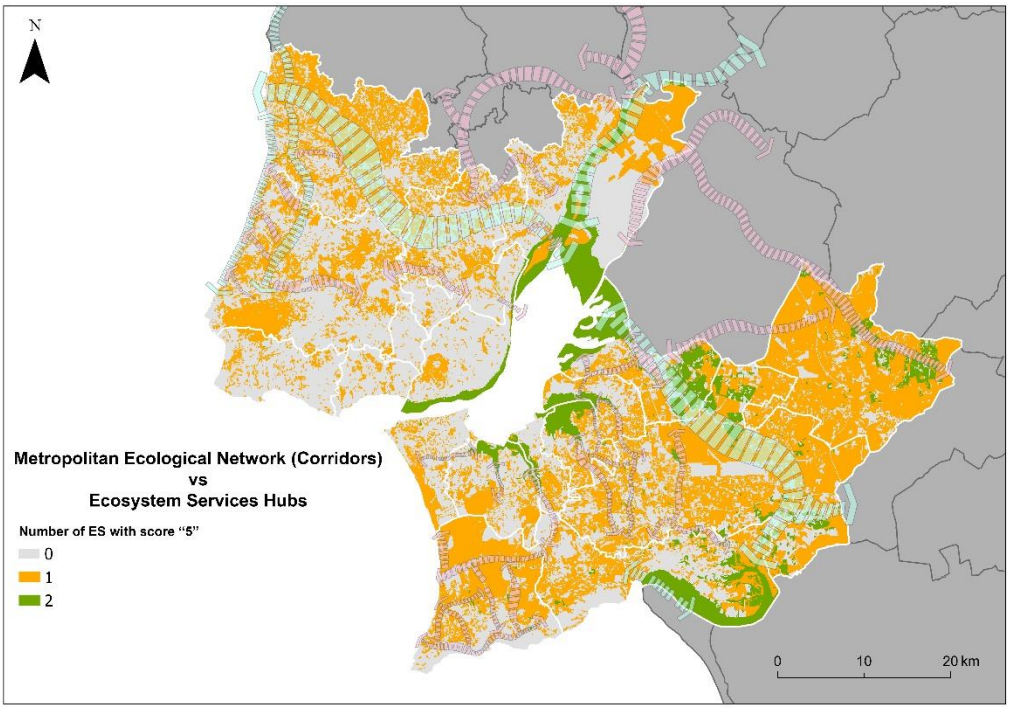


Figure 25 - Metropolitan Ecological Network Corridors (REM) VS. ES HUBS map. Source: WG 2.1. (FCT-NOVA)

Discussion of the results:

The Metropolitan Ecological Network (REM) is more "monofunctional" than the network represented in the ES HUBS map, i.e. it focuses mainly on the biodiversity/ecological values. By looking at figure 25, it's possible to verify that there is some coherence between the corridors from the REM and the green areas in the ES HUBS map. However, the final aim of the approach developed in this dissertation would be to reach a multifunctional green infrastructure network, associated with the diversity of the existing ES, which the current model of the REM does not address.

Regarding the Metropolitan Ecological Network, the estuaries are classified as the main areas. Looking at the Northern area, there are almost no green areas (only one residual in Mafra). In the South there is a corridor that connects both estuaries. On the coastline of Sintra and Mafra there are also main corridors, even though there is no coincidence between these corridors and the green areas of the ES HUBS map.

Looking to the secondary corridors, we see that, in the South, the Coina river is closely associated to the watercourses and that there is some partial coincidence with the ES HUBS map. It's also noteworthy that the Lagoa de Albufeira, that should constitute an HUB, is not represented as one in the ES HUBS map. This lagoon is the only coastal lagoon in the LMA that doesn't appear highlighted on the HUBS

map. This can be explained by the fact that the municipality of Sesimbra, which is the municipality to which this ecosystem belongs to, did not fill the matrix which could explain the under-valuation of this important area. There are thus some aspects of the ES HUBS map that still require corrections and improvements. In the case of the Lagoa the Albufeira, it would be important to insert some correction factor in order to avoid that this area, which has a diverse set of ES associated to it, is devaluated in territorial terms and could integrate the green infrastructure network in the future.

While the estuary in the REM is crossed by the main structure and is received in the secondary structure, in the approach developed by the working group 2.1., the estuary constitutes one of the main elements (a major HUB). This is relevant, considering that the presence of water has a wide influence on multiple ES, in terms of provisioning, regulating and cultural levels. The estuaries, from this multifunctional perspective, should have a greater weight in the green infrastructure network that could be developed in the future. In another words, in the evolution of the current ecological structure to a green infrastructure network, the estuary areas and the multifunctionality of ES associated to them could, and should, be valorized in a different way.

During the final zoom workshop of the Lisbon Living Lab WG 2.1., that took place on October 8th, these six maps were presented to the municipalities and entities present, and a group discussion was promoted in order to collect information on the opinions of the municipalities as well as to address ways to follow-up the work developed within this working group in the future (after the end of the ROBUST project).

Chapter 4. Concluding remarks and future applicability

GI as a territorial planning instrument, contribute to inform and support a sustainable development, having the potential to actively promote a balance between the needs of the populations and the ecosystems.

Undoubtedly, the integration of the Ecological Structure within the RJIGT was a landmark in the planning practice in Portugal. However, with the legislation analysis performed in 3.2.2., it was possible to see that this structure still lacks further clarification in regard to the areas it should cover, its structural components and the functions it aims to perform. Currently, the inexistence of clear guidelines on how to organize the structure of a GI and articulate the different legal regimens is a clear obstacle to the implementation of this structure by the municipalities, who often struggle in the interpretation of these vague criteria.

With the aim of trying to tackle the issues of the existing GI, WG 2.1. focused on the development of a collaborative ES mapping approach, that could serve as a starting point for the creation of a real GI metropolitan network. The conceptual model used in this WG aimed to promote a process of innovation and co-creation of useful knowledge amongst the stakeholders involved, focusing on the development of a bottom-up and ecosystem services-based approach suited for regional up-scaling. The methodology used the perception of local stakeholders (e.g., urban planners and practitioners from diverse areas) regarding ES provision. During the process of evaluation, both rural and urban flows had to be considered, due to the heterogeneity of the LMA which comprehends municipalities with different land cover types.

The workshops held online by WG 2.1., within the scope of the ROBUST project, focused on promoting intersectoral interaction and rural-urban synergies. As the work progressed, various approaches were tested and alternative paths were tried out, following an iterative methodology that sought to provide answers to the various questions that emerged. What distinguished the work developed within this WG 2.1. from other similar ES mapping exercises was the linking of societal and scientific practice.

On one hand, the active involvement of the stakeholders was crucial, enabling local actors from different municipalities to share the specific challenges they encountered in the implementation of GI in their territories as well as promoting an inter-municipal discussion on the best way to progress towards the development and management a GI metropolitan network.

On the other hand, the presence of scientific partners (e.g., IST, FCT-NOVA) allowed for an increase of stakeholder literacy, providing answers to the doubts that have arisen. This knowledge acquired by local stakeholders can in turn be transferred to their institutions and translate into new studies and projects that might be developed in the future. At the same time, the workshops enabled the identification of the main “knowledge gaps” which can, and should, be seen as opportunities from the point of view of scientific research, allowing scientific partners to provide concrete answers to the local actors in the territory.

In regard to the interviews conducted, these were a useful tool for harnessing stakeholders' perspectives on the path towards a metropolitan network GI as well to receive feedback from the participants on the exploratory ES based approach used. With the interviews, it was possible to highlight the main potentials and bottlenecks associated to the used methodology and, at the same time, to gain a deeper understanding of the rationale used by each municipality throughout the process. The answers of the stakeholders emphasized the potential of this exploratory ES mapping approach, which could in the future become a tool for achieving a more articulated network that makes the most of the potentials provided by the ES.

From the interview responses, a confidence matrix was subsequently elaborated based on the confidence level of the stakeholders in the attribution of the classifications to the different cells of the matrix. The confidence matrix highlighted that the category of "cultural services" was associated to the higher levels of uncertainty (Annex IV), very likely due to intrinsic subjectivity inherent to the classification of cultural services, which are strongly context/user dependent (Baró, 2016). However, in the future, the use of complementary and/or addition participatory methods (e.g. visitors' surveys, use of social media data such as geo-tagged photographs showing recreational activities (Wood et al., 2013), questionnaires on outdoor recreational expectations in urban areas (Burkhard et al., 2014)) could increase the confidence levels in the classifications performed and therefore, the quality of the mapping of cultural services.

In the context of the revision of their masterplans, several municipalities engaging in this WG noted that often, in the process of transposing the PROT-AML guidelines to their Ecological Structure, they experienced several difficulties. They felt the transition was often too rigid and the approach developed within the WG 2.1. could be advantageous in order to promote a more flexible and dynamic process.

On the basis of the obtained results on the present dissertation, it's possible to see the potential that a GI metropolitan network could have to cope with multiple challenges, at different spatial scales. The final map produced – ES HUBS map – identified the areas where more ES overlap. These areas could therefore be seen as possible "nodes" of a future GI network. The planning and management of this GI network requires a holistic approach, that considers the whole range of ES potentially provided by the different types of landcover. In order to reach this multifunctional GI network there is a need for a transdisciplinary coordination between all the authorities dealing with urban and environmental policy.

The importance of the ES should also be highlighted, as they allowed the creation of a common language, eventually becoming a "vehicle" to look at the territory as a whole and for the concertation between the different areas and municipalities. The ES are, therefore, an effective way of densifying the value of the areas integrated in the GI, since their mapping allows for an explicit visualization of the range of values associated with these areas. The analysis of the masterplans reinforced the necessity to integrate ES as a binding instrument of these documents. This step of integrating ES in the existing legal documents is essential to enable their operationalization.

The bottom-up approach developed within WG 2.1. shows great promise for the future development of an innovative governance model for the GI network. Even though the present study wasn't able to materialize a final GI metropolitan network, it was very important to outline the path that should be taken, planting a seed towards the co-creation of a real GI network, based on the diversity of territorial actors and in the leadership of the municipalities in the design, implementation and management of a metropolitan GI network.

References

Albert, C., von Haaren, C. (2017). Implications of applying the green infrastructure concept in landscape planning for ecosystem services in peri-urban areas: an expert survey and case study. Plan. Pract. Res. 32, 1–16. https://doi.org/10.1080/ 02697459.2014.973683 - Accessed in 21/11/2021

Andrade, U. M. (2017). O território da casa contemporânea de referência na região de Lisboa: paisagem suburbana e projeto, p. 2.

Andresen, T. (2001). Francisco Caldeira Cabral. Landscape Design Trust, Surrey, UK.

Baró, F. (2016). Urban Green Infrastructure: Modelling and mapping ecosystem services for sustainable planning and management in and around cities. Ph.D. Thesis, Program in Environmental Science and Technology, Universitat Autonoma de Barcelona.

Beatley, T. (2000). Green Urbanism: Learning from European Cities. Washington: Island Press.

Beatley, T., Newman, P. (2009). Green urbanism down under-learning from sustainable communities in Australia. Washington: Island Press.

Benedict, M.A., McMahon, E.T. (2002). Green infrastructure: smart conservation for the 21st century. Renew. Resour. J., 20, 12–17.

Braat, L. C., de Groot, R. (2012). The ecosystem services agenda: bridging the worlds of natural science and economics, conservation and development, and public and private policy. Ecosystem Services, 1(1), 4–15. https://doi.org/10.1016/j.ecoser.2012.07.011 - Accessed in 01/02/2022

Burkhard, B., Kroll, F., Müller, F., Windhorst, W. (2009). Landscapes' capacities to provide ecosystem services - A concept for land-cover based assessments. Landscape Online, 15(1), 1–22. https://doi.org/10.3097/LO.200915 - Accessed in 5/05/2021

Burkhard, B., Kroll, F., Nedkov, S., Müller, F. (2012). Mapping ecosystem service supply, demand and budgets. Ecol. Indic. 21, 17–29.

Burkhard, B., Kandziora, M., Hou, Y., Müller, F. (2014). Ecosystem Service Potentials, Flows and Demands – Concepts for Spatial Localization, Indication and Quantification. Landscape Online 32, 1–32.

Burkhard, B., Maes, J . (2017). Mapping Ecosystem Services. Pensoft Publishers, Sofia, p.374

Cabral, F. C. (1980). O continuum naturale e a conservação da natureza (p. 11). Serviços de Estudos do Ambiente.

Campagne, C., Roche, P. (2018). May the Matrix Be with You! Guidelines for the Application of Expert Based Matrix Approach for Ecosystem Services Assessment and Mapping. One Ecosystem, 3. https://doi.org/10.3897/oneeco.3.e24134 - Accessed in 03/04/2021

Chatzimentor, A., Apostolopoulou, E., Mazaris, A. (2020) A review of green infrastructure research in Europe: Challenges and opportunities. Landsc. Urban Plan. Volume 198. https://doi.org/10.1016/j.landurbplan.2020.103775 - Accessed in 03/02/2022

Chaudhary, S., McGregor, M., Houston, D., Chettri, N. (2015). The evolution of ecosystem services: A time series and discourse-centered analysis. Environmental Science & Policy 54, 25–34.

Costanza, R., d'Arge, R., de Groot, R., Grasso, M., Hannon, B., Limburg, K., Naaeem, S., O´Neiil, R.V., Paruelo, J., Raskin, R.G., Sutton, P., Van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. Nature 387, 253–260. https://doi.org/10.1038/387253a0 - Accessed in 28/04/2021

Costanza, R., de Groot, R., Braat, L.C., Kubiszewski, I., Fioramonti, L., Sutton, P., Farber, S., Grasso, M. (2017). "Twenty years of ecosystem services: How far have we come and how far do we still need to go?," Ecosystem Services, Elsevier, vol. 28, 1-16. https://doi.org/10.1016/j.ecoser.2017.09.008 - Accessed in 28/04/2021

Correia, I. (2012). Das Estruturas Ecológicas municipais às Infraestruturas Verdes. Tese de Mestrado em Urbanismo e Ordenamento do Território, Instituto Superior Técnico. - Accessed in 30/04/2021

Crossman, N. D., Burkhard, B., Nedkov, S., Willemen, L., Petz, K., Palomo, I., Drakou, E., Martín-López, B., McPhearson, T., Boyanova, K., Alkemade, R., Egoh, B. N., Dunbar, M. B., Maes, J. (2013). A blueprint for mapping and modelling ecosystem services. Ecosystem services, 4, 4-14. https://doi.org/10.1016/j.ecoser.2013.02.001- Accessed in 05/06/2021

Czúcz, B., Arany, I., Potschin-Young, M., Bereczki, K., Kertész, M., Kiss, M., Aszalós, R. and Haines-Young, R. (2018). Where concepts meet the real world: A systematic review of ecosystem service indicators and their classification using CICES, Ecosystem Services. Volume 29, Part A, 145-157. https://doi.org/10.1016/j.ecoser.2017.11.018 – Accessed in 28/06/2021

Egoh, B.N., Drakou, E.G., Dunbar, M.B., Maes, J., Willemen, L. (2012). Indicators for mapping ecosystem services: a review. Joint Research Centre / Publications Office of the European Union, Luxembourg.

Ehrlich, P.R., Mooney, A.H. (1983). Extinction, Substitution, and Ecosystem Services. BioScience, vol. 33, nº. 4, 248–54, https://doi.org/10.2307/1309037- Accessed 05/03/2022

Elliott, R.M., Motzny, A.E., Majd, S., Chavez, J.V., Laimer, D., Orlove, B.S., Culligan, P.J. (2019). Identifying linkages between urban green infrastructure and ecosystem services using an expert opinion methodology. Ambio 49 (2): 569-583.

European Commission. (2011). The EU Biodiversity Strategy to 2020. Publications Office of the European Union, Luxembourg. https://doi.org/10.2779/39229 Accessed in 12/05/2021

European Commission. (2013a). Green Infrastructure (GI) – Enhancing Europe's Natural Capital. Publications Office of the European Union. Brussels.

European Commission. (2013b). Building a Green Infrastructure for Europe. Publications Office of the European Union. Luxembourg.

European Commission. (2020). EU Biodiversity Strategy for 2030. https://www.eea.europa.eu/policy-documents/eu-biodiversity-strategy-for-2030-1 - Accessed in 13/05/2021

Ferrão, J. (2011). O ordenamento do território como política pública. Lisboa: Fundação Calouste Gulbenkian.

Geange, S., Townsend, M., Clark, D., Ellis, J., Lohrer, A. (2019). Communicating the value of marine conservation using an ecosystem service matrix approach. Ecosystem Services 35, 150-163. https://doi.org/10.1016/j.ecoser.2018.12.004 - Accessed in 08/06/2021

Gibbs, H.K. (2006). Major world ecosystem complexes ranked by carbon in live vegetation: an updated database using the GLC2000 land cover product. Oak Ridge (TN): Carbon Dioxide Information Center, Oak Ridge National Laboratory.

Gorn, L., Kleemann, J., Fürst, C. (2018). Improving the matrix-assessment of ecosystem services provision—the case of regional land use planning under climate change in the Region of Halle, Germany. Land 7 (2).

Grêt-Regamey, A., Weibel, B., Kienast, F., Rabe, S. E., Zulian, G. (2015). A tiered approach for mapping ecosystem services. Ecosystem Services, 13, 16–27. https://doi.org/10.1016/j.ecoser.2014.10.008 - Accessed in 06/04/2021

Haines-Young, R., Potschin, M. (2009). The links between biodiversity , ecosystem services and human well-being. Ecosystem Ecology: A New Synthesis, 110–139. https://doi.org/10.1017/CBO9780511750458.007- Accessed in 04/05/2021

Haines-Young, R., Potschin, M. (2018). CICES (Common International Classification of Ecosystem Services): Guidance on the Application of the Revised Structure.

Haines-Young, R., Potschin, M. (2018). Revision of the Common International Classification for Ecosystem Services (CICES V5.1): A Policy Brief. One Ecosystem 3: e27108. https://doi.org/10.3897/oneeco.3.e27108 - Accessed in 07/05/2021

Hansen, R., Pauleit, S. (2014). From Multifunctionality to Multiple Ecosystem Services? A Conceptual Framework for Multifunctionality in Green Infrastructure Planning for Urban Areas. Ambio 43, 516–529. https://doi.org/10.1007/s13280-014-0510-2 - Accessed in 08/06/2021

Hansen, R., Rall, E., Chapman, E., Rolf, W., Pauleit, S. (2017). Urban Green Infrastructure Planning: A Guide for Practitioners. GREEN SURGE.

IPBES. (2020). Global Assessment Report on Biodiversity and Ecosystem Services, 25-26 https://doi.org/10.5281/zenodo.3831852 - Accessed in 28/05/2022

Jacobs, S., Burkhard, B., Van Daele, T., Staes, J., and Schneiders, A. (2015). 'The Matrix Reloaded': a review of expert knowledge use for mapping ecosystem services. Ecol. Model 295, 21–30.

La Bianca, G., Tillin, H., Hodgson, B., Erni-Cassola, G., Howell, K., Rees, S. (2018). Ascension Island-Natural Capital Assessment: Marine ecosystem services report. JNCC.

Living Lab Report for Lisbon, ROBUST. (2021). ROBUST Task 3.2 Place-based case studies. https://rural-urban.eu/living-lab/lisbon - Accessed in 25/04/2022

Lund, H. G. (2004). INVENTORY: Multipurpose Resource Inventories. Encyclopedia of Forest Sciences, 414-420. https://doi.org/10.1016/B0-12-145160-7/00159-9 - Accessed in 12/03/2021

Maes, J., Teller, A. (2013). Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments. European Comission, Luxembourg. https://doi.org/10.2779/12398 - Accessed in 28/04/2022

Maes, J., Teller, A., Erhard, M. (2014). Mapping and Assessment of Ecosystems and their Services. Indicators for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Publications office of the European Union. Luxembourg https://doi.org/10.2779/75203 - Accessed in 28/05/2022

Magalhães, M. (1994). Paisagem urbana e Interface Urbano-Rural. Em Paisagem (p. 99). Lisboa: Direcção Geral do Ordenamento do Território e Desenvolvimento Urbano.

Martínez-Harms, M. J., Balvanera, P. (2012). Methods for mapping ecosystem service supply: A review. International Journal of Biodiversity Science, Ecosystem Services & Management, 8(1–2), 17–25. https:// doi.org/10.1080/21513732.2012.663792 - Accessed in 06/11/2021

Mascarenhas, A., Ramos, T.B., Haase, D., Santos, R. (2015). Ecosystem services in spatial planning and strategic environmental assessment - a European and Portuguese profile Land Use Policy, 48 , 158-169.

Mell, I. C. (2008). Green Infrastructure : concepts and planning. Forum Journal, 8, 69–80.

Mell, I. C. (2012). Green infrastructure planning: A contemporary approach for innovative interventions in urban landscape management. Journal of Biourbanism No.1, 29–39.

Millennium Ecosystem Assessment (Program). (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. https://www.millenniumassessment.org/en/index.html - Accessed in 30/05/2022

Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R.E., Lehner, B., Malcolm, T.R., Ricketts, T.H. (2008). Global mapping of ecosystem services and conservation priorities. Proceedings of the National Academy of Sciences of the United States of America, 105, 9495–9500.

Quintas, V. A. (2014). Génese e evolução dos modelos de Estrutura Verde Urbana na estratégia de desenvolvimento das cidades in A Obra Nasce, 8, pp. 153-167.

Ribeiro, J. F. (2009). PROT- AML. Cenários de desenvolvimento para a área metropolitana de Lisboa no cenário de 2020, p. 4.

Rouse, D. C. (2013). Green Infrastructure: A landscape approach. Chicago, IL: The American Planning Association.

Sandström, U.G., Angelstam, P., Khakee, A. (2006). Urban comprehensive planning—Identifying barriers for the maintenance of functional habitat networks. Landscape Urban Plan. 75, 43–57.

Schröter, M., Barton, D.N., Remme, R.P., Hein, L. (2014). Accounting for capacity and flow of ecosystem services: A conceptual model and a case study for Telemark, Norway. Ecol. Indic. 36, 539–551.

Schulp, C.J.E., Lautenbach, S., Verburg, P.H. (2014). Quantifying and mapping ecosystem services: Demand and supply of pollination in the European Union. Ecol. Indic. 36, 131–141.

Searns, R.M. (1995). The evolution of greenways as an adaptive urban landscape form. Landscape Urban Plan. 33, 65–80.

Stürck, J., Poortinga, A., Verburg, P.H. (2014). Mapping ecosystem services: The supply and demand of flood regulation services in Europe. Ecol. Indic. 38, 198–211.

Vaz, I. (2018). Linking Green infrastructure and land cover mapping in spatial planning: an exploratory approach. Tese de Mestrado em Urbanismo e Ordenamento do Território, Instituto Superior Técnico. Accessed in 30/05/2022

Wendland, KJ., Honzák, M., Portela, R., Vitale, B., Rubinoff, S., Randrianarisoa, J. (2010). Targeting and implementing payments for ecosystem services: opportunities for bundling biodiversity conservation with carbon and water services in Madagascar. Ecol. Econ. 69(11):2093–2107.

Wilson, C.M., Matthews, W.H. (1970). Man's impact on the global environment: report of the study of critical environmental problems (SCEP). Cambridge, MA: MIT Press

Wolff, S., Schulp, C.J.E., Verburg, P.H.(2015). Mapping ecosystem services demand: A review of current research and future perspectives. Ecol. Indic. 55, 159–171.

Wood, S. A., Guerry, A. D., Silver, J. M., and Lacayo, M. (2013). Using Social Media to Quantify Nature-Based Tourism and Recreation. Sci. Rep. 3, 2976. https://doi.org/10.1038/srep02976 - Accessed in 06/05/2021

Annexes

Annex I – Analysis of the 2nd generation masterplans components

Annex I (table 1) - Summary table of the analyzed components of the 2nd generation masterplans

Munícipios	Ano	Publicação	Conceito EEM	Inclusão do Conceito de Serviço de Ecossistema (menção explícita)	Estrutura
Sintra	2020	RCM 7 B/2020 20FEV2020	Conjunto de áreas de solo que, em virtude das suas caraterísticas biofísicas, ecossistémicas ou culturais da sua continuidade ecológica e do seu ordenamento, têm por função principal contribuir para a biodiversidade, para o equilíbrio ecológico e para a proteção, conservação e valorização ambiental, paisagística e do património natural do solo rústico e urbano. (Artigo 9)	SIM	Estrutura Verde Primária; Estrutura Verde Secundária; Estrutura Azul Primária; Estrutura Azul Secundária;
Cascais	2015	Aviso n.º 7212- B/2015 29JUN2015	Conjunto de áreas de solo que, em virtude das suas caraterísticas biofísicas, ecossistémicas ou culturais da sua continuidade ecológica e do seu ordenamento, têm por função principal contribuir para a biodiversidade, para o equilíbrio ecológico e para a proteção, conservação e valorização ambiental, paisagística e do património natural dos espaços rurais ou urbanos. (Artigo 9)	SIM	Estrutura Ecológica Fundamental; Estrutura Ecológica Complementar; Estrutura Ecológica Urbana;
Lisboa	2012	Aviso n.º 11622/2012, 30AGO2012	Visa assegurar a continuidade e complementaridade dos sistemas naturais no território urbano, a sustentabilidade ecológica e física do meio, as funções dos sistemas biológicos, a biodiversidade, o controlo dos escoamentos hídricos e circulação do vento, o conforto bioclimático e a valorização do património paisagístico. (Artigo 11)	NÃO	Estrutura Ecológica Fundamental; Estrutura Ecológica Integrada;
Loures	2015	Aviso n.º 6808/2015, 18 JUN2015	Visa a preservação e manutenção da integridade dos principais recursos e valores naturais e do funcionamento dos processos ecológicos, integrando-os numa estrutura contínua, com características variadas consoante a realidade em que se inserem. (Artigo 166)	NÃO	Nível Nacional e Internacional; Nível Regional (Rede Primária e Secundária); Nível Local;
Mafra	2015	Aviso n.º 6614/2015, 15JUN2015	Constituída pelo conjunto das áreas que têm como função principal contribuir para o equilíbrio ecológico, proporcionando a protecção, a conservação e a valorização ambiental e paisagística do solo rural e urbano. (Artigo 62)	NÃO	Áreas de protecção; Áreas de valorização específica;
Odivelas	2015	Aviso n.º 10014/2015 de 2SET2015	Objeto de um instrumento de gestão municipal de caráter executivo e integrado com vista à salvaguarda, valorização e monitorização da mesma, como garante da sustentabilidade ecológica e de prevenção de riscos, valorização paisagística bem como suporte de funções complementares urbanas de recreio e lazer. (Artigo 14)	NÃO	Componente Rural; Componente Urbana;
Oeiras	2015	Aviso n.º 10445/2015 14SET2015	Integra o conjunto de áreas, valores e sistemas fundamentais que, em virtude das suas características biofísicas ou culturais, da sua continuidade ecológica e do seu ordenamento, têm por função principal contribuir para o equilíbrio ecológico e para a proteção, conservação e valorização ambiental do território do Município de Oeiras. (Artigo 3)	NÃO	Estrura Ecológica Fundamental; Estrutura Ecológica Complementar;
Vila Franca de Xira	2009	Aviso n.º 20905/2009, 18NOV2009	Constituída pelos solos classificados como Espaços Agrícolas de Produção Tipo I e Tipo II, Espaços Florestais, Espaços Naturais, Espaços de Indústria Extractiva e Solos Afectos à Estrutura Ecológica Urbana. (artigo 11)	NÃO	Componente Rural; Componente Urbana;
Moita	2010	Aviso 10488/2010, de 26MAIO2010	Constituída pelo solo rural, pelos espaços naturais de proteção à rede hídrica, pelos espaços canais da rede viária estruturante e pelos espaços verdes urbanos, estabelecendo a articulação entre o solo urbano, o solo rural e os corredores verdes de ligação, em conformidade com o Plano Regional de Ordenamento do Território da Área Metropolitana de Lisboa. (Artigo 48)	NÃO	Componente Urbana; Componente Rural; Corredores de protecção da rede viária;
Seixal	2015	Aviso 2388/2015, de 4MAR2015	Constituída pelo conjunto de áreas que, em virtude das suas características biofísicas ou culturais, da sua continuidade ecológica e do seu ordenamento, têm por função principal contribuir para o equilíbrio ecológico e para a proteção,conservação e valorização ambiental e paisagística dos espaços rurais e urbanos, constituindo uma garantia da salvaguarda dos ecossistemas e da intensificação dos processos biofísicos, decorrendo muitas das áreas da aplicação das orientações do PROT-AML. (Artigo 22)	NÃO	Nível Regional (Área Prioritária 1; Área Prioritária 2; Corredores Estruturantes Principais;Corredores Estruturantes Secundários;Áreas Vitais;) Nível Local (Áreas Verdes de Proximidade);

Annex I (table 2) – Synthesis of the criteria for the delimitation of the Municipal Ecological Structure

Município	Critérios de Delimitação da EEM			
	Estrutura Verde		Estrutura Azul	
	Primária	Secundária	Primária	Secundária
Sintra	compreende a delimitação das duas principais serras do concelho de Sintra-Serra de Sintra e a Serra da Carregueira;	Os corredores ecológicos previstos no MDT e que estabelecem a ligação entre as áreas com maior relevância enquanto recurso e valor natural;	Principais cursos de água do concelho e da frente marítima(orla costeira), enquanto importantes recursos naturais e corredores suporte de sistemas ecológicos fundamentais;	grandes vales pronunciados associados à estrutura azul primária, e às arribas, abrangendo áreas de relevante valor ecológico e paisagístico para o território;
Cascais	Estrutura Ecológica Fundamental		Estrutura Ecológica Complementar	Estrutura Ecológica Urbana
	Integram a estrutura ecológica fundamental os solos qualificados como espaço natural de nível 1. Composta pelas áreas que integram os sistemas ecológicos fundamentais que garantem a sustentabilidade do território, onde as medidas de proteção são indispensáveis e alguns recursos naturais que, pelo seu inquestionável valor, devem ser salvaguardados;		Integram a estrutura ecológica complementar os solos qualificados como espaço natural de nível 1 e de nível 2. Integra ocorrências e valores naturais, paisagísticos ou histórico-culturais relevantes a nível concelhio mas que, pelas suas características, não obrigam à sua inclusão num regime total de proteção;	Inclui os solos qualificados como espaço natural de nível 3,espaço verde de recreio e produção, espaço verde de proteção e conservação e espaço verde de proteção a infraestruturas. Abrange os vazios de edificação em solo urbano, incluindo jardins públicos, parques urbanos, árvores de arruamento, espaços verdes de recreio, lazer, produção, enquadramento e de proteção;
Lisboa	Estrutura Ecológica Fundamental		Estrutura Ecológica Integrada	
	É constituída pelos seguintes sistemas: •**Sistema de corredores estruturantes**- Integra áreas públicas e privadas consolidadas ou a consolidar que estabelecem as ligações existentes e definem reservas para as ligações a promover no âmbito de projetos ou planos; •**Sistema húmido**- Integra as áreas correspondentes a linhas de drenagem a céu aberto, áreas adjacentes, bacias de retenção de águas pluviais, zonas de ressurgências hídricas, zonas aluvionares e zonas sujeitas a inundações; •**Sistema de transição fluvial-estuarino**- Integra a superfície de contacto entre o fluxo proveniente dos sistemas naturais de drenagem fluvial, as linhas de água afluentes, as marés e o fluxo proveniente do estuário do Tejo;		Inclui os espaços verdes e os logradouros verdes permeáveis a preservar identificados na Planta da estrutura ecológica municipal e na Planta de qualificação do espaço urbano, e ainda os espaços verdes de enquadramento a áreas edificadas e os eixos arborizados assinalados na Planta da estrutura ecológica municipal, tendo por objetivo uma articulação entre os sistemas naturais e culturais e a sua gestão numa perspetiva sustentável e integrada do território municipal;	
Loures	Nível Nacional e Internacional	Nível Regional	Nível Local	
	Integra as áreas que constituem o suporte dos sistemas ecológicos fundamentais e os recursos naturais indispensáveis à sustentabilidade do território, sendo a sua proteção conferida por instrumentos de ordenamento do território de nível nacional e internacional. Compreende os solos afectos à **RAN, à REN e ao Plano Setorial da Rede Natura 2000;**	Integra as áreas do território municipal consideradas estruturantes e decisivas para a sustentabilidade ambiental da AML, definidas de acordo com a Rede Ecológica Metropolitana do PROTAML. Compreende os solos afetos: •**À Rede Primária** -Área Estruturante Primária; Ligação / Corredor Estruturante Primário; •**À Rede Secundária-** Áreas Estruturantes Secundárias; Corredores Estruturantes Secundários;	Integra as ocorrências naturais que,complementarmente aos níveis superiores da Estrutura Ecológica Municipal, contribuem para a sustentabilidade do território, para a qualificação do carácter da Paisagem do Município de Loures e para uma melhor identidade do mesmo. Compreende os solos afetos: •**Aos Valores Naturais**-Património geomorfológico;Vegetação natural e seminatural; Solos de elevado valor ecológico; • **À Estrutura Ecológica Urbana**; • **Às Áreas Vitais**; •À**s Ligações / Corredores Vitais;** • À Região Demarcada do Vinho de Bucelas.	
Mafra	Áreas de Protecção		Áreas de Valoração Específica	
	Correspondem solos afectos a: •Áreas da REN, com excepção das praias; •Áreas do domínio hídrico; •Áreas da RAN; •Áreas da Rede Natura 2000; •Áreas e corredores secundários, com uma largura de 20m a partir da margem e conforme a Carta de EEM.		Priviligiam usos e actividades que promovam o recreio, o lazer e desporto, a cultura e o turismo, e compreendem solos afectos a: • Áreas de REN relativas a praias; • Áreas do regime florestal, conforme a legislação específica em vigor; • Área relativa à Tapada Militar, conforme a categoria de espaços florestais; • Áreas da EEM em solo urbano, conforme a categoria de espaços verdes.	
Odivelas	Espaços afectos à EEM em Solo Rural		Espaços afectos à EEM em Solo Urbano	
	Integra as seguintes categorias: •Espaço Agropastoril; •Espaço Florestal de Produção; •Espaço Naturalizado de Proteção ou Enquadramento; •Aglomerado Rural; •Espaço de Equipamentos e Outras Estruturas; Aos espaços integrados nestas categorias é reconhecida vocação para atividades florestais e agrícolas, ou, no locais onde existem estruturas construídas, para uma utilização com caráter de recreio e lazer.		Integra as seguintes categorias: • **Espaço Urbanizado Consolidado Verde** - classificação atribuída aos espaços verdes tratados existentes que têm funções de enquadramento, lazer e equilíbrio ambiental, neles sendo permitidas apenas pequenas edificações de apoio às atividades compatíveis; • **Espaço Urbanizável Verde** - Classificação atribuída aos espaços urbanos programados que deverão acolher espaços verdes tratados com funções de enquadramento, lazer e equilíbrio ambiental, neles sendo permitidas apenas pequenas edificações de apoio às atividades compatíveis;	
Oeiras	Estrutura Ecológica Fundamental		Estrutura Ecológica Complementar	
	Composta pelas áreas enquadradas pelos seguintes regimes: •Áreas integradas na Reserva Ecológica Nacional; •Áreas integradas na Reserva Agrícola Nacional; •Áreas do domínio público hídrico; •Áreas integradas no regime florestal; •Áreas de povoamento de sobreiros e azinheiras; •Áreas vitais da Rede Ecológica Metropolitana; •Áreas afetas a habitats de interesse comunitário; Nas áreas integradas na estrutura ecológica fundamental aplicam-se os regimes legais que se encontram definidos para proteção dos valores em causa.		Integra as áreas que, pelos seus valores e características biofísicas intrínsecas e pelos seus valores e ocorrências culturais, são aptas para estabelecer a continuidade dos sistemas e funções ecológicas no território concelhio, potenciam corredores demobilidade suave e assumem, também, uma função social relevante. Integra as seguintes áreas: •Áreas de salvaguarda do sistema hidrogeológico; •Áreas de produção de biomassa; •Áreas verdes urbanas; •Áreas de conetividade e sistema de vistas.	
Vila Franca de Xira	Espaços afectos à EEM em Solo Rural		Espaços afectos à EEM em solo Urbano	
	Integra as seguintes componentes: •Espaços Agrícolas de Produção Tipo I de Nível I e II (definem os regimes de proteção parcial e complementar integrados na área da RNET); • Espaços Agrícolas de Produção Tipo I de Nível III; •Espaços Agrícolas de Produção Tipo II; • Espaços Agrícolas Complementares; •Espaços Florestais; •Espaços Naturais de Nível I e II (definem os regimes de proteção parcial do tipo I e do tipo II integrados na área da RNET); •Espaços naturais de nível III; •Espaços de Indústria Extrativa; •Outras áreas abrangidas por REN que não se incluem nas categorias acima mencionadas;		A EEU destina-se a assegurar o funcionamento dos sistemas biológicos, o controlo de escoamentos hídricos e conforto bioclimático, a promover a melhoria das condições ambientais e a qualidade do espaço urbano e, tal como referido anteriormente, decorrem da aplicação das orientações do PROTAML. Nestes espaços apenas se permitem atividades socioculturais, de recreio, de desporto e lazer, compatíveis com a natureza e condicionantes legais aplicáveis. Os solos afectos à EEU podem ou não ser coincidentes com a REN. São integradas as seguintes componentes: •Faixas de proteção a linhas de água; •Faixas de proteção de infraestruturas viárias,ferroviárias e urbanas; •Espaços que constituem locais privilegiados para atividades de animação e lazer da população, nomeadamente, jardins e parques urbanos;	
Moita	Espaços afectos à EEM em Solo Rural		Espaços afectos à EEM em Solo Urbano	Corredores de protecção da rede viária
	A EEM é constituída no concelho da Moita pelo solo rural, que integra as seguintes categorias: •Espaços Agro-Pecuários; •Espaços Agrícolas Periurbanos; •Espaços naturais, constituídos pelos corredores de proteção à rede hídrica, áreas de risco de cheia, bem como pelas áreas ribeirinhas de sapais, salinas, viveiros, praias e arribas;		Compreende as seguintes categorias: •Espaços Verdes Urbanos Existentes; •Espaços Verdes Urbanos Propostos; As categorias acima mencionadas podem integrar: -Áreas verdes públicas equipadas; -Áreas verdes de utilização privada, em que se incluem áreas de atividade agrícola, floricultura, viveiros, espaços pedagógicos e espaços de lazer;	Integra as seguintes componentes: •Vias Estruturantes Primárias Existentes; •Vias Estruturantes Primárias Projectadas; •Itinerário Complementar;
Seixal	Nível Regional			Nível Local
	Área Prioritária 1	Área Prioritária 2	Corredores Estruturantes Principais / Corredores Estruturantes Secundários	Áreas Vitais / Verdes de proximidade
	Área estruturante de proteção e conservação, inserida no sítio de importância comunitária PTCON00054 – Fernão Ferro / Lagoa de Albufeira, área sujeita ao regime do Plano Setorial da Rede Natura 2000;	Área correspondente ao estuário do Tejo – elemento central da AML e constitui uma área húmida da maior importância a nível nacional e europeu;	Estruturas lineares que correspondem aos leitos e margens de cursos de água – rio Judeu, a ribeira do Vale Longo, vala das Amoreiras e vala do Guarda-Mor. Funcionam como principais elementos de conetividade entre as Áreas Prioritárias 1 e 2; Estruturas lineares que correspondem aos leitos e margens de cursos de água e valas – vala de Santa Marta, ribeira do Farol, vala dos Brejos da Palmeira, rio Judeu e vala da Quinta do Algarve, ribeira Vale de Figueira e afluente da Vala da Queimada-Milhaço bem como, estruturas lineares livres de edificação, que funcionam como principais elementos de conetividade entre as Áreas Vitais;	Compreende as áreas que, complementarmente às Áreas Prioritárias, contribuem para a sustentabilidade do território, correspondendo aos espaços livres considerados como vitais para a manutenção da função ecológica dominante e da conectividade entre as áreas e os corredores; Áreas livres situadas no interior de espaços urbanos consolidados, que pela sua reduzida dimensão, não foram classificadas como Áreas Vitais nem decorrem da delimitação da REM (nível regional) mas que foram integradas na EEM, por representarem ao nível local espaços de desafogo indispensáveis, como locais priviligiados para a estadia e/ou lazer bem como para garantia do enquadramento paisagístico das áreas edificadas.

Annex II – Considered COS2018 landcover classes in the matrix

Category (COS2018 Level 1)	Subcategory (COS2018 Level 4)
1. Artificial Land	1.1.1.1. Continuous built fabric predominantly vertical
	1.1.1.2. Continuous built fabric predominantly horizontal
	1.1.2.1 Discontinuous built fabric
	1.1.2.2 Sparse discontinuous built fabric
	1.1.3.1 Parking areas and patios
	1.1.3.2 Empty spaces without construction
	1.2.1.1 Industry
	1.2.2.1 Commerce
	1.2.3.1 Agricultural installations
	1.3.1.1 Renewable energy production infrastructures
	1.3.1.2 Non-renewable energy infrastructures
	1.3.2.1 Infrastructures for collection, treatment and supply of water for consumption
	1.3.2.2 Infrastructures for waste and wastewater treatment
	1.4.1.1 Road Network and related spaces
	1.4.1.2 Railway network and associated spaces
	1.4.2.1 Sea and river port terminals
	1.4.2.2 Shipyards and dry docks
	1.4.2.3 Marinas and fishing docks
	1.4.3.1 Airports
	1.4.3.2 Aerodromes
	1.5.1.1 Open-cast mines
	1.5.1.2 Quarries
	1.5.2.1 Landfills
	1.5.2.2 Dumps and Scrap Sites
	1.5.3.1 Areas under construction
	1.6.1.1 Golf courses
	1.6.1.2 Sporting facilities
	1.6.2.1 Camp sites
	1.6.2.2 Leisure equipments
	1.6.3.1 Cultural equipments
	1.6.4.1 Graveyards

Category (COS2018 Level 1)	Subcategory (COS2018 Level 4)
1. Artificial Land	1.6.5.1 Other tourist facilities and equipments
	1.7.1.1 Parks and gardens
2. Agriculture	2.1.1.1 Non-irrigated and irrigated temporary crops
	2.1.1.2 Rice fields
	2.2.1.1 Vineyards
	2.2.2.1 Orchards
	2.2.3.1. Olive groves
	2.3.1.2. Temporary crops and/or improved pastures combined with orchards
	2.3.1.3. Temporary crops and/or improved pastures combined with olive groves
	2.3.2.1 Complex cultural and parcel mosaics
	2.3.3.1 Agriculture with natural and semi-natural spaces
	2.4.1.1 Greenhouses and nurseries
3. Pastures	3.1.1.1 Improved pastures
	3.1.2.1 Spontaneous Pastures
4. Agroforestry Areas	4.1.1.1 AFS of cork oak
	4.1.1.2 AFS of holm oak
	4.1.1.4 AFS of stone pine
	4.1.1.5 AFS of other species
	4.1.1.6 AFS of cork oak with holm oak
	4.1.1.7 SAFS of other mixtures
5.Forests	5.1.1.1 Cork oak forests
	5.1.1.2 Holm oak forests
	5.1.1.3 Other oak forests
	5.1.1.5 Eucalyptus forests
	5.1.1.6 Forests of invasive species
	5.1.1.7 Forests of other broadleaf trees
	5.1.2.1 Pinus pinaster forests

Category (COS2018 Level 1)	Subcategory (COS2018 Level 4)
5. Forests	5.1.2.2 Stone pine forests
	5.1.2.3 Other coniferous forests
6. Woodland shrubs	6.1.1.1 Woodland shrubs
7. Open spaces or sparsely vegetated	7.1.1.1 Inland beaches, dunes and sands
	7.1.1.2 Coastal beaches, dunes and sands
	7.1.2.1 Bare rock
	7.1.3.1 Sparse vegetation
8. Wetlands	8.1.1.1 Marshes
	8.1.2.1 Saltmarshes
	8.1.2.2 Tidal flats
9. Surface water bodies	9.1.1.1 Natural watercourses
	9.1.1.2 Modified or artificial watercourses
	9.1.2.1 Artificial lakes and ponds
	9.1.2.2 Natural inland lakes and ponds
	9.1.2.3 Reservoirs of dams
	9.1.2.4 Reservoirs of dams or weirs
	9.1.2.5 Ponds
	9.2.1.1 Aquaculture
	9.3.1.1 Salinas
	9.3.2.1 Coastal lagoons
	9.3.3.1 River mouths
	9.3.4.1 Ocean

Annex III – Interview Guideline conducted to the stakeholders via Zoom (stakeholders from the municipalities of the Lisbon Metropolitan Area).

The present interview is exclusively for academic purposes in the context of the preparation of a master's Dissertation in Environmental Engineering in Instituto Superior Técnico of the Technical University of Lisbon.

The interview's subject addresses the methodological approach developed within the ROBUST project Lisbon Living Lab WG 2.1. , having chosen the Lisbon Metropolitan Area as a case study.

A special thanks to all the stakeholders interviewed, for their availability and valuable contribution to the study developed in this dissertation.

Ema Maranha (nº 87450, IST)

Interview- Questionnaire

How to progress towards the integration of the ecosystem service mapping approach in GI planning at a metropolitan scale

I. Motivation

1. What motivated you to participate in this group and to maintain your interest throughout the various sessions?

2. What interest do you see in the development of a metropolitan green infrastructure network?

II. Filling in the ES matrix

3. Have you ever worked with ES before, and if so, what methodology did you use? And in what context? Did you use it in the delimitation of the ecological structure?

4. During the filling of the matrix did you feel the need to speak with other colleagues working in different sectors and/or consult additional documentary information? Which were the assessments in which you felt the most/least confidence?

5. When filling out the matrix, did you assign the classifications considering the actual production of ecosystem services (i.e. considering the current management of the occupation class) or did you consider the potential for the production of ecosystem services that the class of occupation might have?

III. Integration into Planning

6. What potential do you see in the application of ES mapping in your municipality (particularly regarding the integration of this methodology into spatial planning)? Do you also see limitations?

7. In what ways do you consider that ES could be a tool to improve the planning and operationalization of Municipal Ecological Structures?

IV. Governance

8. How do you think this initiative for the development of a metropolitan green infrastructure network could be followed up (in a future scenario)?

9. Who do you consider has the “responsibility” for the management of the metropolitan green infrastructure network and how do you think this management should be done? What will be the role of the municipalities in this management?

Annex IV – Confidence Matrix : Exploratory Approach

Annex IV (table 1) - Legend of the abbreviations used for the ES in the confidence matrix

Provisioning Services	Regulating Services	Supporting Services	Cultural Services
FS - Food supply **WS** – Water Supply **RM** – Raw Materials **GR**- Genetic Resources **MR** – Medicinal Resources **OR**- Ornament Resources	**AR** - Air regulation **NR**- Noise Reduction **CR**- Climate Regulation **MEE**- Moderation of extreme events **WR** – Waterflow regulation **WT**- Waste treatment **EC** - Erosion control **SM** – Fertility of the soil and cycle of nutrients maintenance **P** - Pollination **BC** - Biologic control	**LCM** - Life cycles maintenance **GDM** - Genetic diversity maintenance	**A** - Aesthetic **RO** - Tourism and recreative activities opportunities **CI** - Inspiration for culture, art and design **SE**- Spiritual experience **CDI** - Information for cognitive development

Annex IV (Table 2) – Final confidence matrix. The most negative values (associated to the higher uncertainty levels) are highlighted in yellow.

		Provisioning						Regulating										Supporting		Cultural				
		FS	WS	RM	GR	MR	OR	AR	NR	CR	MEE	WR	WT	EC	SM	P	BC	LCM	GDM	AI	RO	CI	SE	CDI
Category (COS2018 Level 1)	**Subcategory (COS2018 Level 4)**	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
1. Artificial land	1.1.1.1. Continuous built fabric predominantly vertical	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.1.1.2. Continuous built fabric predominantly horizontal	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.1.2.1 Discontinuous built fabric	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.1.2.2 Sparse discontinuous built fabric	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.1.3.1 Parking areas and patios	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.1.3.2 Empty spaces without construction	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.2.1.1 Industry	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.2.2.1 Commerce	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.2.3.1 Agricultural installations	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.3.1.1 Renewable energy production infrastructures	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.3.1.2 Non-renewable energy infrastructures	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.3.2.1 Infrastructures for collection, treatment and supply of water for consum	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.3.2.2 Infrastructures for waste and wastewater treatment	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.4.1.1 Road Network and related spaces	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.4.1.2 Railway network and associated spaces	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.4.2.1 Sea and river port terminals	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.4.2.2 Shipyards and dry docks	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.4.2.3 Marinas and fishing docks	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.4.3.1 Airports	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.4.3.2 Aerodromes	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.5.1.1 Open-cast mines	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.5.1.2 Quarries	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.5.2.1 Landfills	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.5.2.2 Dumps and Scrap Sites	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.5.3.1 Areas under construction	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.6.1.1 Golf courses	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.6.1.2 Sporting facilities	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.6.2.1 Camp sites	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.6.2.2 Leisure equipments	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.6.3.1 Cultural equipments	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.6.4.1 Graveyards	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.6.5.1 Other tourist facilities and equipments	-1	-1	-1	-2	-2	-1	-1	-2	-1	-1	-1	-1	-1	-3	-1	-1	-1	-1	-5	-5	-5	-5	-6
	1.7.1.1 Parks and gardens	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
2. Agriculture	2.1.1.1 Non-irrigated and irrigated temporary crops	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	2.1.1.2 Rice fields	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	2.2.1.1 Vineyards	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	2.2.2.1 Orchards	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	2.2.3.1. Olive groves	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	2.3.1.2. Temporary crops and/or improved pastures combined with orchards	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	2.3.1.3. Temporary crops and/or improved pastures combined with olive groves	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	2.3.2.1 Complex cultural and parcel mosaics	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	2.3.3.1 Agriculture with natural and semi-natural spaces	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	2.4.1.1 Greenhouses and nurseries	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
3. Pastures	3.1.1.1 Improved pastures	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	3.1.2.1 Spontaneous Pastures	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
4. Agroforestry Areas	4.1.1.1 AFS of cork oak	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	4.1.1.2 AFS of holm oak	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	4.1.1.4 AFS of stone pine	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	4.1.1.5 AFS of other species	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	4.1.1.6 AFS of cork oak with holm oak	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	4.1.1.7 SAFS of other mixtures	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
5. Forests	5.1.1.1 Cork oak forests	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	5.1.1.2 Holm oak forests	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	5.1.1.3 Other oak forests	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	5.1.1.5 Eucalyptus forests	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	5.1.1.6 Forests of invasive species	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	5.1.1.7 Forests of other broadleaf trees	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	5.1.2.1 Pinus pinaster forests	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	5.1.2.2 Stone pine forests	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	5.1.2.3 Other coniferous forests	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
6. Woodland shrubs	6.1.1.1 Woodland shrubs	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
7. Open spaces or sparsely vegetated	7.1.1.1 Inland beaches, dunes and sands	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	7.1.1.2 Coastal beaches, dunes and sands	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	7.1.2.1 Bare rock	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	7.1.3.1 Sparse vegetation	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
8. Wetlands	8.1.1.1 Marshes	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-1	-3	-4
	8.1.2.1 Saltmarshes	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-3	-3	-4
	8.1.2.2 Tidal flats	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-3	-3	-4
9. Surface water bodies	9.1.1.1 Natural watercourses	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-3	-3	-4
	9.1.1.2 Modified or artificial watercourses	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-3	-3	-4
	9.1.2.1 Artificial lakes and ponds	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-3	-3	-4
	9.1.2.2 Natural inland lakes and ponds	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-3	-3	-4
	9.1.2.3 Reservoirs of dams	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-3	-3	-4
	9.1.2.4 Reservoirs of dams or weirs	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-3	-3	-4
	9.1.2.5 Ponds	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-3	-3	-4
	9.2.1.1 Aquaculture	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-3	-3	-4
	9.3.1.1 Salinas	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-3	-3	-4
	9.3.2.1 Coastal lagoons	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-3	-3	-4
	9.3.3.1 River mouths	1	1	1	0	0	1	1	0	1	1	1	1	1	-1	1	1	1	1	-3	-3	-3	-3	-4
	9.3.4.1 Ocean																							

Annex V – Maps that resulted from the aggregation of all the ES that belong to the categories of "Regulation", "Support" and "Cultural"**, respectively, considering a weighting factor of "2" for the 5 ES voted as more relevant. Source: WG 2.1. (FCT-NOVA)**