NOVA SCHOOL OF SCIENCE & TECHNOLOGY

DEPARTMENT OF ENVIRONMENTAL SCIENCES AND ENGINEERING

INTEGRATION OF GREEN INFRASTRUCTURE PLANNING PRINCIPLES INTO SPATIAL PLANNING

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Master in Environmental Engineering

DOCTORATE IN ENVIRONMENT AND SUSTAINABILITY

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Integration of Green Infrastructure Planning Principles into Spatial Planning

A todos os da minha vida

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This is it. After four challenging years, I can finally say that it is over. My Ph.D. thesis is complete, and an important journey of my life has ended. Perhaps the most important one to this date. There were laughs and tears, happy days and stressful nights, frustration mixed with hope. But, at the end of the day, I wound not have traded my bumpy ride with anything else - and that is the beauty of it. Although it was (sometimes) a solitary path, many people accompanied me with kindness, patience, and unwavering support throughout my four-year journey. For that reason, I want to show sincere gratitude to the people that supported me along the way. The next few paragraphs are for them.

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" There's only so much you can learn in one place,

The more that you wait, the more time that you waste"

(Madonna Louise Ciccone).

ABSTRACT

Green infrastructure is a strategically planned network of natural and semi-natural areas that are designed and managed to deliver a wide range of ecosystem services. It incorporates green and blue spaces and other physical features in terrestrial and marine areas. In addition to its ecological benefits, green infrastructure serves as a planning tool that promotes social and economic benefits, resulting in competitive, resilient, sustainable, and inclusive metropolitan communities. Since its initial appearance in the literature in the 1990s, the concept of "green infrastructure" has become widely used the academia, political actors, and policymakers. However, despite the extensive literature on the subject, there is still a level of complexity associated with the concept of "green infrastructure" that makes its implementation at the local level more difficult. Because of that, this research aims to investigate which green infrastructure planning principles should be considered in spatial planning and how practitioners and policy makers can integrate them into policies and environmental planning. To accomplish that, three research questions were answered: (1) What green infrastructure planning principles should be considered in spatial planning? (2) What are the views and priorities of practitioners and urban planners on green infrastructure planning principles? (3) How are these principles being integrated into spatial planning? To answer these questions, this research follows a transdisciplinary approach and participatory methods applied to a case study - Lisbon Metropolitan Area -, such as an integrative literature review, an analytic hierarchy process, desk research, and spatial plan document analyses. Findings show that the green infrastructure planning principles that must be incorporated into spatial planning are connectivity, multifunctionality, applicability, integration, diversity, multiscale, governance, and continuity, with the principles of connectivity, multifunctionality, governance and multiscale being the most cited in the literature, and applicability the least considered. Furthermore, the green infrastructure planning principles considered most important for professionals in the Lisbon Metropolitan Area, resulting from the exercise of analytic hierarchy process, were connectivity, followed by multifunctionality and applicability. As a result of the last exercise, although the principles of connectivity, diversity and applicability stood out, the results showed that, moving into practice, all municipalities analysed in this study present significant challenges regarding the integration of green infrastructure planning principles into their planning plans and territorial planning strategies. Because of that, this work encourages further research on this topic in general and especially recommends investigating cases in other countries, at different scales. This research is recommended for practitioners to help them find opportunities and define priorities for planning, implementing, and monitoring green infrastructure in their organizations.

Keywords: Green Infrastructure; Spatial Planning; Principles; Analytic Hierarchy Process; Urban Planners; Decision Makers; Lisbon Metropolitan Area; Portugal

Resumo

A infraestrutura verde é uma rede estrategicamente planeada de áreas naturais e seminaturais que são projetadas e geridas para fornecer uma ampla gama de serviços dos ecossistemas. Incorpora espaços verdes e azuis e outras características físicas em áreas terrestres e marinhas. Além dos seus benefícios ecológicos, a infraestrutura verde é uma ferramenta de planeamento que promove benefícios sociais e económicos, contribuindo para comunidades metropolitanas competitivas, resilientes, sustentáveis e inclusivas. Desde que surgiu na literatura na década de 1990, o conceito de "infraestrutura verde" tornou-se amplamente utilizado pela academia, atores e decisores políticos. No entanto, apesar da extensa literatura sobre o assunto, ainda existe um nível de complexidade associado ao conceito de "infraestrutura verde", o que dificulta a sua implementação a nível local. Por esse motivo, esta investigação tem como objetivo perceber quais princípios de planeamento da infraestrutura verde que deverão ser considerados no planeamento espacial e como é que os praticantes e atores políticos podem integrá-los nas políticas e no planeamento ambiental. Para isso, três questões de investigação foram respondidas: (1) Quais princípios de planeamento da infraestrutura verde que devem ser considerados no planeamento espacial? (2) Quais são os pontos de vista e prioridades dos profissionais e planeadores urbanos sobre os princípios de planeamento da infraestrutura verde? (3) Como é que esses princípios estão a ser integrados no ordenamento do território? Para responder a essas questões, esta investigação seguiu uma abordagem transdisciplinar com recurso a métodos participativos aplicado a um caso de estudo - Área Metropolitana de Lisboa -, nomeadamente uma revisão integrativa da literatura, um processo de análise hierárquica, pesquisa documental e análise de documentos de plano de ordenamento do território. Os resultados mostram que os princípios de planeamento da infraestrutura verde que deverão ser tidos em conta nos processos de planeamento são a conectividade, multifuncionalidade, aplicabilidade, integração, diversidade, multiescala, governança e continuidade, sendo os princípios da conectividade, multifuncionalidade, governança e multiescala os mais citados na literatura, e a aplicabilidade o menos considerado. Para além disso, os princípios de planeamento de infraestruturas verdes considerados mais importantes para os profissionais dos municípios da Área Metropolitana de Lisboa, resultantes do exercício da análise hierárquica foram a conectividade, seguida da multifuncionalidade e aplicabilidade. Como resultado do último exercício, embora os princípios da conectividade, diversidade e aplicabilidade se tenham destacado, os resultados demonstraram que, passando para a prática, todos os municípios analisados neste estudo apresentam desafios significativos quanto à integração dos princípios de planeamento da infraestrutura verde nos seus planos de ordenamento e estratégias de planeamento territorial. Tendo isto em conta, este trabalho incentiva mais investigação sobre esta temática em geral e, principalmente, recomenda a investigação de casos noutros países, em diferentes escalas. Esta pesquisa é recomendada para profissionais para ajudá-los a encontrar oportunidades e definir prioridades para planear, implementar e monitorar a infraestrutura verde nas suas organizações.

Palavas chave: Infraestrutura Verde; Ordenamento do Território; Princípios; Processo de análise Hierárquica; Urbanistas; Tomadores de decisão; Área Metropolitana de Lisboa; Portugal

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ACRONYMS

AHP	Analytic Hierarchy Process
CAOP	Official Administrative Charter of Portugal
CCDR LVT	Coordination and Regional Development Commission of Lisbon and Tagus Valley
CI	Consistency Index
CICES	Common International Classification of Ecosystem Services
CR	Consistency Ratio
DHP	Public Water Domain
EC	European Commission
EPA	Environmental Protection Agency
GDP	Gross Domestic Product
GI	Green Infrastructure
INE	National Institute of Statistics
LMA	Lisbon Metropolitan Area
MEN	Metropolitan Ecological Network
NUTS	Nomenclature of Territorial Units for Statistics
PNPOT	National Spatial Planning Policy Program
PROT	Regional Spatial Planning Plan
PROT-AML	Regional Plan for Land Use Planning of Lisbon Metropolitan Area
QCA	Qualitative Content Analysis

RAN	National Agriculture Reserve
REN	National Ecological Reserve
RI	Random Consistency Index
RJIGT	Legal Regime of Territorial Management Instruments
UGI	Urban Green Infrastructure

SYMBOLS

A	Matrix.
λ	Maximum eigenvalue of the matrix A
Σ	Summation
n	Number of elements

1

INTRODUCTION

1.1 Background and motivation

Throughout human history, the urbanization process has been associated with important economic and social transformations, which have contributed to improved geographic mobility, lower birth rates, and increased average life expectancy (United Nations Department of Economic and Social Affairs, 2021). One of those transformations was the Industrial Revolution - characterized by the transition from manual production techniques to mechanized practices - which led to economic development in European countries and, with it, the growth of large urban agglomerations. This phenomenon allowed the increase in the quality of life of people, resulting in a progressive increase in population and, consequently, expansion of urban and suburban areas across the globe (Gallardo-Albarrán & de Jong, 2021; Rees & Wackernagei, 1996).

According to the United Nations (2019), more than 4 billion people lived in urban areas in 2018, and an additional 2.5 billion people are predicted to move into urban areas by 2050. Because they offer a variety of advantages to maintain and improve human livelihoods, such as health, education, and employment, among others, urban areas are quite appealing to the general population (Tan & Abdul Hamid, 2014; Wu, 2010). However, this phenomenon puts cities and their surrounding areas under several social, economic, and environmental pressures, such as poverty, unemployment, crime, political crises, pollution, and the depletion of natural resources (Al-Kofahi *et al.*, 2018; Grimm, Faeth, *et al.*, 2008; Kalnay & Cai, 2003; Tan & Abdul Hamid, 2014). Additionally, the ongoing urban development and the resulting transformation of virgin landscapes into urban agglomerations pose serious threats to biodiversity and associated ecosystem services, which have an impact on human welfare (Haase *et al.*, 2014;

Klimanova *et al.*, 2018). These challenges are aggravated by the lack of urban green spaces in urban areas, due to the threats imposed by densification (De Montis *et al.*, 2022; Haaland & van den Bosch, 2015).

Many ecologically based planning strategies relying on ecosystem services have been created and put into practice globally to help mitigate some of these difficulties and improve both environmental quality and human well-being (Fedele *et al.*, 2018; Ignatieva *et al.*, 2011; Lafortezza *et al.*, 2018; Raymond *et al.*, 2017). Considering that urban dwellers depend on gardens, forests, parks, and other green spaces for both their recreational activities and the provision of other ecological services, Kabisch (2015) claims that the integration of green spaces in urban centres has increasingly taken on a fundamental role in planning processes. This integration normally occurs through the development of a green infrastructure which is assumed as "a strategically planned and interconnected network of natural and semi-natural areas with other environmental features that are designed and managed to deliver a wide range of benefits to people and wildlife (ecosystem services)" (Benedict & McMahon, 2012; European Comission, 2013; Pauleit *et al.*, 2018). These areas may include a variety of green and blue spaces, such as parks, open spaces, playing fields, pocket spaces, lakes, river streams, small incidental green spaces, and neighbourhood gardens, that are linked by tree-lined streets and waterways around and between urban areas (Girma *et al.*, 2019; Jones & Somper, 2014).

As a strategic spatial planning instrument, green infrastructure can respond to several societal changes and challenges as a way of providing social, environmental, and economical benefits (Bolund & Hunhammar, 1999; Kabisch, 2015; Wilker *et al.*, 2016). The environmental advantages include the reduction of flooding threats, improved thermal performance of buildings, control of street temperature, increased carbon storage, and maintenance of freshwater quality and supply due to the mitigation and adaptation of climate change (Demuzere *et al.*, 2014; Jones & Somper, 2014; Kabisch, 2015). Additionally, because green spaces serve as habitats for a variety of species, they help to preserve wildlife and increase biodiversity (Kabisch, 2015). Social advantages stem from exposing people to urban green spaces and are frequently connected to leisure and cultural pursuits including sports, relaxation, and interpersonal connections (Bolund & Hunhammar, 1999; Kabisch, 2015). These benefits improve people's health and well-being (Basnou, 2015; Kabisch, 2015; Tzoulas *et al.*, 2007), increase connectivity between urban and rural areas, and foster a feeling of local identity, social inclusion, and community (Ferreira, Monteiro, *et al.*, 2021; Wright, 2011). Property value increases typically have positive economic effects as they aid in luring and keeping skilled people, entrepreneurs, and high-value enterprises (Forest Research, 2010; Wright, 2011). Decreased healthcare costs and a rise in tourism are two other economic advantages (Forest Research, 2010; Tzoulas *et al.*, 2007). These advantages highlight the potential of green infrastructure to help achieve sustainable growth and a fair standard of living (Wang & Banzhaf, 2018).

Green infrastructure planning has gained a lot of traction around the world (Benedict & McMahon, 2012), and, as an example of this, several projects, such the GREEN SURGE, and GRETA, have been developed in Europe (Carrao *et al.*, 2018; Hansen *et al.*, 2017). However, academics, politicians, and urban planners still do not agree on the optimal concept of green infrastructure (Gradinaru & Hersperger, 2019). Because of this, green infrastructure planning strategies have differed significantly from nation to nation and even from municipality to municipality, which leads to a lack of standard procedures and jeopardizes the instrument's capacity to be replicated and compared (Benton-Short *et al.*, 2017). In addition, ecosystem services are continually undervalued in urban contexts and are not taken into account in current decision-making processes, despite the fact that they are crucial for the development of more resilient communities (Tzoulas *et al.*, 2007) and are increasingly seen as a crucial link between society and the environment (Wu, 2013). As a result, this leads to rigid, out-of-date planning tools that are unable to adapt to current global issues (Cortinovis & Geneletti, 2019).

Several authors have tried to develop different approaches to integrate green infrastructure in decision-making processes concerning spatial planning (Benton-Short *et al.*, 2017; Gradinaru & Hersperger, 2019; Llausàs & Roe, 2012; I. Mell *et al.*, 2017b). As a result, several green infrastructure planning principles have been proposed in the literature. At a conceptual level, green infrastructure planning principles, which are predominantly based on geography, ecology, and landscape ecology (Roe & Mell, 2013), try to incorporate both ecological, social, and economic concerns into the decision-making and implementation process of green areas, in order to support the design and planning of a functional green infrastructure. However, most studies on GI planning focus on promoting its benefits rather than critically examining how to link theoretical considerations with practical planning implications (De Montis *et al.*, 2022; Gradinaru & Hersperger, 2019; H. W. Kim & Tran, 2018). Additionally, the majority of studies in the literature solely consider the urban aspect of planning for green infrastructure and do not take into account the difficulties rural areas experience in addressing these issues, nor do they consider input from practitioners and urban planners regarding this matter (Girma *et al.*, 2018; Gradinaru & Hersperger, 2019). Therefore, it remains unclear how current spatial planning address the green infrastructure principles.

Based on the identified gaps in the literature, this research aims to investigate to what extent GI planning principles are currently included in spatial planning on a local level and includes an assessment of priorities of practitioners and urban planners on green infrastructure planning principles, as well as an assessment on local spatial plans. This study had as a case study the municipalities of Lisbon Metropolitan Area.

1.2 Objective and Research Questions

Urban and rural areas are constantly changing and, due to the various challenges they face, it is increasingly important to make them more resilient and competitive through sustainable land management. However, although at a global level planning and management strategies have changed in favour of urban sustainability, the integration of green infrastructure planning principles in the decision-making processes of territorial management is still not a reality. Besides that, traditional planning instruments, in addition to being static, difficult to understand, and not very innovative, present difficulties in responding efficiently to the problems of contemporary society, characterized by sudden changes in land use and scarcity of resources.

Considering the existing research gaps, the main objective of this study is to understand which green infrastructure planning principles should be considered in spatial planning and how practitioners and policymakers are integrating them into policies and environmental planning. So, to answer the objective of this research and to target the identified research gaps, the following three research questions are answered:

1. What green infrastructure planning principles should be considered in spatial planning?
2. What are the views and priorities of practitioners and urban planners on green infrastructure planning principles?
3. How are these principles integrated into spatial planning?

1.3 Methodological approach

To achieve the aim and answer the research questions, this research took a transdisciplinary approach. Examining how municipalities incorporate green infrastructure planning principles into spatial planning is a complex task that involves multiple variables and processes. Spatial planning, although an important instrument of the economic and social policy of a country because it ensures a balanced and sustained occupancy of the territory (Bailoa & Cravo, 2012), is, in some parts of the world, outdated. In addition to being static, difficult to understand, and unattractive, traditional planning instruments present difficulties in responding efficiently to the problems of contemporary society, characterized by the scarcity of resources and permanent uncertainty that needs to be addressed quickly and flexibly. Therefore, because each discipline only offers partial descriptions of reality, the integration of green infrastructure planning principles into spatial planning cannot be adequately described by individual disciplines alone (Baerwald, 2010).

Several academics characterize a transdisciplinary approach as a method for overcoming the disciplinary silos of knowledge production by constructing new information with original insights and perspectives to meet challenging real-world issues (Baerwald, 2010; Krohn, 2017). In fact, disciplines within sustainability research are inherently transdisciplinary as, for instance, the complexity of the concept of green infrastructure presents a variety of practical issues that call for knowledge from several domains to address and answer (Chatzimentor *et al.*, 2020; Matsler *et al.*, 2021), such as geography, ecology, urban planning, social sciences, and economics, among others. The integration of green infrastructure planning principles into spatial planning is the subject of this thesis, and the literature on green infrastructure is essential to it because it places the main research topic in the context of the broader field of green infrastructure research and serves to highlight the need for additional study as well as the thesis's goal.

Moreover, if transdisciplinary research is structured around real-world issues like green infrastructure planning, it should be investigated using real-world examples and be comprehended in its entirety, taking into account all of its current characteristics and contextual circumstances (Krohn, 2017). As a result, this thesis took a case study approach. Case studies are a useful method for scientific inquiry because they allow for in-depth analysis of contemporary, complex issues in a setting where it is occurring (Eisenhardt, 1989). Case studies gather a lot of details about the unique and comprehensive qualities of individuals, behaviours, social contexts, organizations, or events so that the researcher may comprehend how they function and how they behave (Berg & Lune, 2017). Consequently, the case study approach is particularly appropriate for this thesis as a methodological design approach. This research chooses the Lisbon Metropolitan Area as a case study due to its territorial complexity, diversity of landscape features (including rural and urban), and lack of strong and focused spatial planning regulations in the region. Further information on the case study is provided in the Methods section in Chapters 3 and 4.

Finally, a case study approach often includes a variety of data collection techniques, including observation, interviews, content analysis, and literature studies (Eisenhardt, 1989). A research methodology is known as "mixed methods" involves gathering and analysing both quantitative and qualitative data in order to provide a more thorough knowledge of a studied phenomenon while minimizing the flaws and biases of both approaches (Venkatesh *et al.*, 2013). The use of mixed methods was deemed to be a good strategy for responding to various research problems that may call for the use of various methodologies (Venkatesh *et al.*, 2013). Considering the diversity of research questions that needed to be addressed, as well as the intricate and multi-layered nature of the topic at hand, this thesis adopted a mixed methods approach. An overview of the research design and methodological structure is provided in Figure 1.1, showing how the different methods relate to the research questions, objectives/tasks, and chapters of this thesis. In the following subsections, more information on the data collection and analysis methods employed in this study will be briefly offered.

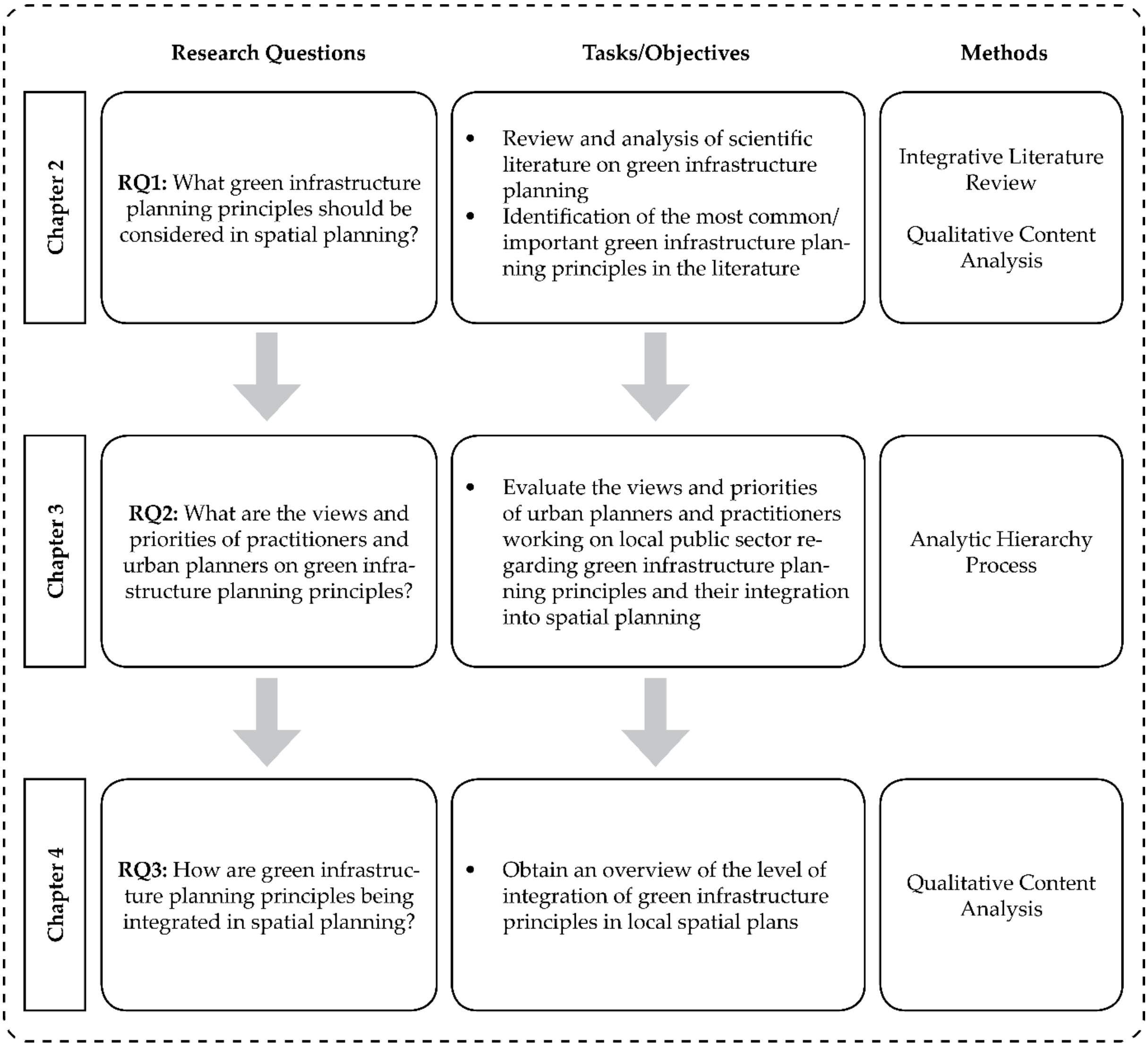

Figure 1.1 - Overview of the research design used in this thesis, including the research questions (RQ), objectives and tasks, and methods used for the main chapters.

1.3.1 Literature reviews

This thesis used literature reviews as a way to introduce and analyse the key topics under consideration, as a preface to conducting the research, and to place the contribution of this thesis within the context of the larger landscape of prior research (Torraco, 2005). Peer-reviewed literature was retrieved from several sources and several databases, such as Scopus and Web of Science.

In the introductory sections of each chapter, a narrative literature review was performed, however, in chapter 2, an integrative literature review was conducted in order to address the first research question (What green infrastructure planning principles should be considered in spatial planning?). An integrative literature review of a growing topic like this provides the opportunity for a holistic conceptualization and synthesis of the literature to date; that is, an initial or preliminary conceptualization of the topic (Torraco, 2005). The choice to conduct an integrative literature review to select the principles to take into consideration in green infrastructure planning is appropriate, as it allows the selection of relevant studies through a broad sampling of diverse sources, including theoretical and empirical sources, or experimental or non-experimental studies. More information on the specific steps of the integrative literature review can be found in the Methods section of Chapter 2.

1.3.2 Analytic Hierarchy Process

An Analytic Hierarchy Process was used as a data collection method in Chapter 3, in order to address the second research question (What are the views and priorities of practitioners and urban planners on green infrastructure planning principles?). The AHP method is a multi-criteria approach built on mathematics and psychology (R. W. Saaty, 1987; T. L. Saaty, 2008). It is used to organize and analyse complex issues and unforeseen circumstances that call for a variety of evaluation criteria and comprehensions (Shin *et al.*, 2020), such as the incorporation of green infrastructure planning principles into spatial planning. The AHP method depends on the establishment of priorities through weights and ranks on a pairwise comparison to simplify criteria by outlining the overarching objective of the problem and organizing the criteria into a hierarchical structure (L. Li *et al.*, 2020; Park *et al.*, 2020; Shin *et al.*, 2020; Xu *et al.*, 2019; Young *et al.*, 2010). The AHP is capable of handling stakeholder involvement and the integration of qualitative judgments in a range of domains and applications, including operations, economics, and planning (Axelsson *et al.*, 2021), among others. It also considers the many-layered dimensions of decision-making processes (Shin *et al.*, 2020).

Both objective and subjective factors play a significant role during the decision-making process, and the AHP offers a simple, practical decision-making procedure that aids the decision maker in precisely making conclusions and judgments regarding a particular topic (OğuztiMur, no date). For that reason, this was the method chosen for this research. The AHP process involves identifying the overall goal, choosing evaluation criteria, selecting stakeholders followed by their criteria evaluation, validating the results, and establishing weighted values and ranks for the criteria considered in the process. More information on the specific steps of the AHP can be found in the Methods section of Chapter 3.

1.3.3 Qualitative content analysis

A qualitative content analysis (QCA) is a research method used for describing and interpreting textual data through a systematic coding procedure (Assarroudi *et al.*, 2018). Qualitative content analysis research focuses on the properties of language as communication, with a focus on the text's content or context meaning. Text data can come from narrative responses, open-ended survey questions, interviews, focus groups, observations, or print sources like articles, books, or manuals (Assarroudi *et al.*, 2018; Elo & Kyngäs, 2008; Hsieh & Shannon, 2005). The result of data analysis is the identification of categories, themes, and patterns.

A qualitative content analysis was performed in both chapters 2 and 4. In chapter 2 the main objective of the content analysis was to build up several green infrastructure planning principles based on theoretical studies, evidence, and implemented projects. In chapter 4, this method was used to systematically evaluate the content of local master plans, in order to address research question 3 (how are these principles being integrated into spatial planning?). More information on qualitative content analysis can be found in the Methods section of Chapter 4.

1.3.4 Reliability and Validity of the results

High-quality research work must have a sufficient level of reliability and validity to be assessed as scientifically sound work (Bryman, 2016). Because the methodology used in this thesis is well-documented and transparent, it offers excellent reliability. The protocols used and survey data collection procedures, as well as the lists of the documents utilized in the analysis were fully specified. In addition, the research design, the analysis of the results, and the knowledge contribution of this work, which was published in international journals and is currently being revised in part, have all been strengthened as a result of the peer-reviewing processes that the work underwent.

Concerns regarding the reliability of the findings are referred to as internal and external validity (Bryman, 2016). While external validity is concerned with the generalizability of the findings, internal validity relates to the relationship between the researcher's observations and the interpretation of the results, and it is focused on the researcher's investigation. In addition to submitting the research to peer-review in publication processes, internal validity was further guaranteed because the work was exposed to other peer-review processes throughout its development. The researcher took part in several seminars, team projects, workshops, and gatherings that allowed for peer-review activities with other scholars and colleagues.

1.4 Structure of the dissertation

This dissertation consists of five chapters. This first chapter introduces the subject matter and presents the theoretical background which underlies this research and the methodological approach, as well as its research questions and the main research goal. Thereafter, chapters 2-4 present the core research of this thesis, each of them representing an individual article, published (chapters 2 and 3) or submitted (chapter 4) in international peer-reviewed journals. The articles are sequential, yet they can be read as stand-alone contributions. In addition, some chapters were presented at international academic conferences and the information regarding each chapter is presented in a footnote of the respective title page. The fifth chapter is the concluding chapter.

As the first article of this thesis, chapter 2 introduces the topic with a theoretical study conducting an integrative literature review of green infrastructure planning principles. This chapter also develops and presents a conceptual framework of green infrastructure, highlighting the historical evolution of its concept and the geographical differences in terms of Its implementation approaches. As a result of this literature review, the most common eight green infrastructure planning principles were found: connectivity, multifunctionality, applicability, integration, diversity, multiscale, governance, and continuity. This chapter was published as an open-access feature paper in the Land journal in December 2020.

Chapter 3 comprises an evaluation on the priorities of urban planners and practitioners working in the local public sector regarding green infrastructure planning principles and their integration into spatial planning. Through an Analytic Hierarchy Process methodology, practitioners working in the 17 municipalities of Lisbon Metropolitan Area, were asked to prioritize the eight green infrastructure planning principles previously identified, to understand if there are any differences in the views of these professionals depending on the characteristics of the territory they worked on i.e., urban or rural municipalities. This article was published as an open-access article in the Sustainability journal in April 2022.

Chapter 4 investigates to what extent GI planning principles are currently included in spatial plans and uses a multi-criteria framework to evaluate spatial plans through a qualitative content analysis that assigns numeric scores to criteria that reflect the content and quality of the plans, regarding the green infrastructure planning principles considered. This chapter was submitted to an international scientific journal and is under review.

The final part of this dissertation, Chapter 5, provides a summary of all the findings from the earlier chapters while also discussing the research findings and the research's contributions. Future research and practice recommendations are also given.

1.5 Researcher's Contributions

Renato Monteiro conducted this research under the supervision of Professor José Carlos Ferreira as the main supervisor and Professor Maria Paula Antunes as co-supervisor. Renato Monteiro was the leading author of all chapters in this thesis. He conceptualized the ideas, developed the methodology, conducted the investigation, executed the analytic hierarchy process, drove the formal analyses, curated the data, and wrote the papers. José Carlos Ferreira and Maria Paula Antunes supervised, provided feedback, and reviewed, and edited the research. All authors have read and agreed to the published version of the chapters they were involved in.

The outcomes of this research were disseminated in more than three international research conferences, two international peer-reviewed academic articles, and many academic and non-academic events.

2

Green Infrastructure Planning Principles: An Integrated Literature Review[1]

Abstract

Green infrastructure is a strategically planned network of natural and semi-natural areas, including green and blue spaces and other ecosystems, designed, and managed to deliver a wide range of ecosystem services at various scales. Apart from the ecological functions, green infrastructure, as a planning tool, contributes to social and economic benefits, leading to the achievement of sustainable, resilient, inclusive, and competitive urban areas. Despite recent developments, there is still no consensus among researchers and practitioners regarding the concept of green infrastructure as well as its implementation approaches, which makes it often difficult for urban planners and other professionals in the field to develop a robust green infrastructure in some parts of the world. To address this issue, an integrative literature review was conducted to identify which green infrastructure planning principles should be acknowledged in spatial planning practices to promote sustainability and resilience. As a result of this literature review, the most common eight green infrastructure planning principles were selected – connectivity, multifunctionality, applicability, integration, diversity, multiscale, governance, and continuity. These principles intend to promote and simplify the development and use of green infrastructure by different academic and implementation organizations and provide a more defined model for sustainable landscape management in order to help practitioners and decision-makers during the conceptualization and planning of green infrastructure.

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Keywords: green infrastructure; spatial planning; principles; integrative literature review

2.1 Introduction

In 2018, more than 4 billion people lived in urban areas, and, according to the United Nations (United Nations, 2019a), the urban population will increase by 2.5 billion by 2050. This, however, creates enormous social, economic, and environmental pressures in cities (Grimm, Foster, *et al.*, 2008; Kalnay & Cai, 2003), like poverty, unemployment, criminality increase, political crisis, biodiversity loss, pollution, and natural resources depletion. Urban areas also contribute significantly to climate change, since they are responsible for greenhouse gas emissions (*AR5 Climate Change 2013*, no date), as well as other man-made activities, such as agriculture. To address these challenges, several nature-based solutions and ecosystem services strategies have been developed across the world, that simultaneously contribute to human well-being and environmental protection (Fedele *et al.*, 2018; Ignatieva *et al.*, 2011; Lafortezza *et al.*, 2018; Monteiro & Ferreira, 2020; Raymond *et al.*, 2017), such as, for example, green infrastructure implementation.

Green infrastructure assumes an important role regarding the challenges previously presented since it comprises a network of green and blue spaces, designed and managed to deliver different kinds of ecosystem services (Benedict & McMahon, 2001; Demuzere *et al.*, 2014; Gómez-Baggethun & Barton, 2013; Ignatieva *et al.*, 2011). These ecosystem services—particularly important when it comes to green infrastructure planning in urban areas—are described as direct or indirect benefits humans obtain from ecosystem functions (Costanza *et al.*, 1997; *Millennium Ecosystem Assessment*, no date; TEEB, 2010), and can be grouped in four categories, namely provision, regulation, support and cultural (Bolund & Hunhammar, 1999; Demuzere *et al.*, 2014; Salmond *et al.*, 2016). However, to overcome the different existing ecosystem services classifications, the Common International Classification of Ecosystem Services (CICES) was proposed in 2009 and revised in 2013 (Haines-Young & Potschin, no date). Similar to other classifications, this document groups ecosystem services in the categories previously presented—provision, regulation, and cultural—but the "support" category is not considered. This does not mean the supporting services are less important, but such narrowing down of the assessment scope is essential to avoid double accounting when valuing the ecosystem services (Ruskule *et al.*, 2018). In this sense, provisioning services are products, goods, and services obtained from ecosystems that provide direct utilitarian value to people, that include food, water, and raw materials. Regulating services are the ones related to the maintenance of valuable ecological processes, which include climate regulation, diseases, and flood control or even erosion prevention. Cultural services are all the non-material outputs that affect the physical and mental state of human beings, like recreation activities, spiritual experiences, or aesthetic appreciation. Supporting services underpin all the other services and include habitat for species, soil maintenance, or nutrient cycles, for example.

Green infrastructure planning has been increasing worldwide since the end of the last century (Davies & Lafortezza, 2017; I. C. Mell, 2017). However, there is still no consensus regarding the concept, planning principles, and/or implementation measures of green infrastructure among researchers, political actors, and practitioners. Although several studies have pointed out some green infrastructure planning principles to follow in planning procedures (Benton-Short *et al.*, 2017; Llausàs & Roe, 2012; I. Mell *et al.*, 2017b), some of those principles are too theoretical and do not entirely capture the execution and implementation of the green infrastructure in spatial planning. In addition, due to the rapid transformation of planning methods and the new challenges that are changing the way decision-making processes are executed, such as population increase, environmental degradation, and socio-economic difficulties, new principles must be considered in the green infrastructure planning, in order to meet today's reality and future prospects regarding environmental and urban planning.

For these reasons, the purpose of this research is to identify green infrastructure planning principles through an integrative literature review, in order to identify the principles that green infrastructure must consider promoting sustainability and resilience at the local scale. To achieve this, a brief overview of green infrastructure is presented, as well as its concept evolution, then the methods section highlights the review and selection process of the green infrastructure principles. The paper continues with a description and analysis of the literature sample and concludes with the final remarks, research gaps, and future research directions.

2.2 Green Infrastructure: Earlier Concepts

Green Infrastructure is a term that has received great attention in land conservation, landscape design, and land development since the end of the last century (Benedict & McMahon, 2012). Nevertheless, this concept can have different definitions, depending on which context is used (Benedict & McMahon, 2012; Lennon, 2015; Marino & Lapintie, 2018; Wright, 2011) and by whom the concept is used. Even though its historical roots go back to the 19th and 20th centuries (Searns, 1995; Zube, 1995), the "green infrastructure" concept is widely considered new (Ahern, 1995).

The green infrastructure idea is based on much earlier concepts like parkways, green belts, or garden cities (Ignatieva *et al.*, 2011; I. Mell *et al.*, 2017b; Searns, 1995; Walmsley, 2006). However, it was with the appearance of the "greenway movement" in the 1990s decade that this issue started to gain special attention, not only among planners, urbanists, and landscape architects (Walmsley, 1995), but also among environmental groups, ecologists (Fabos, 1995), and politicians (Erickson, 2004; Fabos, 1995; Jongman & Pungetti, 2004).

The word "greenways" has its origin in North America and acquired great attention in the late 1980s and 1990s with the release of remarkable and important books like Greenways for America by Charles Little (Ahern, 2004; Ryder, 1995; Searns, 1995; Walmsley, 2006) in 1990, Ecology of Greenways by Daniel Smith Paul Hellmund or A Guide to Planning, Design, and Development by Charles Flink and Robert Searns, both in 1993 (Fabos, 1995). Furthermore, numerous greenway-type projects were implemented (Bueno *et al.*, 1995; Searns, 1995) and several papers were published in the same period, which contributed to the greenway movement in the United States. With the publication of Greenways: The Beginning of an International Movement in 1995, Fabos & Ahern, (1995) present a large range of international literature and research, as well as case studies about this issue, contributing to the beginning of an unprecedented international movement at the time. However, it was probably the statement of the President's Commission on Americans Outdoors in 1987 that started that movement (Fabos & Ahern, 1995).

The President's Commission (Outdoors (U.S.), 1987) was responsible for stimulating the interest in this topic since it recommended a network of greenways in order to bring people together and provide outdoor recreation opportunities and open spaces close to their homes (Bueno *et al.*, 1995; Fabos & Ahern, 1995; Lindsey *et al.*, 2001; Walmsley, 1995; Zube, 1995). Nevertheless, Little (Little, 1990) might have been the first person to present a clear definition of greenways in his book, in 1990. Here, greenways were "…described broadly as linear parks, open spaces, and protected areas in cities, suburbs, or the country-side…". Fabos, (1995), however, went further and addressed greenways as "[nature] corridors of various widths, linked together in a network in much the same way as our networks of highways and railroads have been linked" and categorized them into three groups: ecological greenways, recreational greenways, and historical heritage and cultural corridors. For him, greenways were not simply open spaces and corridors with environmentally significant natural systems that were meant to be protected, but also areas and places that could have recreational, educational, and scenic use. Ahern, (1995) even added that "greenways are networks of land containing linear elements that are planned, designed and managed for multiple purposes, (...) including the ones compatible with the concept of sustainable land use".

Greenways were described as planning tools with the potential to serve both human and nature purposes (Searns, 1995). But what were exactly the arguments that supported this greenway movement and why was it so important at that time? According to Searns, (1995), in the second half of the 20th century, the increase in human population and development of urban settlements have contributed to environmental degradation and ecosystem alteration. Besides all the environmental problems originating due to the rapid urbanization and economic growth, negative externalities such as poverty, congestion, unemployment, and crime (Rukumnuaykit, 2015; *State of World Population 2007 | UNFPA - United Nations Population Fund*, no date) started to arise as well. As a result, greenways started to be seen as an adaptative response to the physical and psychological pressures of urbanization, as they pursued multiple environmental and ecological purposes (Bueno *et al.*, 1995; Linehan *et al.*, 1995; Searns, 1995), along with cultural and social ones (Bischoff, 1995).

Although the greenway movement was starting to spread around the globe, due to different geographical, political, and scientific systems (Ahern, 2004), different definitions of this concept have arisen. In Europe, for example, the term ecological networks was prevalent (Ahern, 2004; Jongman & Pungetti, 2004). Ecological networks were defined by Jongman & Pungetti, (2004) as "systems of nature reserves and their interconnections that make a fragmented natural system coherent, so as to support more biological diversity than in its non-connected form". Opdam *et al.*, (2006) complemented this definition referring to ecological networks as "(...) a set of ecosystems of one type, linked into a spatially coherent system through flows of organisms, and interacting with the landscape matrix in which it is embedded. Hence, the ecological (or ecosystem) network is a multi-species concept, linking ecosystems (...)". Both these definitions reinforce the perception that ecological networks have specific functions and objectives related to the protection and enhancement of biodiversity, as well as wildlife conservation and respective habitats (Council of Europe, 1996; Verboom & Pouwels, 2004). Additionally, ecological networks were seen also as planning tools that contributed to improving urban areas' aesthetics, as well as cultural identity, to create more sustainable and greener communities (Ignatieva *et al.*, 2011).

In fact, according to Ignatieva *et al.*, (2011) and Walmsley, (2006), the greenway movement contributed widely to the development of ecological networks in Europe and helped to provide an inclusive urban green infrastructure, along with greenbelts and green wedges.

However, it was not until 2001 that the concept of green infrastructure was introduced by Benedict & McMahon (Benedict & McMahon, 2001) as an "interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations". One year later, Sandström *et al.*, (2006) reinforced this idea, emphasizing the multifunctional role of the green infrastructure and its importance for urban planning, stating even this planning instrument was as important as any other "technological infrastructure" for people's life quality. The green infrastructure should, therefore, be seen as essential in every urban area, as opposed to something nice to have (Walmsley, 2006), and must be planned, designed, and financed like other "regular" infrastructures.

The green infrastructure concept has, since then, gained attractiveness among researchers and decision-makers, and its definition has evolved significantly over the years, with hundreds of papers being published with multiple approaches (Lafortezza *et al.*, 2013). As a result, in 2013, the European Commission presented its definition of green infrastructure in order to enhance it and to become an integral part of spatial planning and territorial development in all its member states (European Commission, 2013). Green infrastructure is thus referred to as "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. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings". This definition captures the role that green and blue spaces take regarding ecosystem services provision at different spatial scales (Gómez-Baggethun & Barton, 2013). However, according to the United States Environmental Protection Agency (US EPA, 2015a), "green infrastructure is a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits (…) designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits". This definition, contrary to what happens in Europe, highlights the focus of many American planning strategies on stormwater management and water flows control (Dunn, 2010; Meerow & Newell, 2017; I. Mell, 2011) and influences a majority of planning practices in America. However, even though green infrastructure started as a tool to address urban stormwater, today it is seen as an instrument that provides other environmental benefits, such as climate regulation. According to Salmond *et al.*, (2016) that has been a number of initiatives to promote the 'greening' of cities through urban reforestation and protection programs to increase thermal comfort—such as the New York City

‘Million Trees’ program and other initiatives that can be found in other North American cities, as stated by EPA (US EPA, 2015b).

Despite the ecological functions being often the main focus of green infrastructure planning, social benefits are also very important criteria in the planning interventions. Not only do green spaces allow numerous recreational activities—which have a positive impact on people’s health (Tzoulas *et al.*, 2007) and well-being—but they also contribute to increasing the connectivity between urban and rural areas, and, therefore, local distinctiveness, social inclusion, and sense of community (Wright, 2011). Apart from that, due to a decrease in health expenses, the capacity of attracting skilled workers and tourists, and the increase in property value (Matthews *et al.*, 2015; Wright, 2011), green infrastructure can promote economic growth in urban areas (Jones & Somper, 2014; Tzoulas *et al.*, 2007). However, to fulfil these multifunctional purposes, both the quantity and quality of urban and peri-urban green spaces must be addressed in planning processes (Tzoulas *et al.*, 2007) and the development of green infrastructure planning principles is fundamental. Green infrastructure principles are, in fact, underlying grounds that help guide and facilitate the planning procedures of green infrastructure, in order to ensure that it contributes to a network of quality and functional green spaces, capable of meeting the needs of a determined urban area, contributing in the best way to the sustainability of a given region or local area, depending on its scale.

Even though the green infrastructure, and all its elements, compensate for many flaws in the traditional planning models, this instrument can only be identified as a “good practice” for achieving urban sustainability when it is combined with traditional grey infrastructure (F. Li *et al.*, 2017). How well other planning instruments are designed and put into practice and the political agenda is developed directly influences the conservation of green spaces and the functionality of the green infrastructure. Understanding the mechanisms between urban design and human actions on ecological functions is significant to achieve sustainability, at a time when effective urban planning is needed. By ensuring green infrastructure planning follows the planning principles that guarantee the right functioning of green spaces, it is possible to meet the growing needs of the population for recreational spaces and natural environments, as well as increasing resilience in urban areas.

2.3 Methods

There are several methods used for literature review processes that are helpful to address new or already known issues, and each provides different insights for knowledge creation, text development, and individuation (Pickering *et al.*, 2015). As a growing research topic, green infrastructure planning principles is an issue that would highly benefit from a synthesis of the literature, since there is still no consensus among researchers, practitioners, and political actors on what principles should be taken into consideration in green infrastructure planning (Gradinaru & Hersperger, 2019). To do so, this research focuses on an integrative literature review of green infrastructure planning principles. An integrative literature review of a growing topic like this provides the opportunity for a holistic conceptualization and synthesis of the literature to date; that is, an initial or preliminary conceptualization of the topic (Torraco, 2005). The choice to conduct an integrative literature review to select the principles to take into consideration in green infrastructure planning is appropriate, as it allows the selection of relevant studies through a broad sampling of diverse sources, including theoretical and empirical sources, or experimental or non-experimental studies (Klein *et al.*, 2020; Whittemore & Knafl, 2005).

The integrative literature review conducted in this research was structured using a combination of several procedures inspired by Klein *et al.* and Pickering *et al.*, among other authors, (Klein *et al.*, 2020; Moher *et al.*, 2009; Pickering & Byrne, 2014; Suprayoga *et al.*, 2020; Teles da Mota & Pickering, 2020; Tranfield *et al.*, 2003), that assure the quality and effectiveness of the review. As presented in Figure 2.1, to define the sampling frame, the methodological approach relied on three main phases: planning of the research; screening and selection of the publications; and content analysis of the remaining documents.

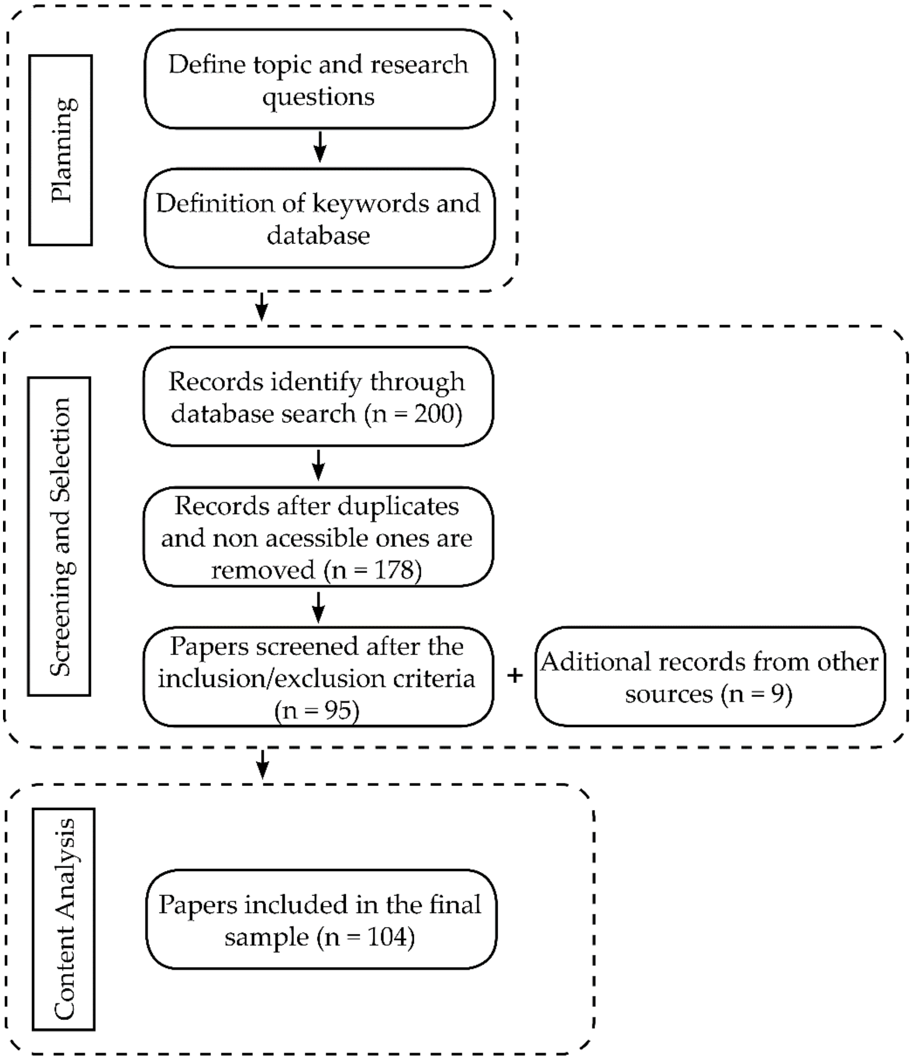

Figure 2.1 - Overview of the methodological approach adapted from Klein *et al.*, (2020)

The first phase consisted of two steps. The first one was to identify and define the research topic, to ensure that it is original and appropriate, as well as to identify what the questions are that should be addressed in the literature (Pickering & Byrne, 2014). Since the focus of the research question is what principles of green infrastructure planning must be considered to promote sustainability and resilience at the local scale, a combination of two sets of terms was selected to ensure a high level of relevance of the resulting documents. Firstly, the expression "green infrastructure planning" was included to make sure that the articles were consistent with the main topic, and then, the terms "principles", "urban", "local" and "practices" were added using the operator "and" in between them in the search expression to incorporate terms related to green infrastructure planning principles at local scale in urban areas. It is important to refer th*et al* these words were selected due to their correlation with the topic studied and the query was designed to search in all fields in the databases, which means the information was screened in all fields (including title, abstract, topic, authors, affiliations, etc.). It is important to state that no filter was applied for the year of the papers, so the sample extracted from the databases included all publication years.

Using Scopus and Web of Science databases, the search query returned a total of 200 documents (at the time this research was conducted), which were then run through a screening and selection process (phase II). This process consisted of the development of specific criteria to scrutinize the papers and, thus, select only the relevant ones (Klein *et al.*, 2020; Ledda *et al.*, 2020). The titles, abstracts, and the full text of the resulting sample were screened for relevance according to the criteria presented in Table 2.1: (1) conceptual and empirical studies on green infrastructure planning practices; (2) inclusion of explicit or implicit green infrastructure planning principles. Although all the criteria were chosen based on their relevance to the research topic, the specific reasons are as follows. First, the inclusion of both conceptual and empirical studies is important to understand not only the theoretical concepts around the topic of research but also the actual practices conducted worldwide, in order to understand the implementation developments regarding green infrastructure planning principles. Although there is a relation between ecosystem services and green infrastructure, all studies only focused on ecosystem services integration in spatial planning were excluded. Since the main focus of this integrative literature review is to understand the principles that should be considered in green infrastructure planning, the inclusion of green infrastructure planning principles in the full text of the papers is a valid and essential criterion. The principles could be either explicitly represented in the full text of the article, or implicitly (that is, when even not clearly expressed in the text, the authors approach the principles in a more subtle yet comprehensive way). In addition to the database results, to obtain a larger sample beyond peer-reviewed sources, a total of 9 publications were added to the initial sample, including peer review papers, as well as other non-academic studies, that were considered relevant for this research and did not appear in the sample obtained from the databases. These 9 additional papers were identified based on the authors' knowledge of various sources outside of the scope of the search query. Only documents written in English were considered in this analysis.

Table 2.1 - Inclusion and exclusion criteria used in the screening process

Criteria	Description
Conceptual and empirical studies on green infrastructure planning practices	The paper may focus on the theory of the topic or may include evidence from practical application
Inclusion of explicit or implicit green infra-structure planning principles	The paper contains explicit information re-garding green infrastructure planning prin-ciples or may briefly describe a green infra-structure planning principle without using the word "principle"

After the screening and selection of the final sample, the 104 documents were scrutinized through qualitative content analysis to summarize the content of the selected data (Mayring, 2000). Content analysis is a research method used to test theoretical issues to enhance understanding of the data, where it is possible to obtain a condensed number of concepts or categories describing a phenomenon, a theory, or a research topic (Elo & Kyngäs, 2008). For the purpose of this study, the main objective of the content analysis of the final sample of papers is to build up a number of green infrastructure planning principles based on theoretical studies, evidence, and implemented projects. So, during the analysis of the papers, the word "principle" was located in each document and, from there, the authors identified what other words or phrases appeared next to it, that were organized into categories (principles). As the research went further, more words were searched in the documents each time an item was reported that did not fit into the existing words that were being searched. Through a careful interpretation of the documents and all the resulting categories, the authors were, then, able to identify the most common green infrastructure planning principles in the literature.

2.4 Results and Discussion

From the 104 documents, it was possible to identify several principles that integrate both the ecological and social components into green infrastructure planning. Some studies only focused on one or two principles, whereas others went even further and were able to identify up to 23 green infrastructure planning principles. Still, as much as some of the concepts presented by these studies were well developed and consistent with other studies, some principles found in the literature were discarded, and only eight were selected. The reasons for the exclusion of those principles relied on two criteria, which are the number of papers mentioning the principles and the execution of the explanation of that principle. As for the first one, principles that were mentioned a few times were not selected and, on the other hand, the ones mentioned in several papers were selected. As for the second criteria, the exclusion reasons were: (1) some concepts presented in some papers did not entirely represent the idea of green infrastructure planning; (2) some of the principles were too vague and lacked clarity (for example "sustainability" or "advocate led policy formation" (I. C. Mell, 2014)); (3) some principles were too simplistic and the information provided was not sufficient to understand what that principle refers to, as for example "promote natural resources and open space" (H. W. Kim & Tran, 2018); (4) others were rather too complex to understand and did not align with the scope of the paper (e.g., "coordination" (Gradinaru & Hersperger, 2019)), which is to present a set of simple yet robust principles to help practitioners and decision makers during the development of green infrastructure; (5) and finally, other were excluded for the fact that were intrinsically considered in the green infrastructure planning, such as accessibility or evidence-based. These reasons conditioned the selection of green infrastructure planning principles, and only a total of eight principles were identified in this research, which includes the more traditional ones, addressed in the early stages of green infrastructure research (e.g., connectivity and multifunctionality), as well as new principles that arise from recent developments regarding green infrastructure planning. These principles intend to promote and simplify the development and use of green infrastructure by different academic and implementation organizations and provide a more defined model for sustainable landscape management. The principles identified in Table 2.2 are: connectivity; multifunctionality; multiscale; integration; diversity; applicability; governance; and continuity.

Table 2.2 - Green infrastructure planning principles identified in the integrated literature review

Principles	Interpretation	References
Connectivity	Connectivity is crucial to sustain species interactions and diversity as well as to maintain the values and services of natural systems. Small parks and urban forests are not large enough to sustain, by themselves, diverse fauna and flora, however connectivity within urban areas enables the migration of certain species, the dispersion of seeds, or even the repopulation of some patches in heterogeneous landscapes. Connectivity also serves as transit and recreation corridors for humans contributing to the system stability and several ecosystem services, and to connect different landscapes. In this way, connectivity aims to create a well-connected green space network that can serve both humans and other species.	(Ahern, 1995, 2013; Ahmed *et al.*, 2019; Artmann *et al.*, 2019; Benedict & McMahon, 2001; Benton-Short *et al.*, 2017; Bolliger & Silbernagel, 2020; Coutts, 2016; Davies & Lafortezza, 2017; Do *et al.*, 2018; Ferrari *et al.*, 2019; Girma *et al.*, 2018; Gradinaru & Hersperger, 2019; Hansen *et al.*, 2017, 2019; Hislop *et al.*, 2019; Hrdalo *et al.*, 2015; Iojă *et al.*, 2018; Jerome *et al.*, 2019; D. Kim & Song, 2019; M. Kim *et al.*, 2018; Lennon *et al.*, 2016, 2017; Lennon & Scott, 2014; Llausàs & Roe, 2012; Lynch, 2016; Mejía *et al.*, 2015; I. Mell, 2015; I. C. Mell, 2014; I. c. (1 Mell 2), 2018; Papageorgiou & Gemenetzi, 2018; Pauleit *et al.*, 2018; Perini & Sabbion, 2016; E. Rall *et al.*, 2019; Roe & Mell, 2013; Rusche *et al.*, 2019; Schiappacasse & Müller, 2015; Selman, 2010; Snäll *et al.*, 2016; Söderman & Saarela, 2010; Szulczewska *et al.*, 2017; Tzoulas *et al.*, 2007; Wang & Banzhaf, 2018; Wirth *et al.*, 2018; Wright, 2011)

Multifunctionality	Multifunctionality assumes significant importance because it directly connects green infrastructure with a wide number of ecosystem services, namely provision, regulation, support, and cultural. A multifunctional green infrastructure is capable to provide multiple social, ecological, and economic functions and possesses a much higher resilience when compared with similar instruments that do not encompass this principle. Multifunctionality not only promotes multiple functions and increases synergies within green spaces, but also increases the effectiveness of these spaces, spatially in urban areas where space is limited and scarce.	(Ahern, 1995, 2013; Ahmed *et al.*, 2019; Anderson *et al.*, 2019; Artmann *et al.*, 2019; Bartesaghi Koc *et al.*, 2017; Beery, 2019; Brears, 2018; Courtenay & Lookingbill, 2014; Coutts, 2016; Davies & Lafortezza, 2017; Demuzere *et al.*, 2014; Dennis & James, 2018; Dorst *et al.*, 2019; Elbakidze *et al.*, 2017; Everett *et al.*, 2015; Gradinaru & Hersperger, 2019; Ibrahim *et al.*, 2020; Jayasooriya *et al.*, 2020; Lähde *et al.*, 2019; Lennon *et al.*, 2014, 2017; Llausàs & Roe, 2012; Madureira & Andresen, 2014; Mejía *et al.*, 2015; I. Mell, 2015; I. C. Mell, 2014; Molla *et al.*, 2019; Papageorgiou & Gemenetzi, 2018; Pauleit *et al.*, 2018; Payne & Barker, 2015; Perini & Sabbion, 2016; E. Rall *et al.*, 2019; Roe & Mell, 2013; Rolf *et al.*, 2019; Schiappacasse & Müller, 2015; Scott *et al.*, 2013; Selman, 2010; Söderman & Saarela, 2010; Szulczewska *et al.*, 2017; Tzoulas *et al.*, 2007; Wang & Banzhaf, 2018; Wirth *et al.*, 2018; Wright, 2011; Xiu *et al.*, 2016; Zhang *et al.*, 2020; Zwierzchowska *et al.*, 2019)

Multiscale	Due to its flexibility and adaptability, green infrastructure can be planned from a building perspective (e.g., green roofs), to a more regional and integrated perspective, which includes landscape interactions and larger natural areas. In this sense, green infrastructure planning should take into account all different scales, so that the interactions between and in these spaces can be enhanced.	(Ahern, 1995; Ahmed *et al.*, 2019; Anderson *et al.*, 2019; Artmann, 2016; Artmann *et al.*, 2019; Benedict & McMahon, 2001; Benton-Short *et al.*, 2017; Coutts, 2016; Davies & Lafortezza, 2017; Demuzere *et al.*, 2014; Do *et al.*, 2018; Dover, 2015; Ferrari *et al.*, 2019; Gill *et al.*, 2015; Gradinaru & Hersperger, 2019; Hislop *et al.*, 2019; Ignatieva *et al.*, 2011; Jayasooriya *et al.*, 2020; Jerome *et al.*, 2019; Lennon & Scott, 2014; Llausàs & Roe, 2012; Lovell & Taylor, 2013; Mejía *et al.*, 2015; I. Mell, 2015; I. Mell *et al.*, 2017b; I. Mell & Clement, 2019; Payne & Barker, 2015; Perini & Sabbion, 2016; E. Rall *et al.*, 2019; E. L. Rall *et al.*, 2015; Roe & Mell, 2013; Sandström *et al.*, 2006; Schiappacasse & Müller, 2015; Szulczewska *et al.*, 2017; Wang & Banzhaf, 2018; Wirth *et al.*, 2018; Xiu *et al.*, 2016; Zalejska-Jonsson *et al.*, 2020)
Integration	Integration mainly concerns the interaction and links between green infrastructures and other urban structures—the so-called grey infrastructures. Usually, this principle regards structures specially developed for stormwater management or mobility purposes, however, this statement is reductive and does not account for the full potential and the multifunctionality of green infrastructure. Integration is thus a principle that considers all connections and synergies between green and grey infrastructures, as well as the landscape interactions with the building environment.	(Ahmed *et al.*, 2019; Artmann *et al.*, 2019; Davies & Lafortezza, 2017; Dorst *et al.*, 2019; Dover, 2015; Girma *et al.*, 2018; Hansen *et al.*, 2017, 2019; Jayasooriya *et al.*, 2020; Jerome *et al.*, 2019; H. W. Kim & Tran, 2018; I. C. Mell, 2013; Molla *et al.*, 2019; Pauleit *et al.*, 2018; Perini & Sabbion, 2016; Prior & Raemaekers, 2007; Qiao *et al.*, 2020; E. Rall *et al.*, 2019; Szulczewska *et al.*, 2017; Wirth *et al.*, 2018; Zwierzchowska *et al.*, 2019)

Diversity	Green infrastructure emphasizes the quantity, the quality of urban green spaces, and the diversity of the solutions presented to solve a specific issue. In fact, there are a wide number of typologies of nature-based solutions that can be implemented within an urban area, meant to address the same or different issues, that can have a more natural or managed approach, and can have a larger or smaller extent. Besides the type of structure (managed or natural) and their size (small or large), the diversity principle also enhances the role and importance of blue infrastructures in green infrastructure planning.	(Ahmed *et al.*, 2019; Arshad & Routray, 2018; Artmann *et al.*, 2019; Bartesaghi Koc *et al.*, 2017; Burton & Rogerson, 2017; Cilliers, 2019; Collier *et al.*, 2013; Coutts, 2016; Dorst *et al.*, 2019; Gradinaru & Hersperger, 2019; Greed, 2015; Hrdalo *et al.*, 2015; Ignatieva *et al.*, 2011; D. Kim & Song, 2019; H. W. Kim & Tran, 2018; Lähde *et al.*, 2019; Lovell & Taylor, 2013; Lynch, 2016; I. Mell, 2015; Papageorgiou & Gemenetzi, 2018; Perini & Sabbion, 2016; Roe & Mell, 2013; Selman, 2010; Shifflett *et al.*, 2019; Söderman & Saarela, 2010; Szulczewska *et al.*, 2017; Tzoulas *et al.*, 2007; van der Walt *et al.*, 2015; Wirth *et al.*, 2018; Zalejska-Jonsson *et al.*, 2020; Zwierzchowska *et al.*, 2019)
Applicability	Several municipalities have developed green infrastructure plans and have made great investments in nature-based solutions in urban areas in recent years. In some places, however, even though plans have been made and exist, with bold and ambitious goals and actions, the majority of projects end up not being accomplished. To avoid these situations, green infrastructure planning must consider the applicability, adaptability, and implementation of the projects, which accounts if the plan (and the green projects) are realistic, can be implemented and developed, and if the solutions presented and adaptable to the considered area or not.	(Artmann *et al.*, 2019; Brears, 2018; Cilliers, 2019; Dorst *et al.*, 2019; Girma *et al.*, 2018; Jerome *et al.*, 2019; Johns, 2019; H. W. Kim & Tran, 2018; Lennon *et al.*, 2014; Lennon & Scott, 2014; Lynch, 2016; I. Mell *et al.*, 2017b; Molla *et al.*, 2019; E. L. Rall *et al.*, 2015; Reimer & Rusche, 2019; Shifflett *et al.*, 2019; Taramelli *et al.*, 2019)

Governance	Governance aims at the collaboration between government actors and citizens in the planning processes. This principle assumes great importance to the development and implementation of green infrastructure because green spaces offer a wide range of recreational functions, focused on people, and their management and maintenance depend directly on the population. If the community does not feel integrated into the planning process, green infrastructure will not succeed, it will not be appreciated and supported by the local population and its objectives and goals will not be accomplished.	(Ahmed *et al.*, 2019; Anderson *et al.*, 2019; Anguelovski *et al.*, 2020; Artmann, 2016; Artmann *et al.*, 2019; Benedict & McMahon, 2001; Burton & Rogerson, 2017; Chaffin *et al.*, 2016; Davies & Lafortezza, 2017; Dennis & James, 2018; Dorst *et al.*, 2019; Elbakidze *et al.*, 2017; Everett *et al.*, 2015; Everett & Lamond, 2018; Feltynowski, 2015; Ferrari *et al.*, 2019; Girma *et al.*, 2018; Gulsrud *et al.*, 2018; Hansen *et al.*, 2017, 2019; Hislop *et al.*, 2019; Ibrahim *et al.*, 2020; Iojă *et al.*, 2018; Jayasooriya *et al.*, 2020; Jerome *et al.*, 2019; H. W. Kim & Tran, 2018; Lennon *et al.*, 2016, 2017; Lennon & Scott, 2014; Llausàs & Roe, 2012; Lovell & Taylor, 2013; Magaudda *et al.*, 2020; Marot *et al.*, 2015; I. c. (1 Mell 2), 2018; I. Mell & Clement, 2019; Moffat *et al.*, 2015; Molla *et al.*, 2019; Pauleit *et al.*, 2018; Perini & Sabbion, 2016; Prior & Raemaekers, 2007; E. Rall *et al.*, 2019; Roe & Mell, 2013; Rolf *et al.*, 2019; Schiappacasse & Müller, 2015; Scott *et al.*, 2013; Shifflett *et al.*, 2019; Suškevičs, 2019; van der Jagt *et al.*, 2019; Wild *et al.*, 2019; Wilker *et al.*, 2016)

Continuity	A major flaw of green infrastructure projects has been a lack of post-implementation monitoring or empirical measurements of outcomes of the ecosystem services and functions they claim to provide. In this sense, to be effective, green infrastructure must require frequent investment, management, and updates, and municipalities must be able to frequently release new information about their projects, their goals, what was accomplished, and what are their prospects regarding green/blue spaces. In this sense, green infrastructure plans must have a monitoring system well identified, or periodic reports on the evolution of the planned green projects.	(Ahern, 2013; Anderson *et al.*, 2019; Artmann, 2016; Brears, 2018; Burton & Rogerson, 2017; Davies & Lafortezza, 2017; Everett & Lamond, 2018; Hislop *et al.*, 2019; Iojă *et al.*, 2018; Jayasooriya *et al.*, 2020; Jerome *et al.*, 2019; H. W. Kim & Tran, 2018; I. Mell *et al.*, 2017b; I. Mell & Clement, 2019; Molla *et al.*, 2019; E. L. Rall *et al.*, 2015; Roe & Mell, 2013; Shifflett *et al.*, 2019; Taguchi *et al.*, 2020; Taramelli *et al.*, 2019)

By examining the results, it is possible to identify connectivity, multifunctionality, and multiscale as the principles that are the most frequently mentioned in the literature. In fact, multifunctionality is mentioned in more than half of the papers analysed (58), and connectivity and multiscale are mentioned in 46 and 38 publications, respectively. Although the number of citations may be relatively high when compared with other principles, these results do not come as a surprise. Multifunctionality, as well as connectivity, are pointed out by several authors as the core elements (or principles) of green infrastructure (D. Kim & Song, 2019; Lähde *et al.*, 2019; Rusche *et al.*, 2019), being the ones that are the most mentioned in the literature. Since the beginning of the green infrastructure research (e.g., greenways), both of these principles were used by the pioneers of this research field, such as Ahern in 1995 or Benedict & McMahon in 2001 (Ahern, 1995; Benedict & McMahon, 2001), as key principles for green spaces and greenways development. Table 2.2 shows these are the only principles that are mentioned in such early literature, apart from multiscale, which is another key principle considered by many. If we examine closely the definition of green infrastructure—"a strategically planned network of natural and semi-natural areas designed and managed to deliver a wide range of ecosystem services"—it is possible to see that both multifunctionality and connectivity principles are embedded in this description, which reinforces the important role these principles have in green infrastructure planning.

The multifunctionality and connectivity principles are indeed the ones that are more cited in the literature. However, through the content analysis of the selected publications, it was possible to understand that both principles were mentioned in more theoretical studies, as opposed to what happens to other principles (e.g., governance). Even though these principles call for a spatial integration of environmental, social, economic, cultural, and aesthetic functions, some concerns and criticisms have been expressed in recent years about their applicability (Madureira & Andresen, 2014). In reality, there has been an increase of studies that focus on understanding how such theoretical concepts can definitely be implemented and evaluated (Bolliger & Silbernagel, 2020; Hansen *et al.*, 2019; Lähde *et al.*, 2019; Rusche *et al.*, 2019; Szulczewska *et al.*, 2017), and this research clearly has shown that. The number of studies regarding ecosystem services in spatial planning and biodiversity enhancement in urban areas has been increasing and attempts to materialize these principles have been equally studied. This is explained by the evolution of the green infrastructure concept which, as previously discussed, started to incorporate ecosystem services very clearly in its definition. Nevertheless, this is still an emerging research field that is growing and must require further investigation, which was perceptible by the number of publications screened regarding that topic.

Other principles that are well established in the literature are diversity and integration. Although considered by some authors as key principles for green infrastructure planning, diversity and integration are still relatively new concepts when compared with multifunctionality and connectivity. In fact, only a few authors were able to explicitly identify integration and diversity as green infrastructure planning principles, and different concepts were sometimes used for the same principle. The integration principle was frequently mentioned as "green-grey integration" and the diversity one appeared several times as a "multi-object" principle. Nevertheless, when these principles were not explicitly identified as green infrastructure planning principles, they would frequently be mentioned implicitly in the studies analysed. For these reasons, both diversity and integration were considered key green infrastructure planning principles in this study.

Because rapid urbanization is affecting the availability of green open spaces in urban areas, the ecological functions of ecosystems and the provision of ecosystem services are at risk. So, the need to incorporate nature-based solutions into the building environment (grey infrastructure) has become more urgent. As a result, the implementation of green infrastructure to deal with environmental problems in urban areas has been growing, especially the problems related to stormwater management and flood control (Girma *et al.*, 2018; Hansen *et al.*, 2017). Although it can also be applied to other functions (Hansen *et al.*, 2017), in the literature, the integration principle is frequently mentioned in studies related to stormwater systems. However, despite green infrastructure practices in North America having a clear focus on stormwater management, compared to other regions (Dunn, 2010; I. Mell, 2011), it was interesting to observe that only three out of the 21 publications that mentioned the integration principle were conducted in American Institutions or have American sites as case studies. These results do not mean, however, that there has been a decreasing trend in green infrastructure planning studies in North America, but rather that other regions in the world are becoming more aware of the benefits of green infrastructure planning as a tool to manage water flows in urban areas sustainably and are considering the integration principle as a key component to be included in their planning strategies.

Public participation has become an important element in spatial planning. The involvement of citizens and local actors in spatial planning processes is an opportunity to take into consideration their knowledge in decision-making, which could be lost in cases where public participation is lacking (Chaffin *et al.*, 2016). Stakeholder engagement in green infrastructure planning is an important issue that is discussed in several studies, as shown in Table 2.2. In fact, in this study, governance was mentioned in 50 papers out of the 104 analysed, which is consistent with the findings of Davies & Lafortezza, (2017) and Dorst *et al.*, (2019), that is, social inclusion is increasingly considered a key feature of green infrastructure planning. These results suggest that strategic approaches to green infrastructure planning must include stakeholders' inputs and considerations, which could involve new planning processes, knowledge, and resources (Davies & Lafortezza, 2017).

Although citizen engagement in green space planning has been recognized as crucial for the success of green infrastructure implementation, few authors considered this a key green infrastructure planning principle. Even though governance, similar to integration and diversity principles, is related to more practical studies, from the 50 papers where it was mentioned, only 10 of them actually defined governance (or social inclusion) as a key principle for green infrastructure planning. The remaining publications acknowledge its importance in spatial planning, especially for green space planning and ecosystem services integration in policymaking, but they do not consider it as a core principle. These results, however, may be linked to the fact that most of the literature concerning green infrastructure still focuses on the theoretical fundaments of this topic, where multifunctionality, connectivity, and multiscale are the prevalent principles in green infrastructure planning. In addition, the involvement of multiple actors in the management of green infrastructure is mentioned by some authors as fundamental to improve other principles of green infrastructure, such as multifunctionality, for example (Anderson *et al.*, 2019). As much as governance may, in fact, contribute to the success of other principles, for example, continuity, governance has gained such importance in planning procedures in recent years that it must be considered by itself a core principle of green infrastructure planning. In reality, governance intends to facilitate more equitable access to green space services (Hansen *et al.*, 2017) and strengthen green infrastructure resilience. Even though the majority of papers analysed concerning governance focused on implementation practices, the importance in considering governance in the policy-making process is unanimous.

One of the findings of this research was the fact that some authors pointed out several green infrastructure principles in their studies that were not seen in any others. For that reason, they were not selected for this study, as they were not mentioned and validated by other peers in different studies. However, two principles, in particular, stood out in more than one study and seemed to be mentioned by several authors. Those principles were accessibility (Bartesaghi Koc *et al.*, 2017; Cilliers, 2019; Jerome *et al.*, 2019; I. Mell & Clement, 2019; Papageorgiou & Gemenetzi, 2018) and evidence-based approaches (Benedict & McMahon, 2001; Llausàs & Roe, 2012; Roe & Mell, 2013). The accessibility principle refers to the guarantee th*et al* people can use, enjoy, and positively contribute to green infrastructure (Jerome *et al.*, 2019), and it is an important ground to be acknowledged in green infrastructure planning. However, in the eyes of the authors of this study, when it comes to green space planning, accessibility is something that is already intrinsic to the concept of green infrastructure. Since one of the most well-known functions of green spaces is recreation and leisure, accessibility is already considered in the planning process of these areas, as well as other public spaces in urban areas. Besides that, other green infrastructure principles that were considered in this research already contemplate (even if indirectly), the accessibility of people to green spaces. In addition, green infrastructure includes not only urban and manmade green spaces but also natural areas and spaces, green or otherwise, for non-recreational purposes, that are not accessible to everyone. For those reasons, accessibility was not identified as a core green infrastructure principle and was not included in the results in Table 2.2. As for the evidence-based approach, some studies defended the idea that green infrastructure planning must be based on robust scientific knowledge gained from several different fields (Roe & Mell, 2013). Nonetheless, as much as this is important and crucial for successful green infrastructure planning and implementation, this principle applies to every planning process or project. Nothing can be planned without sufficient evidence-based knowledge and, for that reason, the authors of this research also considered this an implicit green infrastructure principle, and for that, it was not considered a core principle of green infrastructure planning.

Unlike the previous principles (accessibility and evidence-based approach), none of the 104 papers analysed in this research directly mentioned the applicability or the continuity principles as core green infrastructure principles. Similar to the findings of Lennon & Scott, (2014), there is still limited attention in the literature regarding practical procedures and implementation strategies of green infrastructure. In addition, some studies also mentioned the lack of detailed action strategies or policies, as well as implementation approaches in most green infrastructure plans already developed (H. W. Kim & Tran, 2018), and how much this was a problem for the application of green infrastructure. For these reasons, the authors of this research consider that the applicability should be considered a core green infrastructure principle that must be recognized in the planning processes. As stated previously, green infrastructure planning must consider the applicability, adaptability, and implementation of the projects, which accounts for whether the plan (and the green projects) is realistic, can be implemented and developed, and if the solutions presented and adaptable to the considered area or not.

Similar to the applicability, the lack of post-implementation monitoring, or empirical measurements of the outcomes and benefits of green infrastructure was also referred to by several authors as something that damaged the implementation of green infrastructure. As stated by H. W. Kim & Tran, (2018) local plans should reflect changes as well as follow a monitoring process to ensure plan consistency and future green infrastructure plans should include a continuously monitoring performance and identify barriers to implementing green infrastructure planning. These issues, brought in 21 publications out of the 104 analysed, made the authors of this research consider continuity as a core and important principle of green infrastructure planning.

2.5 Conclusions

Due to its multiple benefits, which include climate change adaptation, risk mitigation, social cohesion human well-being improvement, and urban regeneration, green infrastructure planning has seen an increase around the world. Nevertheless, due to the ambiguity of the term, there is still no uniform process of green infrastructure development. Additionally, some of the existent planning procedures are too complex and difficult to put into practice, and some policymakers may not consider green infrastructure viable as a planning tool. For those reasons, the purpose of this research was to identify the most common green infrastructure planning principles through an integrative literature review of relevant studies and diverse sources, including theoretical and empirical sources, or experimental or non-experimental studies. Those principles are connectivity, multifunctionality, multiscale, integration, diversity, applicability, governance, and continuity, and identify important factors that need to be addressed in future green infrastructure planning procedures.

The literature has pointed out several strategies, guidelines, and principles for innovative green infrastructure planning. The integration of the principles presented in this research in the green infrastructure planning procedures is crucial to evaluate and understand the level of commitment of policymakers regarding green infrastructure planning. The analysis of the publications in this research shows different approaches to identifying, selecting and evaluating green infrastructure planning principles, which may be explained by the different priorities in the pollical agendas, which may be influenced by different geographical locations and cultural dynamics. Still, future research should be conducted to understand the reasons for such different principles presented in the literature and how the principles selected can be evaluated and how can they be put into practice.

3

Green Infrastructure Planning Principles: Identification of Priorities Using Analytic Hierarchy Process[2]

Abstract

Green infrastructure planning has been receiving great attention since the end of the last century. Although green infrastructure has been known for its ability to respond to a wide range of environmental, social, and economic challenges, the concept and associated implementation measures are still being discussed among researchers, decision-makers, and practitioners. To help these discussions, several authors have identified green infrastructure planning principles to help these professionals with planning procedures. However, the perception of practitioners regarding these principles was never taken into consideration. Because of this, the purpose of this research is to learn about the priorities of urban planners regarding green infrastructure planning principles and their integration into spatial planning. To achieve this, an Analytic Hierarchy Process methodology was applied to urban planners working in the 17 municipalities of the Lisbon Metropolitan Area, in order to prioritize the green infrastructure planning principles influencing GI design and development in urban areas. Practitioners were asked to prioritize eight primary green infrastructure planning principles: connectivity, multifunctionality, applicability, integration, diversity, multiscale, governance, and continuity. The results show that the most important green infrastructure planning principle for practitioners

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is connectivity, followed by multifunctionality and applicability. Both integration and multiscale principles were considered more important in municipalities with predominantly urban features.

Keywords: green infrastructure; spatial planning; analytic hierarchy process; Lisbon Metropolitan Area; urban planners; Portugal; ecosystem services

3.1 Introduction

Green and blue areas—green-blue infrastructure—have been highlighted by several authors as important assets that contribute to sustainable development (Madureira *et al.*, 2011; Meerow & Newell, 2017; Wilker *et al.*, 2016). Although they are often explored for their aesthetics and recreational features, these areas have recently shown their true potential in enhancing urban and rural resilience, improving public health, and contributing to well-being. So, to face the intense environmental threats urban and rural areas are facing—mainly due to climate change—green infrastructure (GI) planning has become a priority for decision-makers and practitioners around the world. However, due to its ambiguity, practitioners and decision-makers still struggle to understand its true benefits and the best practices for its implementation and management at the local level (Campagna *et al.*, 2020; Llausàs & Roe, 2012).

In order to address this issue, several authors have tried to identify multiple green infrastructure planning principles to help practitioners during green infrastructure planning procedures, including implementation and management. These principles, which are predominantly based on those of geography, ecology, and landscape ecology (Roe & Mell, 2013), try to incorporate both ecological, social, and economic concerns into the decision-making and implementation process in green areas. However, most of these principles focus only on the urban dimension of green infrastructure planning and do not consider the challenges rural areas face regarding these concerns. Additionally, there are no inputs from practitioners whatsoever regarding which principles are the most relevant for each territory, depending on its typology—urban or rural.

For these reasons, the purpose of this research is to learn about the priorities of practitioners and urban planners regarding the integration of green infrastructure planning principles into spatial planning. With this research, we hope to understand if there are any differences in the views of these professionals depending on the characteristics of the territory they work i.e., urban or rural municipalities. To achieve this, weights and ranks were assigned to the green infrastructure planning principles being considered, which included the establishment of a hierarchical structure and an analysis of pairwise comparisons using an Analytic Hierarchy Process. The respondents consisted of urban planners working for the municipalities of Lisbon Metropolitan Area (LMA), including, engineers, architects, geographers, etc. The green infrastructure planning principles considered in this analysis were those proposed by Monteiro *et al.*, (2020): connectivity, multi-functionality, applicability, integration, diversity, multiscale, governance, and continuity. This paper starts with a brief overview of green infrastructure planning principles, as well as its concept evolution; then the methods section highlights the case study and the Analytic Hierarchy Process. The paper continues with a description and analysis of the results sample and concludes with final remarks, research gaps, and future research directions.

3.2 Framework: Green Infrastructure Planning Principles

Green infrastructure is a concept that has burst onto the academic, political, and policy-making scenes since its first appearance in the literature, in the 1990s (Benedict & McMahon, 2001; Ferreira, Monteiro, *et al.*, 2021; Wright, 2011; Yacamán Ochoa *et al.*, 2020). Due to its flexibility and integrative perspective, green infrastructure has become an important tool for environmental land-use planning at various scales, as well as a strategy for enhancing urban sustainability and resilience (Benedict & McMahon, 2001; Hoover *et al.*, 2021; I. Mell & Clement, 2019). As a result, hundreds of scientific papers, empirical and practical studies, guidelines, reports, and evaluations outlining more or less detailed conceptualizations and definitions of green infrastructure have been published worldwide (Szulczewska *et al.*, 2017). However, despite the substantial literature on this topic, there are still a variety of definitions of green infrastructure, which add some complexity to its understanding (Ferreira, Monteiro, *et al.*, 2021; Wright, 2011).

According to Wright, (2011), the concept of green infrastructure is used loosely by many actors, which results in vast and diverse interpretations depending on the sector and context in which the concept has been developed (Campagna *et al.*, 2020; Honeck *et al.*, 2020). In addition, the geographical location and cultural dynamics in which green infrastructure is being used also influence the different concepts found in the literature (I. Mell & Clement, 2019; Monteiro *et al.*, 2020). This is evident in the two different interpretations that prevail in the green infrastructure literature: one that frames green infrastructure as an engineered technology to manage stormwater flow or water quality, highly influenced by North American planning practices; and another that highlights the role of green and blue spaces in providing a wide range of ecosystem services (Hoover *et al.*, 2021; I. Mell & Clement, 2019; Monteiro *et al.*, 2020). The latest concept highlights the use of nature-based solutions (considered multi-functional, more affordable, and socially inclusive) in contrast with grey infrastructure (that typically is limited to one purpose) (Honeck *et al.*, 2020; Liquete *et al.*, 2015).

Although there are several definitions of green infrastructure, the one suggested by the European Commission (EC) in 2013 seems to be, nowadays, the one that most represents what it truly is. Green infrastructure is defined in the EC communication as "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. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings" (European Comission, 2013). This definition not only captures the role that green and blue spaces take regarding ecosystem services provision at different spatial scales (Gómez-Baggethun & Barton, 2013) but takes into consideration the connections that exist between urban and rural areas and the component of planning and management (Liquete *et al.*, 2015). As a concept for strategic spatial planning through the provision of ecosystem services, green infrastructure can respond to a wide range of environmental, social, and economic challenges (Meerow & Newell, 2017; Wilker *et al.*, 2016). These include climate change mitigation and adaptation, wildlife habitat protection, air pollution mitigation, social inclusion, or an increase in recreation opportunities (Bolund & Hunhammar, 1999; Campagna *et al.*, 2020; H. W. Kim & Tran, 2018; Tzoulas *et al.*, 2007), among others. Green infrastructure is, thus, extremely relevant for the quality of life, not only in urban areas but in all regions (Wilker *et al.*, 2016).

Because of its multi-sectorial nature, green infrastructure is intended to be a systematic and holistic spatial planning approach. Green infrastructure also represents a solution-oriented and cross-sectoral instrument that can be reinforced through strategic initiatives oriented to maintaining, restoring, and connecting existing areas and features, as well as creating new ones (Campagna *et al.*, 2020; Slätmo *et al.*, 2019). However, according to Campagna *et al.*, (2020), there is still no globally recognized consensus regarding green infrastructure design and implementation. Moreover, green infrastructure has been studied recently from the perspective of its benefits, while its potential value has not been fully examined at the planning level (H. W. Kim & Tran, 2018). For these reasons, several authors have tried to develop different approaches to integrate green infrastructure in decision-making processes concerning spatial planning. Despite the fact that numerous papers have been published proposing new green infrastructure methodologies and theoretically highlighting the role of green infrastructure in the planning field (Girma *et al.*, 2018; Hasala *et al.*, 2020; Jeong *et al.*, 2021; Jiaxing *et al.*, 2019), limited studies have studied in depth the integration of green infrastructure principles in spatial planning (Girma *et al.*, 2018; Gradinaru & Hersperger, 2019) considering the practitioners' views.

At a conceptual level, it is possible to identify in the literature several green infrastructure planning principles, which are predominantly based on geography, ecology, and landscape ecology (Roe & Mell, 2013). These proposed principles try to incorporate both ecological, social, and economic concerns into the decision-making and implementation process of green areas, in order to support the design and planning of a functional green infrastructure (Gradinaru & Hersperger, 2019; Roe & Mell, 2013). Nevertheless, as much as various green infrastructure planning principles have surfaced in the literature—since the term was first coined in the 1990's—a question prevails: what exactly are green infrastructure planning principles? Within this debate, Monteiro *et al.*, (2020) tried to answer this question by explaining that green infrastructure planning principles are "underlying grounds that help guide and facilitate the planning procedures of green infrastructure, in order to ensure that it contributes to a network of quality and functional green spaces, capable of meeting the needs of a determined urban area, contributing in the best way to the sustainability of a given region or local area, depending on its scale". This definition highlights the promotion of sustainability as an integrated approach to green infrastructure planning and serves as a starting point for practitioners and decision-makers to understand and decide how they develop and manage the landscape.

Scholars have proposed a set of different green infrastructure planning principles. In the Green Surge project, Hansen *et al.*, (2017) and Pauleit *et al.*, (2018) identified four core principles that should be integrated into green infrastructure planning; green-gray integration; ecological network and connectivity; multi-functionality; and social inclusion. Roe & Mell, (2013) go further and propose more principles, including an evidence-based approach, the importance of scale, and a long-term approach, among others. Gradinaru & Hersperger, (2019) outlined six principles (coordination, multi-functionality, connectivity, multi-scale planning, diversity, and identity) and conducted an evaluation to understand which of these principles of green infrastructure planning are followed in strategic plans for urban regions in Europe. Kim and Tran H. W. Kim & Tran, (2018) also conducted an evaluation of local comprehensive plans for sustainable green infrastructure; however, their case study focuses on the United States alone, and the principles suggested focused more on stormwater management. In this study, we decided to concentrate on the principles proposed by Monteiro *et al.*, (2020), identified in an integrative literature review of 104 documents, including peer review papers. These principles integrate both ecological and social components into green infrastructure planning and intend to promote the development of green infrastructure by different organizations. The principles are connectivity, multifunctionality, multiscale, integration, diversity, applicability, governance, and continuity, and a detailed description can be found in Table 3.1.

Table 3.1 - Green infrastructure planning principles*

Principles	Description
Connectivity	Connectivity aims to create a well-connected green space network that can serve both humans (recreation) and other species, namely fauna, and flora (migrations and interactions).
Multifunctionality	Multifunctionality directly connects green infrastructure with the provision of a wide number of ecosystem services, namely provision, regulation, support, and cultural.
Multiscale	Multiscale relates to the different scales at which green infrastructure can be planned so that interactions between and in these spaces can be enhanced.
Integration	Integration mainly concerns the interactions and links between green infrastructure and other urban structures (grey infrastructure).
Diversity	Diversity enhances the different existing structures (managed/artificial or natural), their size (small or large), and the nature of the areas (green or blue).
Applicability	Applicability considers if the green infrastructure is realistic, can be implemented and developed, and if the solutions presented are adaptable to the considered area or not.
Governance	Governance aims at the collaboration between government actors (practitioners and policymakers) and citizens in the green infrastructure planning processes.
Continuity	Continuity relates to a monitoring system of green infrastructure throughout time, which can (or not) include periodic evaluation reports/communications

*Adapted from Monteiro *et al.*, (2020)

Green infrastructure planning principles are relevant at the international level because they help guide practitioners and decision-makers during the design and implementation of strategic plans. Additionally, these principles can be used to evaluate spatial planning in areas with different features (urban and/or rural), as stated previously (Girma *et al.*, 2018; Hansen *et al.*, 2017; Pauleit *et al.*, 2018; Sandström, 2002; Yirga Ayele *et al.*, 2021). Still, these principles are not widely discussed among professionals (as well as citizens) in some European countries, including Portugal. So, understanding which green infrastructure planning principles are being taken into consideration in spatial planning and which of them are considered most important for practitioners is crucial in order to improve planning approaches. Only with this knowledge can we influence the conservation of green spaces and the functionality of green infrastructure, in order to achieve sustainability in urban and rural areas.

3.3 Materials and Methods

3.3.1 Methodological Framework

This research aims to understand which green infrastructure planning principles are more important to urban planners, using the AHP approach. To achieve this, this study has four main steps, as seen in Figure 3.1. The first consists of the establishment of the criteria we are trying to evaluate, i.e., the green infrastructure planning principles. These principles were selected based on previous work developed by Monteiro *et al.*, 2020 and are connectivity, multifunctionality, multiscale, diversity, integration, applicability, governance, and continuity. The second step focused on the selection of the study area and the respective stakeholders. Because the core of this study is to evaluate the perceptions urban planners have of each green infrastructure planning principle, the study area should contemplate a variety of landscapes, including rural and urban features. For this reason, the LMA was chosen to be the case study, because it contemplates these criteria. After the study area was chosen, the stakeholders (urban planners from each municipality of the LMA) were contacted and invited to participate in the AHP.

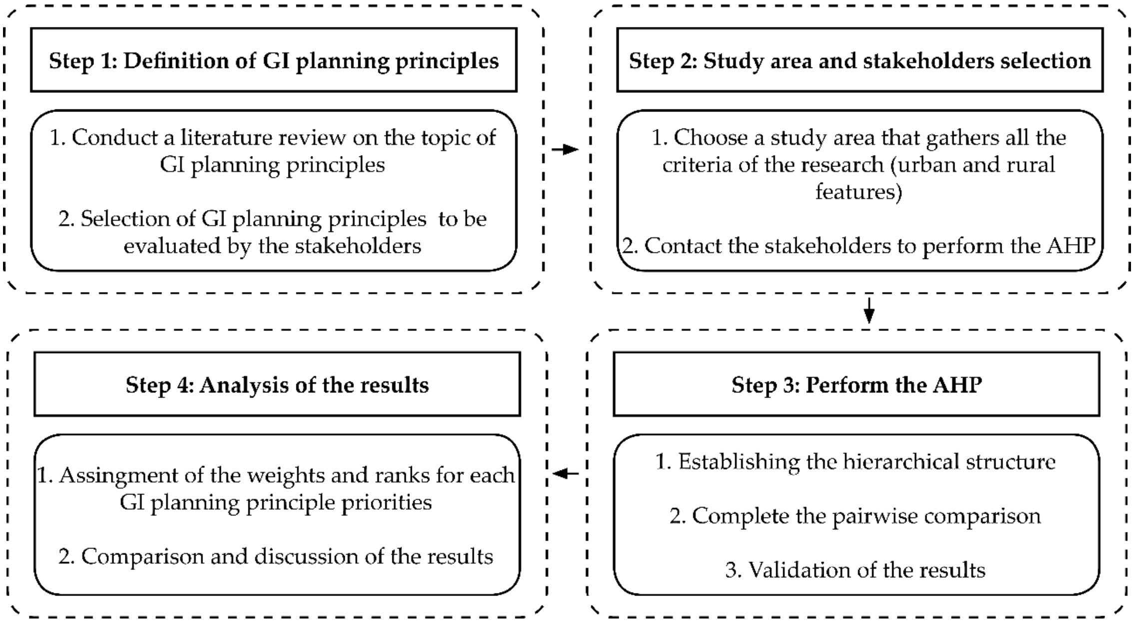

Figure 3.1 - Research methodological framework

In the third step, the hierarchical structure of the problem was developed and the pairwise comparison was completed. Stakeholders were contacted by email to request their participation, and an online interview was conducted to complete the pairwise comparison. Some stakeholders decided to conduct the AHP during the online interview, others chose to conduct the analysis afterward and send the results a few days later. Interviewees were practitioners in the fields of urban planning and landscape architecture and included architects, environmental engineers, geographers, and landscape architects who worked mainly in the urban planning and environment department. Data collection was carried out over two months, between November 2021 and January 2022. After all the answers were gathered, the validation of the responses was conducted through the calculation of consistency index (CI) and consistency ratio (CR), as stated previously. The fourth and last step consisted of the assignment of weights to each green infrastructure planning principle and the ranking of each of them.

3.3.2 Study Area

Lisbon Metropolitan Area (LMA), located on the Atlantic coast of Portugal, is the third-largest urban region in the Iberian Peninsula in terms of population, after Madrid and Barcelona (Mascarenhas *et al.*, 2016). LMA covers an area of approximately 3015 km^2, corresponding to almost 3.4% of Portugal's mainland territory, and encompasses 18 municipalities including the country's capital Lisbon (Marat-Mendes *et al.*, 2021). According to the preliminary results of

Census 2021, LMA had about 2,870,770 inhabitants, around 27.7% of the Portuguese population, and the most densely populated metropolitan area in the country (*INE - Plataforma de divulgação dos Censos 2021 – Resultados Provisórios*, no date). LMA is a NUTS II region divided into two large areas by the Tagus estuary, each of them composed of nine municipalities: (a) Greater Lisbon (on the northern side of the estuary), which includes the municipalities of Amadora, Cascais, Lisbon, Loures, Mafra, Odivelas, Oeiras, Sintra, and Vila Franca de Xira; and (b) the Setúbal Peninsula (on the southern side), which encompasses the municipalities of Alcochete, Almada, Barreiro, Moita, Montijo, Palmela, Seixal, Sesimbra and Setúbal (Marat-Mendes *et al.*, 2021), as seen in Figure 3.2.

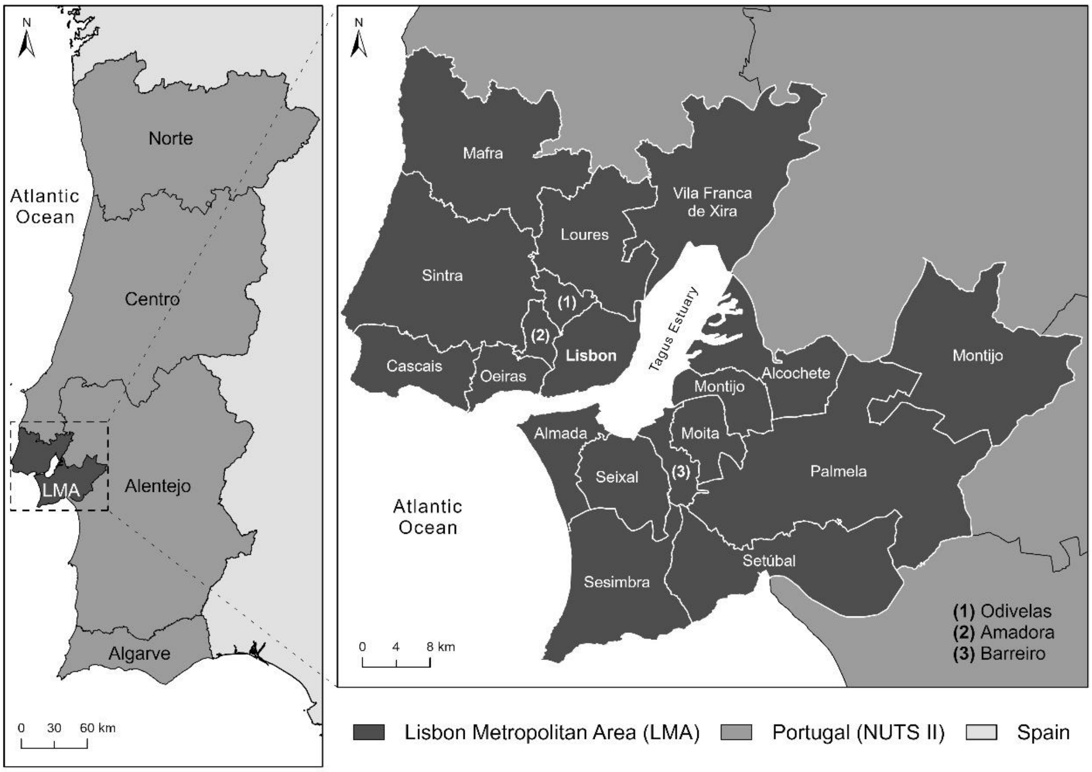

Figure 3.2 - Lisbon Metropolitan Area (Data from: CAOP 2012)

LMA includes distinct biophysical characteristics in its 18 municipalities, which gives it great territorial complexity. Whereas in its southern area rural features prevail, including agricultural land, forests, and wetlands, which are reflected in its lower population density, in the northern area the opposite occurs, and urban features are much more evident. As seen in Table 3.2, only one out of six municipalities with more than 50% of their territory dedicated to urban areas are located in the Setúbal Peninsula, i.e., Almada. The remaining five are all located on the northern side of LMA, with four of them having more than 60% of their territory urbanized. In contrast, the municipalities with lower urban density are those that present a higher percentage of agricultural and natural areas, including forests and water bodies. In fact, despite the presence of major urban areas, the LMA includes eight areas of nature protection that are part of the Natura 2000 network (*European Environment Agency*, 2021), as well as nine national protected areas, covering around 15% of the region's area (Mascarenhas *et al.*, 2016, 2019). LMA climate is classified as the Mediterranean (Csa, according to the Köppen-Geiger classification), having a dryer and warmer summers and mild and wet winters.

Table 3.2 - Characterization of the municipalities of LMA according to area, population and percentage of urban area, agriculture, forest, and water bodies*

Municipality	Area (km^2)	Population (inhab)	Urban Area (%)	Agriculture (%)	Forest (%)	Water Bodies (%)	Coastline (km)
Alcochete	128,36	19 148	6,9	30,2	31,0	31,8	30,3
Almada	70,01	177 400	54,0	14,3	31,4	0,3	47,1
Amadora	23,78	171 719	68,9	7,8	23,2	0,0	-
Barreiro	36,39	78 362	41,1	14,2	30,3	14,3	29,9
Cascais	97,40	214 134	54,3	11,3	34,3	0,1	39,7
Lisboa	100,05	544 851	70,3	1,9	14,2	13,6	34,7
Loures	167,24	201 646	27,1	37,4	33,9	1,6	6,9
Mafra	291,65	86 523	14,5	48,3	37,1	0,1	20,1
Moita	55,26	66 326	22,7	40,3	11,3	25,7	47,4
Montijo	348,62	55 732	7,4	33,2	56,8	2,6	51,0
Odivelas	26,54	148 156	60,5	15,2	24,3	0,1	-
Oeiras	45,88	171 802	63,4	16,6	19,8	0,3	14,6
Palmela	465,12	68 879	9,4	49,6	38,8	2,2	30,5
Seixal	95,45	166 693	46,3	6,8	37,0	9,9	88,4
Sesimbra	195,72	52 465	15,1	12,5	70,9	1,5	67,3
Setúbal	230,33	123 684	17,0	19,8	33,0	30,3	222,6
Sintra	319,23	385 954	28,5	37,6	33,8	0,1	32,5
Vila Franca de Xira	318,19	137 659	10,6	57,8	11,3	20,3	93,6

*Data from Census 2021, Official Administrative Map of Portugal 2018—CAOP 2018, and Land Cover Map of Portugal COS 2018

3.3.3 The Lisbon Metropolitan Area Planning System

The Metropolitan Areas of Lisbon and Porto were only legally defined in the 1990s, along with the introduction of Municipal Master Plans, which aim to establish the rules to be followed for the occupation, use, and transformation of the territory at the municipal level. The introduction of Master Plans in Portugal coincides with several reforms in terms of planning and land management in the country, including the Regional Plan for Land Use Planning of the LMA (PROT-AML). The reforms aimed, for example, to introduce greater agility into processes and the articulation of different levels of territorial management instruments, as well as new concerns, forms, and methods for a better understanding of the dynamics of the territory. This legislative framework also introduced clear objectives for controlling dispersed buildings, containing urban perimeters, and for framing and valuing natural, landscape, and heritage resources, to be adopted in the different territorial management instruments. The LMA Regional Pl5an has as its main development strategies international economic competitiveness and local regional development, environmental sustainability with an emphasis on the issue of urban fragmentation and the protection of natural resources, and social and territorial cohesion (Abrantes, 2016; CCDR_LVT, 2002).

Regarding environmental sustainability and protection of natural resources, the LMA Regional Plan proposes a Regional Environmental Protection and Enhancement Structure, which is implemented/materialized in the territory by the Metropolitan Ecological Network (MEN). This ecological network aims to the preservation of biodiversity and increase of urban green space in the metropolitan area; however, it is the responsibility of the municipalities to implement this territorial model at a local scale through a territorial strategy adjusted to the guidelines defined by the regional spatial plan. Although the MEN stands as the main tool that guides the development of green infrastructure at the municipal level in the LMA, there is still ambiguity regarding the exact procedures and implementation measures for green infrastructure among practitioners and policymakers in this region. This is due to the fact that the regional spatial plan of the LMA is vague and ambiguous regarding environmental sustainability and the ecological network, as well as outdated since the plan was released in 2002 and is still extant. Because of this, different green infrastructure planning approaches have been followed in the LMA, which compromises the efficient integration of the ecological and social components in the land-use planning and policymaking processes of this region.

The fact that the LMA is such a complex territory, with a diversity of landscape features (including rural and urban) poses serious challenges in terms of green infrastructure planning. Additionally, the lack of strong and focused spatial planning regulations in the region makes it more challenging for the development and implementation of green infrastructure strategies at the municipal and local levels. For these reasons, the LMA was chosen to be the case study for evaluating the different priorities each municipality has regarding green infrastructure planning principles.

3.3.4 The Analytic Hierarchy Process (AHP)

This study proposes the use of the Analytical Hierarchy Process to determine the weights of green infrastructure planning principles in a multicriteria inventory classification. The AHP method was developed by Saaty and is a multi-criteria approach based on math and psychology (T. L. Saaty, 1994, 2008), used to organize and analyse complex problems and unpredictable situations that require multiple evaluation standards and understandings (Shin *et al.*, 2020). The AHP method helps simplify criteria by clarifying the overall goal of the problem and organizing the criteria into a hierarchical structure and relies on the establishment of priorities through weights and ranks on a pairwise comparison (L. Li *et al.*, 2020; Park *et al.*, 2020; Shin *et al.*, 2020; Xu *et al.*, 2019; Young *et al.*, 2010).

The AHP contemplates the numerous layered dimensions of the decision-making processes (Shin *et al.*, 2020) and has the ability to handle stakeholder involvement and integration of qualitative judgments in a variety of fields and applications, such as operations, economics, and planning (Axelsson *et al.*, 2021), among others. Although this method relies on complex matrix manipulation, it can be applied effectively without requiring the involved stakeholders to possess an in-depth knowledge of multi-criteria decision-making theory (Young *et al.*, 2010). This method can also rely on the judgments of experts from different backgrounds (such as those involved in this study), so the problem that is being addressed can be evaluated easily from different perspectives and aspects (OğuztiMur, *no date*).

The AHP provides an easily applicable decision-making method that helps the decision maker to precisely make decisions and judgments regarding a specific problem, and both objective and subjective considerations play an important role during the decision process (OğuztiMur, *no date*). The AHP process involves identifying the overall goal, choosing evaluation criteria, selecting stakeholders followed by their criteria evaluation, validating the results, and establishing weighted values and ranks for the criteria considered in the process (T. L. Saaty, 1994; Shin *et al.*, 2020).

The first step of the AHP involves structuring the problem into a hierarchy where the goal is established at the top level and a connection is made between the top and the bottom elements (Park *et al.*, 2020). For this study, the overall goal is to understand which GI planning principles—previously considered—are the most important for practitioners and which of them should be considered in spatial planning. For this, an AHP hierarchical structure was established, where the top layer highlighted the primary objectives of the research, and the first (and only) tier had the GI planning principles as judgment criteria (Figure 3.3).

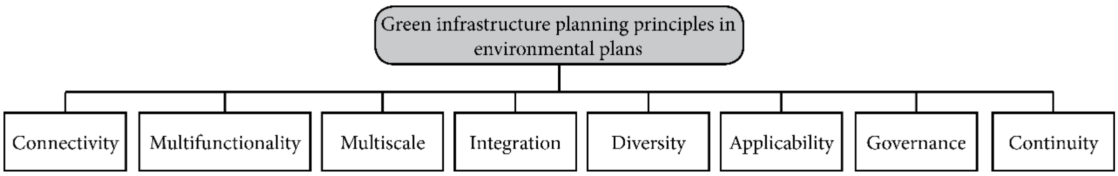

Figure 3.3 - Analytic hierarchy process (AHP) hierarchical structure (source: created by the authors).

The second step involves a pairwise comparison of the decision elements by the stakeholders selected, represented in a square matrix where all the elements are compared with themselves. Each comparison represents the dominance of an element in the column on the left over an element in the row on the top. To obtain the weight of the decision element, we can ask which of the elements is more important and how strongly that importance is, using a nine-point scale proposed by Saaty (T. L. Saaty, 1994) (table 3.3). If the element on the left is less important than the one on the top of the matrix, the reciprocal value is chosen in the corresponding position in the matrix. If both elements have equal importance, the attributed value is one. The result of comparing the elements can be obtained with the comparison matrix $A = (a_{ij})$, in equation 3.1.

$$A = \begin{bmatrix} 1 & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \dots & 1 \end{bmatrix} \quad (3.1)$$

$$i, j = 1,2, \dots, n$$

Table 3.3 - Comparison scale for AHP*

Scale	Definition	Explanation
1	Equal importance	Two criteria contribute equally to the objective
3	Moderate importance	Judgment moderately favors one criterion over another
5	Strong importance	Judgment strongly favors one criterion over another
7	Very strong importance	One criterion is favored very strongly over another
9	Extreme importance	There is evidence favoring one criterion that is of the highest possible order of affirmation
2,4,6,8	Immediate values between those of the above scale	When a compromise is required
Reciprocals	Compared to activity ‘b’, if any of the above numbers is assigned to element ‘a’, ‘b’ is the reciprocal of ‘a’	

* adapted from T. L. Saaty, (1994)

The third step involves validating the results obtained by the stakeholders, by deleting inconsistent values through consistency verification. The consistency test is used to verify whether respondents consistently respond to pairwise comparison questions, in order to avoid conflicting phenomena in the judgments (Chen, 2019; Park *et al.*, 2020). To do this, the consistency index (CI) and consistency ratio (CR) is employed. If the CR is smaller than 0.2, the results are considered reasonable and acceptable (Park *et al.*, 2020; Shin *et al.*, 2020), although the smaller the CI, the more consistent the stakeholders’ responses. The CI and CR can be obtained by Equations (3.2) and (3.3), and RI (Table 3.4) is the random consistency index which depends on the number of elements compared.

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{3.2}$$

$$CR = \frac{CI}{RI} \quad (3.3)$$

Table 3.4 - Random consistency index

n	1	2	3	4	5	6	7	8	9	10
Random Consistency Index	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

The λ_{max} corresponds to the maximum eigenvalue of the matrix and is given by equation (3.4), where W is the weight attributed to each element (priorities). To obtain the priorities of the elements we calculate the geometric means of the rows of the matrix ($\bar{W}_i$), and normalize it using equation (3.5) (Chen, 2019; R. W. Saaty, 1987). After that, if the answers are valid, the elements are ranked based on the results obtained.

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \quad (3.4)$$

$$W_i = \frac{\bar{W}_i}{\sum_{j=1}^{n} \bar{W}_j} \quad (3.5)$$

$$i, j = 1,2, \dots, n$$

After each stakeholder comes to his independent AHP-based ranking, the resulting individual priorities (W_a) are aggregated using a (weighted) arithmetic mean (Ossadnik *et al.*, 2016; Yedla & Shrestha, no date), given by equation 3.6.

$$W_a = \sum_{i=1}^{n} \frac{W_i}{n} \quad (3.6)$$

$$i, j = 1,2, \dots, n$$

3.4 Results and Discussion

For the purpose of this research, all 18 municipalities of the Lisbon Metropolitan Area were contacted and invited to participate in this study. The invitations were addressed to one specific person, but it was open to more than one person to participate in the exercise. In total, 17 completed AHP analyses were collected, one from each municipality, with the exception of Montijo, which, after numerous contacts, did not respond to any of our attempts. Some of the received AHP analyses had input from only one practitioner, while some considered inputs were from two or more practitioners. Next, the received answers were validated according to the consistency ratio (CR). All 17 answers had a CR below 0.2, therefore all of them were consistent and considered in our analysis. The individual results for each municipality, as well as the aggregated results, are shown in Table 3.5[3].

[3] Individual answers can be found in appendix A

Table 3.5 - Outcome of the Analytic Hierarchy Process analysis

GI Planning Principles	**Municipalities**																		
	Alcochete	Almada	Amadora	Barreiro	Cascais	Lisboa	Loures	Mafra	Moita	Montijo	Odivelas	Oeiras	Palmela	Seixal	Sesimbra	Setúbal	Sintra	Vila Franca de Xira	**Overall**
Connectivity	0,23	0,32	0,23	0,17	0,21	0,12	0,22	0,26	0,17	NDA	0,16	0,21	0,22	0,29	0,33	0,19	0,13	0,26	**0,22**
Multifunction-ality	0,25	0,32	0,23	0,21	0,13	0,14	0,19	0,16	0,18	NDA	0,09	0,05	0,15	0,19	0,18	0,09	0,06	0,31	**0,17**
Multiscale	0,07	0,15	0,10	0,08	0,17	0,16	0,14	0,08	0,11	NDA	0,09	0,03	0,10	0,09	0,08	0,07	0,03	0,06	**0,09**
Integration	0,05	0,13	0,10	0,07	0,08	0,15	0,09	0,13	0,12	NDA	0,14	0,11	0,10	0,13	0,10	0,09	0,17	0,05	**0,11**
Diversity	0,05	0,04	0,05	0,07	0,18	0,07	0,06	0,12	0,12	NDA	0,05	0,03	0,07	0,09	0,08	0,08	0,07	0,03	**0,08**
Applicability	0,04	0,03	0,16	0,13	0,10	0,11	0,12	0,08	0,09	NDA	0,26	0,28	0,12	0,10	0,11	0,29	0,20	0,03	**0,13**
Governance	0,27	0,03	0,04	0,15	0,04	0,12	0,12	0,07	0,11	NDA	0,10	0,03	0,02	0,08	0,09	0,13	0,14	0,27	**0,11**
Continuity	0,08	0,02	0,09	0,12	0,07	0,12	0,03	0,12	0,09	NDA	0,11	0,29	0,01	0,05	0,08	0,09	0,16	0,06	**0,09**

By examining the results, we can see that, in the aggregated results, the green infrastructure planning principle with the highest weight is connectivity, followed by multifunctionality, with 0.22 and 0.17, respectively. These results are in accordance with the findings of Monteiro *et al.*, (2020), where connectivity and multifunctionality are the most commonly mentioned green infrastructure planning principles in the literature, often considered by several authors as the core elements of green infrastructure (Hansen & Pauleit, 2014; Kambites & Owen, 2006; D. Kim & Song, 2019). In addition, an assessment of green infrastructure planning principles integration into strategic planning in European regions, developed by Gradinaru & Hersperger, (2019), also showed how connectivity and multifunctionality are at the core of planning strategies across Europe, in which Lisbon Metropolitan Area is included. Results from a study from Shin *et al.*, (2020), where the AHP methodology was applied to examine the decision criteria of GI practitioners in terms of design priorities, showed that ecological functions (connectivity) were also considered by most practitioners to be the key priority for UGI development. This was followed by air quality improvement, providing nature within urban areas, climate control, conservation of urban ecology, and stormwater management (multifunctionality).

Connectivity and multifunctionality have been used as key principles for green spaces and greenways development worldwide since the beginning of green infrastructure research. In Portugal, and especially the Lisbon Metropolitan Area, the same is true. According to Ribeiro & Barão, (2006), the first Portuguese attempts at landscape planning demonstrate a certain awareness concerning the protection of resources based upon linear territorial patterns, and plans developed for the region are major evidence of the use of linear structures to improve landscape connectivity. The development of legal planning instruments such as RAN and REN (National Agriculture Reserve and National Ecological Reserve, respectively), also fostered the creation of green structures at a regional scale, as a way of linking green urban systems with the surrounding rural landscape. These legal instruments, as well as the development of a greenway plan for the Lisbon Region in 1994 (Ahern, 2004; Machado & Ahern, *no date*), anticipated the greenway concept and identified the importance of green corridors in Portugal, which may explain why the connectivity principle is considered the most important for spatial planners in the Lisbon Metropolitan Area. Looking at the individual results, connectivity is the most important principle for 8 out of the 17 municipalities considered—Almada, Amadora, Cascais, Loures, Mafra, Palmela, Seixal, and Sesimbra—and the highest weight (0.33) was recorded by the municipality of Sesimbra. The second highest weight for connectivity was from Almada (0.32); however, together with Amadora (0.23), these two municipalities considered connectivity and multifunctionality to have the same importance. Although it is not possible to identify a specific pattern among rural and urban municipalities regarding the connectivity principle, it is interesting to see that, in addition to being the most important principle for the majority of municipalities, connectivity also had the highest weight value of all weight value entrances.

Apart from Almada and Amadora—which both considered connectivity and multifunctionality of equal importance—surprisingly, multi-functionality only acquired great relevance for four municipalities: Vila Franca de Xira (0.31), Alcochete (0.25), Barreiro (0.21) and Moita (0.18). These results can also be explained by the landscape planning history in Portugal. According to Jongman *et al.*, (2004), the first greenway plans in Portugal were mainly destined for ecological and recreational purposes, which included river systems. These plans' approaches were initiated by universities and NGOs in cooperation with urban authorities, to address the existing gap concerning protected areas and areas to be protected for both biodiversity conservation and cultural and recreational values. So, as expected other environmental, economic, and social functions (multifunctionality) were not considered in those plans, including the Regional Environmental Protection and Enhancement Structure plan, which is implemented/materialized in the territory by the Metropolitan Ecological Network (MEN). Because of this, most municipalities in LMA do not consider multi-functionality to be a GI planning principle of high priority.

It is also important to recognize that the multifunctionality principle itself has changed in the last decades. Even though greenways started as being "networks of land containing linear elements that were planned, designed and managed for multiple purposes, such as ecological, recreational, cultural, aesthetic, and the ones compatible with the concept of sustainable land use" (Ahern, 1995), only when the ecosystem services concept emerged in the literature has the multi-functionality principle started to become more relevant in green infrastructure planning. Ecosystem services are, nowadays, a concept that is well established within the scientific community and decision-makers are starting to pay more and more attention to this topic. Besides being responsible for providing countless benefits to society and contributing to human well-being, ecosystem services have also been recognized recently as a useful approach to dealing with climate change and other risks in urban areas (Fedele *et al.*, 2018; Matthews *et al.*, 2015). Yet, despite receiving great attention from decision-makers, there is limited awareness of the relevance of ecosystem services for several policy goals as well as a lack of knowledge and knowledge exchange on this topic. In addition, the ecosystem services approach is still not properly developed in Portuguese (and European) law, which, together with the already established professional norms, competencies, and codes of conduct, make practitioners rely on traditional solutions, such as grey infrastructure instead of green-blue infrastructure (Saarikoski *et al.*, 2018).

Nowadays, multifunctionality is not just a principle that guarantees biodiversity conservation and (some) cultural and recreational values, but a principle that promotes the provision of ecosystem services and increases synergies within green spaces. As this principle became more complex, the challenge to incorporate it into green infrastructure planning processes increased. Because of this, practitioners have searched for ways to implement green infrastructure strategies, and the applicability principle has gained relevance among them, being the third most important principle, as seen in the results. This is even more evident in municipalities with substantial urban areas, such as Setúbal, Oeiras, Odivelas, Sintra, and Amadora. Unlike connectivity and multifunctionality, applicability is not considered a core green infrastructure planning principle and it is not easily found in the literature (Monteiro *et al.*, 2020). However, it is, surprisingly, one of the most relevant principles for the spatial planners included in this study. This may be explained by the limited attention in the literature regarding practical procedures and implementation strategies for green infrastructure (Lennon & Scott, 2014), and the lack of detailed action strategies or policies, as well as implementation approaches, in existing plans (H. W. Kim & Tran, 2018). This creates concerns regarding the applicability of green infrastructure at the local level, so practitioners struggle to find practical examples of green infrastructure implementation strategies in spatial planning. Given the current challenges urban areas are facing—environmental problems, climate change, poverty, social inequality, unemployment, and crime—spatial planners are pressured to abandon traditional solutions and develop new integrative strategies in current and future planning practices to address these concerns, such as green infrastructure.

Although multiscale, integration, and diversity have been often considered important elements in green infrastructure planning by some authors (Girma *et al.*, 2018; Hansen *et al.*, 2017), they were not given high priority by the practitioners considered in this study. In fact, diversity was the principle considered less important out of the eight considered. Nevertheless, the municipalities where these principles, especially multiscale, have more importance are the ones where more than 50% of the territory is urban—Cascais, Lisboa, and Almada. When it comes to the integration principle, more urban municipalities still prevail, but semi-urban municipalities (with around 20% of the urban territory) also consider this principle quite important—Sintra, Moita, and Mafra. So, regarding both these principles, we can identify a pattern among urban municipalities, which was expected. Due to rapid urbanization, urban areas are becoming more and more compact and overpopulated, and the availability of green spaces is decreasing, which puts ecological functions and ecosystem services provision at risk. In places where space is scarce and much needed, every square meter counts. The need to integrate nature-based solutions into the building environment and to consider multiscale approaches in these areas has become more relevant and urgent.

Continuity is considered one of the least important green infrastructure principles for the practitioners involved in this study. Although urban planners consider important post-implementation continuity of green infrastructure, as well as follow-up monitoring processes, to ensure planning consistency, unfortunately, this can be hard to achieve, for various reasons. First is the lack of funding to guarantee continuous monitoring. Funding is extremely important to guarantee the preservation, restoration, and development of green infrastructure. Nevertheless, according to a study by Slätmo *et al.*, (2019), funding flows mainly from public funding sources (national or European) to public actors and institutions. Most funding programs fund the initial developments of green infrastructure projects, but the monitoring phase is not considered afterward. This creates enormous pressure among local authorities who have limited financial resources to continue to monitor green infrastructure projects. Second, the fact that local authorities have elections regularly (every four years), may result in a change of local governments, leading to uncertainty regarding policies and action plans already approved and implemented by previous governments. So, because of these reasons, the continuity principle may be, somehow, forgotten by local authorities and not be given the attention that it needs.

Even though governance was not the least prioritized principle, it still managed to receive little attention from the participants of this study, which is coherent with the findings of Monteiro *et al.*, (2020), that is, governance is not considered a key green infrastructure planning principle in the literature. This may be one of the reasons for these results; however, the main reason may also be linked to the current public participation processes in Portugal. According to Nunes Silva, (2020), Portugal has a vast corpus of national legislation on citizen participation in public policy and is a member of international organizations that encourage and stimulate the use of citizen participation as an instrument of good governance. Yet, because of the unclear formulation of some of those legal acts, associated with the lack of proper knowledge of practitioners and lack of financial and human resources of institutions, legislation is not always applied conveniently in all branches of public administration. In addition, because public participation processes are usually complex and time-consuming, they are often undervalued in spatial planning. In other cases, the reasons for this are related to the lack of political will of those in power to implement public participation processes, as they could potentially undermine preferred decisions already defined. These sorts of reasons explain why citizen participation has been predominantly passive in Portugal, and why the governance principle may be seen as not as important as the others considered in this study. Still, it is important to acknowledge that governance has gained great attention in planning procedures in recent years, and some authors are starting to consider it a fundamental principle for green infrastructure planning.

3.5 Conclusions

Green infrastructure planning has been increasing worldwide since the end of the last century. However, there is still no consensus regarding its concept, its implementation measures, and which planning principles should be followed among researchers. This is even more evident among political actors and practitioners. Several studies have pointed out green infrastructure planning principles to follow in planning procedures; however, there were no studies that focused on the perception of practitioners regarding these principles. So, the objective of this research was to learn about the priorities of urban planners regarding green infrastructure planning principles and their integration into spatial planning, namely: connectivity, multifunctionality, applicability, integration, diversity, multiscale, governance, and continuity. To achieve this, weights and ranks were assigned to the green infrastructure planning principles considered, which included the establishment of a hierarchical structure and an analysis of pairwise comparisons using an Analytic Hierarchy Process. The respondents consisted of urban planners working for the municipalities of Lisbon Metropolitan Area (LMA), including, engineers, architects, geographers, etc., and, in total, 17 completed AHP analyses were collected.

The green infrastructure principles with the highest weights were connectivity, followed by multifunctionality, applicability, and integration. Three of these principles are usually considered core elements of green infrastructure planning in the literature, so these results do not come as a surprise. On the other hand, the applicability principle, although not very established in the literature, is, at the moment, one of the most important green infrastructure principles for urban planners and practitioners, who are more and more pressured to abandon traditional solutions and to develop new integrative strategies in current and future planning practices. Multiscale, governance, continuity, and diversity were those that were considered the least important.

Contrary to our hypothesis, there was no specific pattern observed regarding rural or urban municipalities, for any green infrastructure principle, with the exception of the integration and multiscale principles. Both these principles were considered more important for urban municipalities, probability due to the lack of space available for the development of green infrastructure projects. In urban areas, the availability of green spaces is decreasing, which puts ecological functions and ecosystem services provision at risk. Because of this, the integration of nature-based solutions into the building environment has, possibly, become more relevant and urgent.

Understanding the perception of urban planners and practitioners regarding green infrastructure planning is crucial to evaluate and understand their level of commitment to this issue. This is the novelty of this research. As much as regional and national entities, such as the European Environment Agency, are aware of the benefits of green infrastructure, well as the best planning practices for this instrument, the same is not true for local entities and local practitioners. Local territories are different and face different challenges, so it is important to comprehend the views of local urban planners and practitioners on green infrastructure planning principles since there are still many questions to be answered regarding this topic.

Although this study is important to help shape future green infrastructure planning practices, there are some limitations that should be addressed in future studies. For example, the AHP conducted could be complemented with some detailed interviews with the practitioners, in order to understand some of their choices and points of view on green infrastructure planning principles. As much as the results were enlightening, some questions were not answered, such as why some green infrastructure planning principles are more important in some municipalities than others. A wider sample and another case study should be used to confirm our results, or, on the contrary, to understand if there is, in fact, a pattern among rural and urban territories regarding these green infrastructure planning principles.

4

GREEN INFRASTRUCTURE PLANNING PRINCIPLES: PRACTICES AND IMPLEMENTATION IN LOCAL SPATIAL PLANS[4]

Abstract

There is now widespread scientific agreement that green spaces and nature-based solutions provide a variety of benefits to urban citizens and communities. Consequently, environmental considerations have increasingly become an integral part of spatial planning techniques and decision-making processes around the world. Even though there are a growing number of studies on the design of green infrastructure, the majority of them concentrate on the advantages (including environmental, social, and economic) and planning techniques rather than critically analysing how green infrastructure is viewed in spatial plans. Because of this, in this study, we look at how well local spatial plans in the municipalities of Lisbon Metropolitan Area integrate green infrastructure planning principles (connectivity, multi-functionality, applicability, integration, diversity, multiscale, governance, and continuity). Using a multi-criteria framework to evaluate spatial plans, we conducted a qualitative content analysis and assigned numeric scores to criteria that reflect the content and quality of the plans. Although no clear-cut pattern was observed regarding the way in which each municipality approach green infrastructure planning, the results showed that connectivity and diversity principles were the ones with the highest scores, followed by applicability and integration.

[4] This paper was presented In the 16th International Conference Littoral 22.

Keywords: Green infrastructure; spatial planning; local spatial plans; qualitative content analysis; Lisbon Metropolitan Area; Portugal

4.1 Introduction

Since the second half of the last century, the world's population has increased abruptly. According to United Nations Department of Economic and Social Affairs, (2021), the global population reached an estimated 7.8 billion in 2020 – an increase of more than 5 billion from 1950 – and it is expected to climb to 8.5 billion in 2030, the target date for achievement of the Sustainable Development Goals (SDGs). Such rapid growth, unprecedented in human history before the industrial era, is a direct consequence of a process known as the "demographic transition", in which decreasing levels of mortality and fertility, lead to longer and healthier lives and smaller families.

Although social and economic changes have led to higher standards of living and healthier life in general for humans, the fast global population growth puts enormous pressure on the earth's natural resources. The need for spaces to accommodate a growing human population and changing patterns of production and consumption (Donati *et al.*, 2022; United Nations Department of Economic and Social Affairs, 2021), are typically the causes of environmental damage. As urban sprawl increases and agriculture becomes more intense, the degradation and fragmentation of natural ecosystems and ecosystem services intensify as well, leading to air, water, and soil pollution, scarring of landscapes, and waste production (De Montis *et al.*, 2022; Donati *et al.*, 2022; Sanches *et al.*, 2021; Sun *et al.*, 2022).

Urban areas provide a range of benefits to sustain and improve human livelihood, such as health, education, and employment, among others (Tan & Abdul Hamid, 2014; Wu, 2010). However, the continuous increase of urban sprawling and the consequent transformation of virgin landscapes into urban agglomerations, pose significant challenges for biodiversity and related ecosystem functions and services, which affect human welfare (Haase *et al.*, 2014; Klimanova *et al.*, 2018). These challenges are aggravated by the lack of urban green spaces in urban areas, because of the threats imposed by densification (De Montis *et al.*, 2022; Haaland & van den Bosch, 2015). Additionally, as urbanization expands, other social and economic challenges arise with major consequences for humanity, such as the intensification of poverty, high unemployment rates, criminality increase, and political crisis, for example (Ferreira, Vasconcelos, *et al.*, 2021; Haaland & van den Bosch, 2015; Rukumnuaykit, 2015).

According to Abass *et al.*, (2019), the depletion of green spaces in urban areas is a global phenomenon, which affects both developed and developing countries. Urbanization has been identified as a key factor for this phenomenon since the urban expansion has often occurred at the expense of green spaces with negative implications for city dwellers and different other species (Wu, 2010). Consequently, environmental considerations have increasingly become an intrinsic element of worldwide spatial planning techniques and decision-making processes, to the point where there is now a broad scientific consensus that green spaces and nature-based solutions provide diverse benefits to urban citizens and communities (Cilliers, 2019; Llausàs & Roe, 2012; Monteiro *et al.*, 2022; Sanches *et al.*, 2021; Wright, 2011). Despite nature-based solutions being often seen as ineffective and inefficient by some more conservative landscape planners and policymakers, the reality is, compared to traditional urban solutions, these strategies are a key element in sustainable urban planning (Lafortezza *et al.*, 2018; Raymond *et al.*, 2017; Xing *et al.*, 2017). So, policymakers and practitioners are expanding green infrastructure as a strategy to achieve sustainable planning goals (Goodspeed *et al.*, 2021), in the medium and long term, in both urban and rural areas.

Green infrastructure is, according to the European Commission, "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. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings" (European Comission, 2013). This concept encompasses not only the importance of green and blue spaces in the supply of ecosystem services at various spatial scales (Demuzere *et al.*, 2014; Gómez-Baggethun & Barton, 2013; I. Mell & Clement, 2019; Rozas-Vásquez *et al.*, 2018) but also the links that exist between urban and rural regions (Ferreira, Monteiro, *et al.*, 2021; Liquete *et al.*, 2015). Green infrastructure can respond to a wide range of societal challenges, due to the environmental, social, and economic benefits it provides (Bolund & Hunhammar, 1999; European Comission, 2013; Wilker *et al.*, 2016), that is, the ecosystem services. Climate change mitigation and adaptation, such as the reduction of flooding hazards, increase in building thermal performance, street temperature regulation, carbon storage increase, and freshwater quality and supply maintenance, are some of the environmental benefits (Bolund & Hunhammar, 1999; Demuzere *et al.*, 2014; Jones & Somper, 2014). Furthermore, green spaces serve as a habitat for a variety of animals and plants, contributing to biodiversity enhancement and wildlife conservation (De Montis *et al.*, 2022; Donati *et al.*, 2022). Social benefits are usually associated with recreational and cultural activities, such as sports, relaxation, and social contacts, and are related to inhabitants' exposure to urban green spaces (Bolund & Hunhammar, 1999; Haase *et al.*, 2014; Kabisch, 2015). These benefits contribute to people's health and well-being, as well as increasing connectivity between urban and rural areas, which enhances local identity, social inclusion, and a sense of community among citizens (Monteiro *et al.*, 2020; Tzoulas *et al.*, 2007; Wright, 2011). Economic benefits include property values increase, which helps to recruit and maintain high-value industries, new business start-ups, entrepreneurs, and talented workers (Ferreira, Monteiro, *et al.*, 2021; Wright, 2011). A drop in health-care costs and an increase in tourism (Tzoulas *et al.*, 2007) are two further economic benefits of green infrastructures, which highlight the importance of green infrastructure in attaining sustainable growth and a fair quality of life (De Montis *et al.*, 2022).

The concept of green infrastructure has received great attention among researchers and practitioners regarding land conservation, landscape design, and land development, since it emerged in the 1990s (Benedict & McMahon, 2001, 2012; Wright, 2011). In the last decade, the number of peer review papers and publications, as well as studies for governmental bodies regarding green infrastructure and ecosystem services, increased exponentially (Chatzimentor *et al.*, 2020; Ying *et al.*, 2021). However, despite the growing interest in the topic, there are still a lot of different approaches, implementation strategies, and structural/institutional support at the national and subnational levels regarding green infrastructure planning, due to its diverse and complex concept (Campagna *et al.*, 2020). To help guide and facilitate the planning procedures of green infrastructure for decision-makers and practitioners, some scholars have proposed a set of different green infrastructure planning principles which are predominantly based on geography, ecology, and landscape ecology. Some of those principles are considered core elements of green infrastructure, since they were used by the pioneers of this research field in the 1990s, and include multifunctionality, connectivity, and diversity. Other principles include coordination, evidence-based approach, green-gray integration, social inclusion, long-term approach, and identity, for example, and resulted from more recent research projects and studies. In this study, we decided to concentrate on the principles proposed by Monteiro *et al.*, (2020), identified in an integrative literature review of 104 documents, including peer review papers. The principles are connectivity, multifunctionality, multiscale, integration, diversity, applicability, governance, and continuity. These proposed principles attempt to incorporate both ecological, social, and economic concerns into the decision-making and implementation process of green areas, in order to support the design and development of a functional green infrastructure (Ayele *et al.*, 2022; Monteiro *et al.*, 2022).

Due to its multiple benefits, incorporating green infrastructure planning principles in spatial plans is crucial for the future development of urban and rural areas. Even though there are several studies on green infrastructure planning, most of them focus on its benefits (including environmental, social, and economic) and planning strategies, rather than critically examining how green infrastructure is being perceived in spatial plans (De Montis *et al.*, 2022; Gradinaru & Hersperger, 2019; H. W. Kim & Tran, 2018). As a result, it's still unclear how current local spatial plans integrate green infrastructure and its planning principles in some European countries, including Portugal. To tackle this issue, (Gradinaru & Hersperger, 2019) conducted an analysis of 14 European strategic spatial plans at the urban region level, that is, the metropolitan level. However, some of these plans are purely strategic, designed to guide and coordinate the objectives and proposals of municipal plans, which, in some cases, do not reflect the work that is done by practitioners and policymakers at a local scale. H. W. Kim & Tran, (2018) also conducted an evaluation of 60 comprehensive plans in the United States, to empirically understand how such plans have addressed green infrastructure-related policies and principles in planning practices. But, in this case, the green infrastructure planning principles were purely focused on rainwater management, which is reductive and does not integrate other ecological and social components.

For these reasons, in this study, we investigate the level of integration of green infrastructure principles in local spatial plans in the municipalities of Lisbon Metropolitan Area, Portugal. Understanding how the green infrastructure planning principles are applied in practice can help scholars and practitioners to comprehend theoretically based breakthroughs regarding green infrastructure development, as well as gain knowledge that is crucial for future green infrastructure planning evaluations and quality assessments. To achieve this, we developed a multi-criteria framework to evaluate spatial plans by conducting a qualitative content analysis and assigning numeric scores to criteria that reflect the content and quality of the plans, regarding the green infrastructure planning principles proposed by Monteiro *et al.*, (2020). This paper starts with a brief overview of green infrastructure planning practices in Portugal, as well as the Portuguese planning system; then the methods section highlights the case study and the multi-criteria framework used. The paper continues with a description and analysis of the results sample and concludes with final remarks, research gaps, and future research directions.

4.2 Framework

4.2.1 Spatial Planning in Portugal

In Portugal, the framework of territorial planning and management is currently based on two pieces of legislation: Law 48/98 – rectified by the current law 31/2014 – which establishes the general principles of spatial development and urban planning; and the decree-law 80/2015, which defines the new regime of planning instruments (Gorzym-Wilkowski & Trykacz, 2022). These laws assume significant importance because they define Portugal's spatial and urban planning policy framework while taking into account the European framework. They also establish a territorial management system that regulates and coordinates the interactions between the various levels and sectors of the public administration (Bailoa & Cravo, 2012; Gorzym-Wilkowski & Trykacz, 2022).

The Portuguese spatial planning system is divided into territorial "plans" and "programs", among which only plans are binding to private entities, while programs are binding to public administration only (Fidélis, 2018; Santos & Virtudes, 2020; Vergílio & Calado, 2016). This system comprises four levels of intervention and action: national, regional, inter-municipal, and municipal (Oliveira & Breda-Vázquez, 2011; Santos & Virtudes, 2020; Sousa, 2019). Civil parishes, undoubtedly owing to their small territory and weak powers, are excluded from this system (Gorzym-Wilkowski & Trykacz, 2022).

The National Spatial Planning Policy Program (PNPOT), a sectoral program established at the national level, lays down the rules for the spatial distribution of governmental strategies for socio-economic development, particularly the distribution of planned public investment projects of national significance. Thus, the document contains geographical instructions referencing a variety of public authority topics and regulates, among other things, the development of rural areas, the distribution of technical infrastructure, the location of other important public facilities on a national scale, and areas significant from the perspective of environmental protection or preservation of cultural heritage resources (Bailoa & Cravo, 2012; Gorzym-Wilkowski & Trykacz, 2022; Santos & Virtudes, 2020; Sousa, 2019). The protection of the public interest in areas of particular value, such as archaeological sites, estuaries, protected areas, coastal zones, and public reservoirs, is also a primary priority of special programs, another category of documents at the national level in Portugal (Bailoa & Cravo, 2012; Oliveira & Breda-Vázquez, 2011; Vergílio & Calado, 2016).

Regional programs (PROT) created for NUTS II areas currently serve as Portugal's regional representation for spatial planning. These programs consider, among other things, arrangements concerning the structure of the urban system and infrastructure of regional importance, environmental protection, and cultural heritage preservation (Gorzym-Wilkowski & Trykacz, 2022; Sousa, 2019). They also state goals for where the major public investment projects and arrangements should be located, such as those found in PNPOT, and highlight the already executed plans and programs at the regional level (Gorzym-Wilkowski & Trykacz, 2022).

The last two levels of the Portuguese framework of territorial planning and management are the inter-municipal and local levels. The inter-municipal level occurs when two or more municipalities decide to collaborate with each other, on a voluntary basis. This level of the spatial planning framework comprises the inter-municipal program, the inter-municipal master plan, the urbanization plan, and the detailed plan (Santos & Virtudes, 2020). Local planning, however, is the responsibility of municipalities and involves the development of a comprehensive plan – Municipal Master Plan –, compulsory for all municipalities and legally binding (Gorzym-Wilkowski & Trykacz, 2022; Sousa, 2019). This document establishes the municipal spatial development strategy, the spatial planning policy, and other urban policies, and sets the spatial organization model of the municipality. This plan also establishes the regional action programs, the sectoral interventions by the central government in the municipality, and the strategic framework for territorial development for the creation of additional municipal spatial plans (Urbanization Plans and Detailed Plans) (Sousa, 2019). The Municipal Master Plan, like other plans created by a municipality, must be in accordance with the regional program and programs created by the central administration (Oliveira & Breda-Vázquez, 2011; Santos & Virtudes, 2020).

4.2.2 Green Infrastructure in Portuguese Spatial Plans

As previously stated, there is still a complexity associated with the concept of green infrastructure, which influences the different approaches and implementation strategies regarding green infrastructure planning. Greenways, ecological networks, and green corridors are some of the examples found in the literature to describe the same concept – green infrastructure – and Portugal is no different.

The term "green infrastructure" was first introduced and legally framed in Portugal in 1987 as "*continuum natural*" in the Portuguese Environmental Policy Act. This act, which was revoked in 2014, established the framework for a national environmental policy with a focus on sustainable development and the preservation and optimization of natural resources. In addition, this Act also creates a mechanism to protect the "public right to a human and ecologically balanced environment, as well as the state's duty to promote this through individual and community initiatives". However, it was not until 1999 that the concept of green infrastructure was formally introduced into Portuguese legislation, with the Decree-Law nº 380/99 (Corgo, 2021), the legal framework for territorial management instruments that establish the criteria for land classification and qualification, and the technical concepts for territorial management and urban domain.

With the approval of the Decree-Law nº 380/99 (RJIGT 1999), the delimitation of the green infrastructure at the municipal level becomes mandatory for all the municipalities. However, the technical concept and the decision about which areas should integrate the green infrastructure were only defined in the Regulatory Decree nº 9/2009. According to this decree, green infrastructure – referred to in the document as municipal ecological structure – is defined as the "set of areas that due to its biophysical, cultural and landscape characteristics, its ecological continuity and structure, has, as the main function, the contribution to the ecological balance, protection, conservation and environmental assessment, landscape and natural heritage of rural and urban space" (*Decreto Regulamentar n.º 9/2009 | DRE*, *no date*). This regulatory decree was revoked in 2019 to ensure that the concepts linked to indicators, parameters, symbology, and graphic systematization to be employed by the territorial management instruments were up to date and in line with the development of the legal system. In the new version, the concept of ecosystem services was also introduced (Maranha, 2022).

In the Portuguese spatial planning framework, green infrastructure is incorporated within the master plan at the municipal level, which is a legally binding document. However, according to Portuguese law, green infrastructure is also composed of other legally binding elements, such as RAN, REN, and DPH (National Agriculture Reserve, National Ecological Reserve, and Public Water Domain, respectively). The green infrastructure within the urban boundary includes public green spaces as well as other spaces required to maintain environmental balance and protect natural heritage, i.e., areas that support the regulation of the hydrologic cycle, bioclimatic regulation, improvement of air quality, and biodiversity preservation. Outside the urban boundaries, the green infrastructure is composed of areas that belong to the so-called "Fundamental Network for Nature Conservation" as well as natural areas which are prone to risks, vulnerable and areas selected due to municipal protection and preservation interest of natural and landscape heritage (Vaz, 2018). The legal framework for nature and biodiversity conservation states that the "Fundamental Network for Nature Conservation" is composed of core areas for nature conservation and preservation (National Network of Protected Areas, Natura 2000 Network, and Classified areas under international commitments) and continuity areas (RAN, REN, and DPH) (*Legislação Consolidada - Decreto-Lei n.º 142/2008 - Diário da República n.º 142/2008, Série I de 2008-07-24 | DRE*, *no date*).

4.3 Methodology

4.3.1 Study Area

With a population of approximately 2,870,770 inhabitants, Lisbon Metropolitan Area is the most densely populated metropolitan area in Portugal, and the third most populated in the Iberian Peninsula (*INE - Plataforma de divulgação dos Censos 2021 – Resultados Provisórios*, *no date*; Mascarenhas *et al.*, 2016; Monteiro *et al.*, 2022). Located on the Atlantic coast, LMA spans an area of roughly 3015 km^2, corresponding to almost 3.4% of Portugal's mainland territory (Marat-Mendes *et al.*, 2021), and encompasses 18 municipalities including the country's capital Lisbon: Alcochete, Almada, Amadora, Barreiro, Cascais, Lisboa, Loures, Mafra, Moita, Montijo, Odivelas, Oeiras, Palmela, Seixal, Sesimbra, Setúbal, Sintra e Vila Franca de Xira (figure 4.1). The LMA integrates two main distinct sub-regions: Greater Lisbon and Setubal Peninsula, separated from each other by the Tagus Estuary. These areas are very different from both demographic, economic, and social points of view. The Greater Lisbon Area is organized around the capital - Lisbon - and constitutes one of the largest centres of business services and public services in Portugal (Marat-Mendes *et al.*, 2021). Setubal Peninsula, on the other hand, is characterized by a strong industrial tradition (Ferreira, Monteiro, *et al.*, 2021).

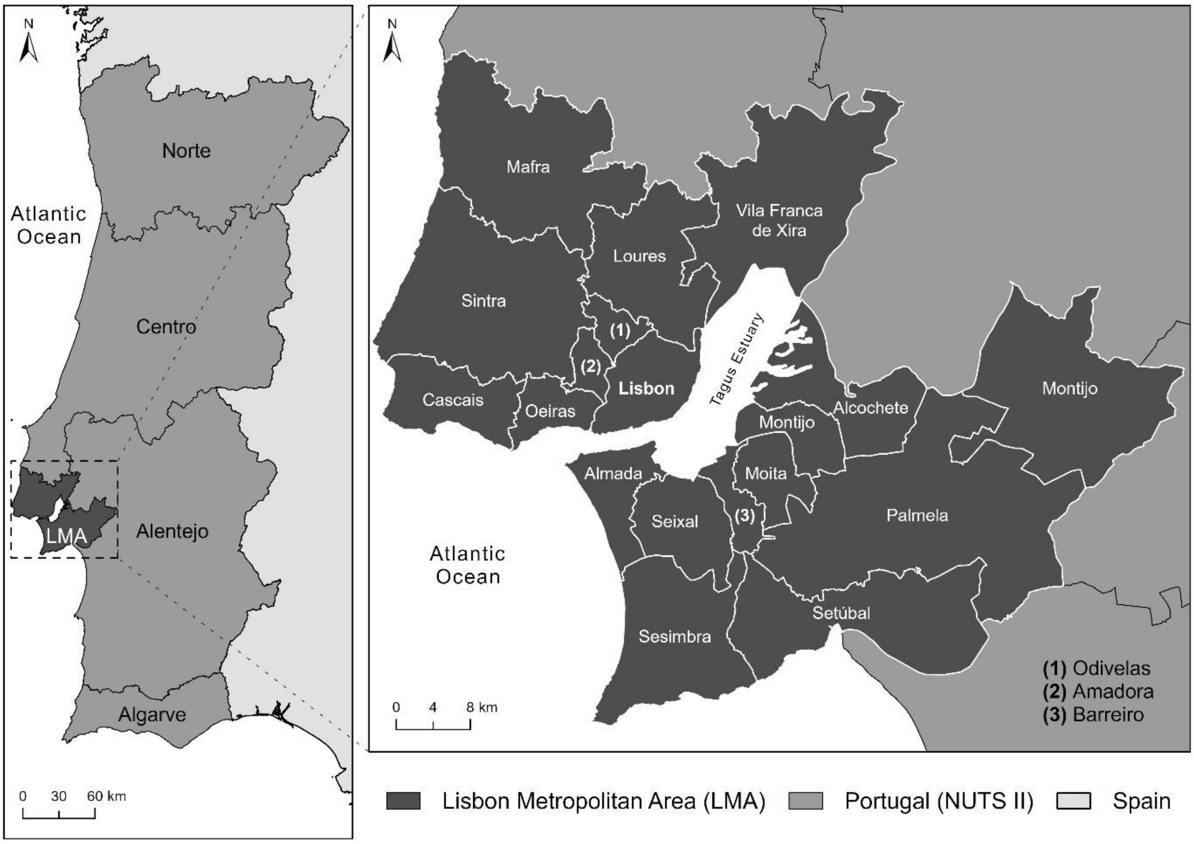

Figure 4.1 - Lisbon Metropolitan Area (Data from CAOP 2012)

According to the Regional Plan of Territorial Planning of Lisbon Metropolitan Area (PROT-AML), this area of Portugal has the highest GDP per capita, the widest range of activities, the densest concentration of knowledge-based enterprises, the most creative expression, and the best regional interconnectedness on a national scale (CCDR_LVT, 2002). Even though LMA is markedly occupied by built-up areas, making it the densest area in the country, it also has a diversity of landscapes and resources, 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). In fact, nearly 50% of the region's land has agriculture and forestry as its main uses. LMA includes eight areas of nature protection that are part of the Natura 2000 network, as well as nine national protected areas, covering around 15% of the region’s area (CCDR_LVT, 2002; *European Environment Agency*, 2021).

In this study, because the concept of green infrastructure (or ecological structure, as the Portuguese law names it) only appeared in the Portuguese law in 1999, only the master plans published after this year were considered. To this date, only nine out of the 18 municipalities considered have their second-generation masterplans published – Cascais, Lisboa, Mafra, Moita, Odivelas, Oeiras, Seixal, Sintra, and Vila Franca de Xira. However, two municipalities have their master plans under evaluation to be published in the near future, which also were considered – Amadora and Setúbal. All documents were either taken from the municipalities' websites or provided directly by the responsible for the urban planning department of the respective municipality. Table 4.1 shows the master plans considered in this study, as well as the documents analysed and the year of its publication.

Table 4.1 - Spatial plans considered in this study, date of publication, and plan components

Municipality	Year of publication	Information base	Vision, objectives, and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)
Alcochete	1994	Not considered				
Almada	1993	Not considered				
Amadora	2021	X	X	X	X	X
Barreiro	1994	Not considered				
Cascais	2014	X	-	X	X	X
Lisboa	2012	X	X	X	X	X
Loures	2015	Not considered				
Mafra	2015	X	X	X	X	X
Moita	2007	X	X	X	X	X
Montijo	1997	Not considered				
Odivelas	2015	X	X	X	X	X
Oeiras	2015	X	X	X	X	X
Palmela	1996	Not considered				
Seixal	2014	X	X	X	X	X
Sesimbra	1998	Not considered				
Setúbal	2021	X	X	X	X	X
Sintra	2017	X	X	X	X	X
Vila Franca de Xira	2009	X	X	X	X	X

4.3.2 Qualitative content analysis of strategic plans documents

Qualitative content analysis (QCA) is a research method used for describing and interpreting textual data through a systematic coding procedure (Assarroudi *et al.*, 2018). Qualitative content analysis research focuses on the properties of language as communication, with a focus on the text's content or context meaning. Text data can come from narrative responses, open-ended survey questions, interviews, focus groups, observations, or print sources like articles, books, or manuals (Assarroudi *et al.*, 2018; Elo & Kyngäs, 2008; Hsieh & Shannon, 2005). The result of data analysis is the identification of categories, themes, and patterns.

There are two types of qualitative content analysis: Inductive and deductive (Bengtsson, 2016; Elo & Kyngäs, 2008; Kibiswa, 2019). The inductive approach – or conventional approach (Hsieh & Shannon, 2005) – is used when the existing theory or research literature on a phenomenon is limited if this knowledge is fragmented. When the structure of the analysis is operationalized based on prior knowledge and the study's goal is hypothesis testing, deductive content analysis – or directed content analysis – is applied. According to Elo & Kyngäs, (2008), inductive data-based approaches progress from the specific to the general, while deductive data approaches progress from general to specific. Although there are discipline-specific rules and investigator styles in doing content analysis, there is no universal content analysis schema that should be followed. In terms of the research process, experts do not recommend a specific method for doing qualitative content analysis, whether inductive or deductive (Kibiswa, 2019).

Content analysis is a suitable research approach for systematically evaluating the content of a local master plan as a product of the plan-making process and as an input into the local development management decision-making process (Norton, 2008). Because spatial plans are "communicative policy acts", this method is usually employed to determine whether certain plan characteristics or criteria are present in the plans (Lyles & Stevens, 2014). This evaluation might influence local development and outcomes regarding the criteria that are being evaluated, and lead to changes in the decision-making processes.

The aim of this research is to evaluate the extent how the green infrastructure planning principles previously mentioned are included in spatial plans. However, for this research, only local master plans were considered in the qualitative content analysis because these are the main territorial management instruments in the Portuguese context responsible of changing the territory in the whole country and implement public policies. These instruments apply, directly in the territory, the guidelines and macro-orientations of the plans and programs of higher hierarchy, such as PNPOT and PROT.

The analysis of the strategic spatial plans was based on a modified version of the approach proposed by Baker *et al.*, (2012) and Geneletti & Zardo, (2016) where a "direct content analysis" was performed. The authors carried out the analysis by reading all the documents linked with the chosen plans and identifying the content related to the GI planning principles for each of the documents. Given that there is still no well-established language on this subject, and plans employ a variety of vocabulary to refer to ideas linked to green infrastructure in general (Conway *et al.*, 2020; Llausàs & Roe, 2012; I. Mell *et al.*, 2017a; Monteiro *et al.*, 2022), this technique was recommended over a keyword-based analysis (Gradinaru & Hersperger, 2019). As a result, we looked for the presence of the various measures, regardless of whether the plan used the name of the principle considered or not (Geneletti & Zardo, 2016; Rozas-Vásquez *et al.*, 2018).

4.3.3 Plans evaluation components

The plans' content was separated into five categories prior to the analysis and is a modified version of (Baker *et al.*, 2012): information base; vision, objectives, and strategy; management regulation; actions and implementation; and visual representation. These components represent thematically different parts of the plans. The information base includes an examination of the territory's conditions at the time the plan was implemented. The description of the plan's ambition and strategy, as well as the general and particular objectives and goals the plan seeks to achieve in a long-term vision, are included in the vision, objectives, and strategy. Documents with a description and methodological explanation about green infrastructure – which Setúbal and Vila Franca de Xira have – were also included in this section. The management regulation defines standards and rules for land use, occupation, and transformation within the municipal territory. The actions and implementation plan proposes a set of actions (projects and actions) to meet the plan's objectives and aims. And the visual representation depicts the municipal territory's spatial organization concept, which incorporates the delimitation of municipal green infrastructure.

These five plan components were used to evaluate the plan quality, and they reflected the key functional portions of a plan production, which influence the overall quality of a plan. Plan quality evaluation involved rating how well each of the eight GI planning principles were reflected in relation to the five plan components, shown in table 4.2.

Table 4.2 - Description of plan components used as evaluation categories in the plan quality evaluation

Plan component/Part	Concepts
Information base	The information base includes the analysis of the conditions of the territory at the time the plan was executed. This section usually includes data and analysis of local assets and natural resources, social and economic data, and risk assessments, among others. This information is typically presented in the introductory parts of the planning documents or in a side document and is performed to provide a basis for the subsequent development of the plan’s objectives and actions.

Vision, objectives, and strategy (Report)	This section includes the statement of the ambition and strategy of the plan, as well as the general and specific objectives and goals the plan intends to achieve in a long-term vision.
Management Regulation	The management regulation is a mandatory document that accompanies the strategic plan and establishes the guidelines and rules for the use, occupation, and transformation of land use in the entire municipal territory.
Actions and Implementation	The actions and implementation plan consist of a group of measures (projects and actions) that the plan proposes, to achieve its objectives and goals. This section may include spatial designs, policies, and/or strategies for implementation (including budget-related ones) to ensure that actions are carried out.
Visual representation (Maps)	The visual representation represents the spatial organization model of the municipal territory and includes the delimitation of the municipal green infrastructure.

4.3.4 Scoring system

To evaluate the local strategic spatial plans regarding the GI planning principles, a coefficient system was used to measure the qualitative assessment quantitatively, which allocated quantitative values to the evaluation categories. Using a five-point scale (0,1,2,3 and 4), each component of the local plans – as previously stated – was evaluated in regard to the level of integration of each of the GI planning principles considered (Baker *et al.*, 2012; Cortinovis & Geneletti, 2019; Jaligot & Chenal, 2019). A score of 0 is given when there is no evidence of the GI planning principle in the document. When it is mentioned but not further explained, or when the explanation is unclear, a score of 1 is awarded. A score of 2 is given when the principle is mentioned but lacks local application and analysis. However, if the principle is mentioned in the document and includes a limited level of locally specific application, a score of 3 is given. A score of 4 is given if a detailed analysis of the principle is provided and it is addressed in a locally specific manner (table 4.3). The goal of this procedure is to determine how well GI planning principles are entrenched in planning and to make comparisons between plans easier (Jaligot & Chenal, 2019).

Table 4.3 - The scoring system used to code data

Coefficient	Meaning
0	No evidence of the principle throughout the document
1	The principle is acknowledged but lacks further definition and there is no detail provided
2	The principle is mentioned and includes a moderate level of detail. However, it is entirely descriptive and lacks local application and analysis.
3	The principle is mentioned and includes a limited level of a locally specific application. However, it is largely descriptive.
4	A detailed analysis of the principle is provided, and it is addressed in a locally specific manner

Each plan quality score regarding the GI planning principles was derived by aggregating the plan quality component scores. Each GI planning principle had a maximum score of 20 points (five plan components, each with a total possible score of four). Each overall plan quality score was the sum of its specific criteria ratings and the maximum potential score of the plan regarding the integration of GI planning principles was 160 (i.e., eight GI planning principles, each with a total possible score of 20). Finally, the final results were normalized and converted to percentages (Baker *et al.*, 2012).

In this type of evaluation, a certain amount of subjectivity was unavoidable (Baker *et al.*, 2012; Drestalita & Saputra, 2019; Jaligot & Chenal, 2019). However, to improve uniformity and reliability in the awarding of ratings, only one person evaluated each plan, and all its components. Similar to the work of (Baker *et al.*, 2012), our evaluation was mostly qualitative in character and did not use statistical approaches, despite the fact that it used a quantitative framework to code the data.

4.4 Results and Discussion

In this research, all 18 municipalities of the Lisbon Metropolitan Area were contacted and invited to participate in this study. The main purpose of this study was to analyse the local spatial plans of the contacted municipalities regarding the integration of green infrastructure planning principles. However, not all municipalities were available to participate in this study, due to the fact their master plans were not available yet and, because of that, only 11 spatial plans were evaluated. As previously stated, all documents were either taken from the municipalities' websites or provided directly by the responsible for the urban planning department of the respective municipality.

The eight green infrastructure planning principles identified previously by Monteiro *et al.*, (2020) – connectivity, multifunctionality, applicability, integration, diversity, multiscale, governance, and continuity – were used to measure local government progress towards green infrastructure planning. As previously stated, in the Portuguese legal framework, the concept of green infrastructure is referred to as municipal ecological structure, and, as this concept, some green infrastructure planning principles also had different terms in the Portuguese spatial planning framework. So, because of that, the evaluation conducted in this study had to consider these nuances. Overall, none of the municipalities received at least 50% of the total possible scores, which means all municipalities analysed present significant challenges regarding the integration of green infrastructure planning principles in their planning strategies. The municipality of Setúbal received the highest score (40% of the total possible score), followed by Lisboa, Odivelas, and Oeiras (30% each) and Cascais (29%). The municipalities with the lowest scores were both Mafra and Moita, with 13% of the total possible score each (figure 4.2).

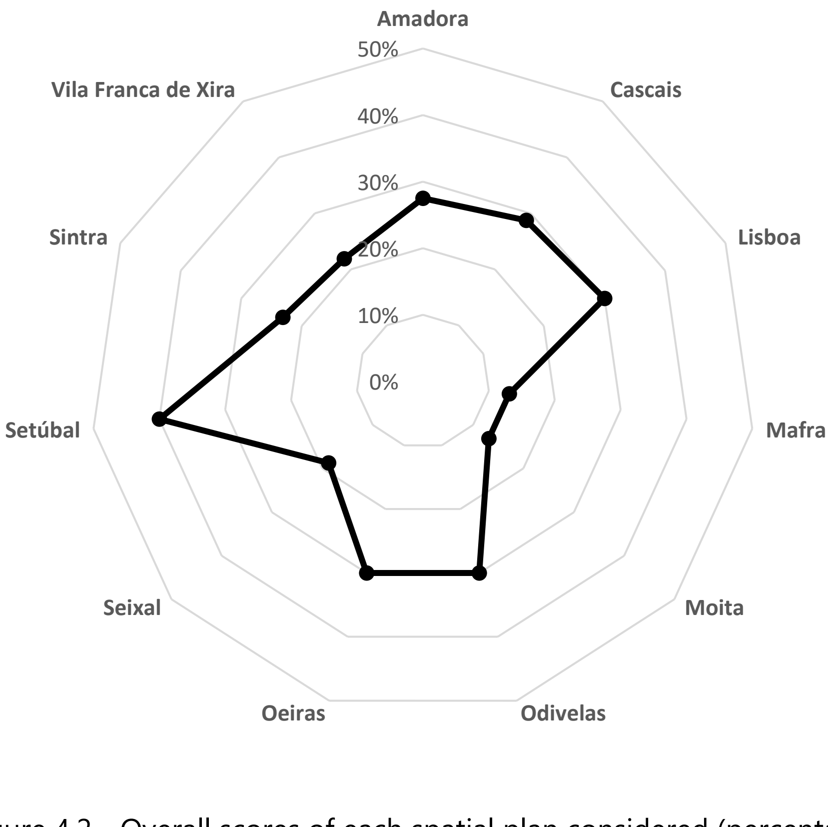

Figure 4.2 - Overall scores of each spatial plan considered (percentage)

A study conducted by H. W. Kim & Tran, (2018) where the authors employed a content analysis method to examine the quality of local comprehensive plans regarding sustainable green infrastructure in 60 municipalities in the United States, found the low scores of sample plans might be caused by plans that are outdated. Because recent concepts and practices regarding green infrastructure are included within our evaluation criteria, the considered plans that were not recently updated should have relatively low scores compared to up-to-date plans. However, although the most recent plan analysed is the one with the highest score (Setúbal) and the oldest one is the municipality with the lowest score (Moita), some of the other results do not follow this logic. For example, Amadora also has a very recent spatial plan (2021), but the level of integration of the green infrastructure planning principles is not that high when compared with other municipalities that have not so recent spatial plans, such as Cascais (2014), Lisboa (2012), Odivelas and Oeiras (2015). The same happens with Mafra, which has one of the lowest scores, but its plan dates 2015, the same as Odivelas and Oeiras. Contrary to what was expected, these results show that the date of the spatial plans is not the only factor influencing the level of integration of green infrastructure planning principles into planning strategies. In fact, it depends on other factors, such as the urban planners and practitioners' knowledge of the topic, as well as the political will to change to a more sustainable spatial planning that relies on green infrastructure and nature-based solutions.

One of the observations of these results is that all planning principles are followed by at least half of the analysed plans (figure 4.3). Nevertheless, some of them are more frequently observed than others. Additionally, there are some differences in how each planning principle is interpreted. Considering each principle individually, it is possible to see that connectivity and diversity are the most mentioned principles in the spatial plans analysed. In fact, if we sum all the individual scores of each municipality, the connectivity and diversity principles are the ones with the highest score (82). Despite that, if we look at each individual score (Appendix B), it is possible to see the connectivity principle has the highest score in more municipalities than diversity, which is in line with the findings of Monteiro *et al.*, (2020) and Gradinaru & Hersperger, (2019). Connectivity not only is one of the most frequently mentioned green infrastructure planning principle in the literature, but also one of the most found in planning strategies and spatial plans across Europe, in which the Lisbon Metropolitan Area is included. Plus, according to another study conducted by Monteiro *et al.*, (2022), where practitioners were asked to prioritize the same eight green infrastructure planning principles of this study, connectivity was also the principle with the highest score. Diversity, on the other hand, came as a surprise. Although considered by some authors as key principles for green infrastructure planning, diversity and integration are still relatively new concepts when compared with connectivity, for example. If we look at the scores individually, we can see that results are no higher than the connectivity principle, but the fact that Setubal has such a higher score for this principle (15), made the final score go up. In addition, diversity was the least scored principle by practitioners in the study developed by Monteiro *et al.*, (2022), which adds more questions to our results. However, those results may be explained because the diversity principle is already so embedded in the planning strategies of the municipalities considered, and so, it was not considered so important by the practitioners in that study in particular.

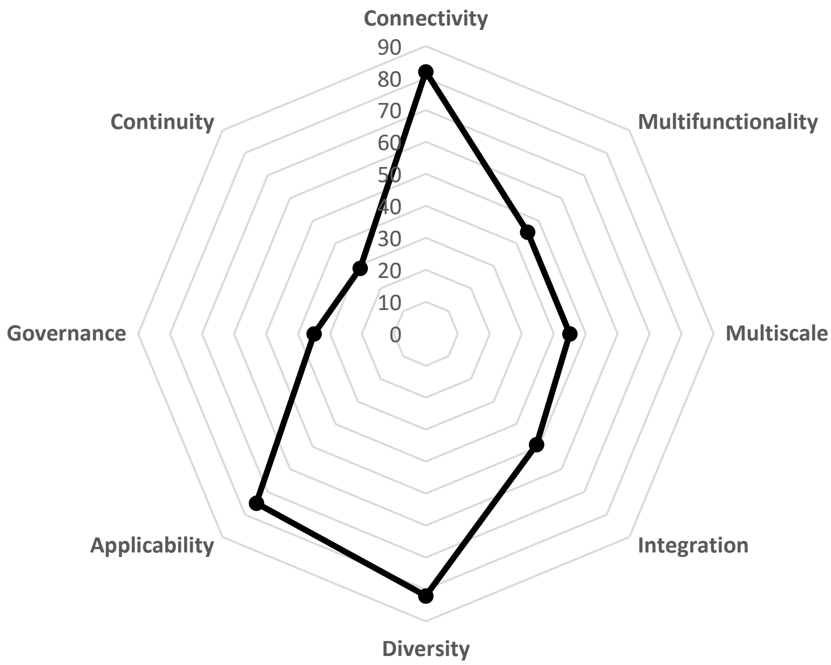

Figure 4.3 - Overall scores of each green infrastructure planning principle in the spatial plans sample

Even though multiscale and integration have been often considered important elements in green infrastructure planning by some authors (Girma *et al.*, 2018; Hansen *et al.*, 2017), they were not considered as relevant as other principles in the spatial plans of the municipalities analysed in this study. Both the multiscale and integration principles appear with similar global results, namely 45 and 49, respectively. For these two principles, Setúbal is the municipality that presents higher individual scores (including for multifunctionality), however, is interesting to see that all municipalities mentioned both principles considered (in different levels), except for Moita, which does not incorporate the multiscale principle in their planning strategies. In fact, this municipality is the only one that does not integrate two green infrastructure planning principles in its spatial plan – multiscale and continuity –, which is coherent with the findings of the previous study by Monteiro *et al.*, (2022). In their study, when the practitioners of Moita were asked about the importance of each green infrastructure planning principle, the continuity one was the least voted by them, followed by multiscale. So, the lack of integration of both these principles in Moita's spatial planning does not come as a surprise. In addition, in the same study conducted by Monteiro *et al.*, (2022), the applicability and governance principles were also considered not as important as others (e.g. connectivity), but, in our results, both these principles have the highest individual scores for Moita. However, these scores are still very low, when compared with the highest possible individual score of each principle (20), as well as the individual scores of other principles in other municipalities (e.g., diversity in Setúbal).

As one of the most frequently referenced green infrastructure planning principles in the literature, multifunctionality is seen by many authors as a fundamental component of green infrastructure development. Multifunctionality has been used by the pioneers of this research field since its beginning and even in the definition of green infrastructure, it is possible to identify this principle. However, multifunctionality was one of the least considered principles in the eleven spatial plans analysed in the present study, as well as in a recent study conducted in Ethiopia (Ayele *et al.*, 2022). Multifunctionality is the principle that is directly connected with the provision of ecosystem services, namely provision, regulation, support, and cultural. A multifunctional green infrastructure is capable to provide multiple social, ecological, and economic functions and possesses a much higher resilience when compared with similar instruments that do not encompass this principle. But the concept of ecosystem services is still not well perceived by urban planners, practitioners, and decision-makers, as well as established in planning policies. According to Qiu *et al.*, (2022), research on ecosystem services for planning and relevant case studies are largely theory-inspired, with few practice-inspired studies. Existing studies also have demonstrated that while few policy and guidance documents have explicitly referenced ecosystem services, implicit references to them can be found where plans refer to the benefits provided by nature, as happens in the present study. However, the inclusion of ecosystem services appears uneven and potentially limited to a few services when an ecosystem service-based approach has not been adopted (Lam & Conway, 2018).

Contrary to the previous ones, applicability, governance and continuity are not considered core green infrastructure planning principles in the literature (Monteiro *et al.*, 2020). Because of that, the low scores on governance and continuity principles were expected. As previously stated by Monteiro *et al.*, (2022), Portuguese local governments lack the necessary financial and personnel resources, as well as the necessary knowledge of public participation, and, as a result, the law is not always easily applied in all areas of public administration. Additionally, because public participation procedures are typically lengthy and difficult, they are frequently underestimated in the context of spatial planning. The same is true with the continuity principle. Due to a lack of financial resources, local authorities are unable to monitor green infrastructure (and other) projects, even though a monitoring plan is usually presented in their planning strategies. Plus, most of the monitoring actions described in the analysed plans relate to the quality of water, air, and other environmental features. Applicability, on the other hand, has one of the highest global scores, mainly due to the management regulation component of the plans. Although the principle is not specifically identified and described in those documents, several measures for the implementation of actions and projects are presented in the management regulation, which is a mandatory document that accompanies the strategic plan.

In this study, contrary to the findings of Gradinaru & Hersperger, (2019), there was no level of ambiguity regarding the definition of the green infrastructure concept provided in the plans, because all plans relied on the same definition, incorporated in the Portuguese law. Besides that, no clear-cut pattern was observed regarding the way in which each municipality approach green infrastructure planning, namely the incorporation of its planning principles, which may be linked to the very nature of strategic spatial planning. This suggests that strategic plans are developed to address specific regional issues and adjust to unique planning settings, meaning that significant variances may exist even within the same planning system (Albrechts, 2004; Gradinaru & Hersperger, 2019). Additionally, the absence of green infrastructure planning principles in local spatial plans may be caused by the preferences of the professionals involved in the planning process (Lennon *et al.*, 2017), the term's novelty (Davies & Lafortezza, 2017), a lack of familiarity with or understanding of it, or the use of terms that are already defined by national law (Niță *et al.*, 2018).

4.5 Conclusions

Green infrastructure planning has received a lot of focus recently and studies on how spatial plans address green infrastructure have increased. However, research on how local spatial plans integrate green infrastructure planning principles is scarce, especially in the Portuguese context. Considering a multicriteria evaluation of green infrastructure planning principles integration into spatial plans in Lisbon Metropolitan Area, this research provides a multifaceted picture of gaps in spatial planning to address and incorporate GI concepts, components, functions, and principles.

The results of this study have revealed that municipalities are likely to have a relatively low awareness of green infrastructure, because the overall scores were all below 50% of the total possible score. This means all municipalities analysed present significant challenges regarding the integration of green infrastructure planning principles in their planning strategies and that local planners might not recognize the importance of green infrastructure or systematically embrace the major strategies and components of green infrastructure planning. Because of that, more workshops, training, and outreach programs should be offered to diverse entities to promote its understanding on green infrastructure. Also, local governments ought to offer a wider range of policies that combine regulations and incentives. In addition, the results for each individual principle shows that neither one of the 11 plans examined follows a similar pattern in terms of how much the planning principles are taken into account. There is no common strategy among the plans, which may be explained by the strong context-specific development of green infrastructure in the strategic spatial plans. Additionally, in terms of methodology, the variation shows that the eight green infrastructure principles represent independent aspects of green infrastructure.

Although this study focused on a specific case study, similar to other studies, these findings serve as a wake-up call to planning and municipal authorities worldwide about the development, implementation, and monitoring of green infrastructure policies. The assessment framework used in this study and the eight criteria considered (green infrastructure planning principles) offer a widely available, easy and accessible self-assessment tool that can be used in planning research and practice to evaluate the effectiveness of existing and new green infrastructure policies in distinct strategies or development plans, at various scales.

This study methods and results close a significant gap in knowledge and application, and it is important to help shape future green infrastructure planning practices globally. However, as this is only a pilot study, there are some limitations that should be addressed in forthcoming studies a great deal of room for the framework to improve. For example, this evaluation could be complemented with some detailed interviews with practitioners of the municipalities, in order to understand some of the results and a wider sample could also be used, in other to evaluate if there is in fact, or not, a pattern in terms of how much the green infrastructure planning principles are taken into account in spatial plans. Also, only generic municipal master plans were assessed. Other plans may also address green infrastructure but were not considered in this study. Therefore, while evaluating the success of local government on the subject of green infrastructure, just examining comprehensive plans may omit some viable plans. Future research on other regional plans that incorporate green infrastructure planning would be useful.

5

CONCLUSIONS AND RECOMMENDATIONS

The integration and implementation of green infrastructure into spatial planning are key to the growth of more competitive, resilient, and inclusive communities, as well as to the increase of sustainable development. This topic has been gaining attention in literature and practice for a few decades now, however, there is still some complexity related to it, which influenced this research. Thus, the present research aimed to simplify and understand the overall green infrastructure planning processes, by proposing a set of green infrastructure planning principles that should be considered in spatial planning and analysing how they were integrated into policies and environmental planning, having the Lisbon Metropolitan Area as a case study.

The overall research goal is divided into three research questions which are addressed in a transdisciplinary approach including a variety of methods. This research particularly contributes to the literature on green infrastructure planning through i) a literature review on existing green infrastructure planning principles and practices across different geographies; ii) an empirical study on understanding the views of practitioners and urban planners on the green infrastructure planning principles; iii) and another empirical study on how local spatial plans integrated those green infrastructure planning principles considered. This concluding chapter highlights the key findings and recommendations for practitioners, as well as the limitations of the study and further research needs.

5.1 Key findings of the research

This research aimed to understand which green infrastructure planning principles should be considered in spatial planning and how practitioners and policymakers were integrating them into policies and environmental planning. To achieve that, the research is organized into three distinct, yet related chapters.

The landscape of previous research on green infrastructure planning and the research gaps were provided as a first step towards achieving the aim (Chapter 2). This first review of the literature on the topic has shown that, although there is a substantial number of studies regarding this matter, the concept of green infrastructure and associated implementation actions are still being discussed among researchers, decision-makers, and practitioners. In fact, despite recent improvements, researchers and practitioners are still divided over the definition of green infrastructure and the best ways to implement it at the local level. Furthermore, this chapter has also shown that this concept is used loosely by many actors, which leads to a wide range of interpretations depending on the context in which the term emerged. The many conceptions identified in the literature are also influenced by the geographical location and cultural dynamics in which green infrastructure is implemented. This is evident in the two different interpretations that predominate in the literature: one frames green infrastructure as an engineered technology to manage stormwater flow or water quality, which is heavily influenced by North American planning practices; and another emphasizes the role of green and blue spaces in providing a wide range of ecosystem services. Lastly, the literature review shows that despite various studies that have identified some planning principles for green infrastructure planning, some of those principles are shown to be overly theoretical and do not adequately reflect the execution and implementation of green infrastructure in spatial planning.

Based on this transdisciplinary literature review and using a holistic perspective, a conceptual framework was developed (Chapter 2) as a contribution to green infrastructure planning research. This review proposed a set of green infrastructure planning principles be incorporated in spatial planning, based on the different areas of research and elements highlighted as missing by previous literature that needed further study. Those principles were connectivity, multifunctionality, multiscale, integration, diversity, applicability, governance, and continuity, and intended to promote and simplify the development and use of green infrastructure by different academic and implementation organizations. Although these eight principles were the most found in the literature, the results showed that the connectivity, multifunctionality, and multiscale ones were the most frequently mentioned, and are often considered core green infrastructure planning principles, as opposed to others.

Green infrastructure planning principles are relevant on a global scale because they help guide practitioners and decision-makers in the formulation and execution of strategic plans. Additionally, these principles can also be used to assess spatial planning in regions with various characteristics (urban and/or rural). Yet in some European nations, such as Portugal, these concepts are not frequently discussed among practitioners (as well as residents). For that reason, chapter 3 aims to understand the views of urban planners regarding the green infrastructure planning principles identified in the previous chapter, and to assess their priorities for each principle. To achieve that, an Analytic Hierarchy Process methodology was applied to urban planners working in the 17 municipalities of Lisbon Metropolitan Area, to prioritize the green infrastructure planning principles influencing green infrastructure design and development at local scale. The practitioners (which included engineers, architects, geographers, etc.) were asked to prioritize the eight green infrastructure planning principles identified in the previous chapter. The results showed that connectivity and multifunctionality were also the principles with the highest scores, which was consistent with the findings of the literature review. Furthermore, the applicability principle, although not very established in the literature, is, at the moment, one of the most important green infrastructure principles for urban planners and practitioners In the Lisbon Metropolitan Area, because there is, nowadays, an increasing intention by the local administration to implement nature-based solutions to deal with environmental pressures, such as climate change.

Chapter 3 contributes to new knowledge by providing empirical evidence on how public employees perceive green infrastructure planning principles. In addition, this chapter also contributes to the calls made by previous literature for the inclusion of practitioners' views regarding green infrastructure planning, as opposed to the conceptual and theoretical studies typically found in the literature. Besides that, although the results of this chapter were important to evaluate and understand the level of commitment of local authorities about this issue, it is still unclear how current local spatial plans integrate green infrastructure and its planning principles. To answer that, chapter 4 was developed to critically examining on how green infrastructure is being perceived in local spatial plans, having the same municipalities of Lisbon Metropolitan Area as the case study.

In the last chapter of this thesis, the results showed that municipalities considered in the study disregard green infrastructure in their spatial plans and that every one of them faces significant difficulties in incorporating green infrastructure planning principles into their planning strategies. Additionally, the findings also demonstrated that none of the plans examined adhere to a comparable pattern in terms of how much the planning principles are considered, which means that strategic plans are developed to address specific regional issues and adjust to unique planning settings, meaning that significant variances may exist even within the same planning system. Furthermore, the lack of green infrastructure planning principles in local spatial plans could be a result of the preferences of the professionals involved in the planning process, the terms' novelty, a lack of familiarity or understanding with it, or the use of concepts that are already defined by national law. This chapter contributes to green infrastructure planning research by providing empirical evidence of the extent to which green infrastructure planning practices are embedded in Portuguese local spatial plans as well as insights into the main implementation strengths, weaknesses, challenges, and opportunities for the public sector to consider for future research and practices.

Each of the chapters of this thesis presented a different methodological approach to answer a different research question and the results varied in each of the chapters. In chapter 2, as previously stated, connectivity, multifunctionality, governance and multiscale were the ones most frequently mentioned in the literature, and applicability the one least considered (table 5.1). As for the chapter 3, connectivity was the principle considered most important for the practitioners, as well as the most observed in the local spatial plans (chapter 4). This does not come as a surprise, as connectivity and multifunctionality have been used as key principles for green spaces and greenways development worldwide since the beginning of green infrastructure research. However, applicability is one of the most relevant principles for the spatial planners and is one of the most found in the spatial plans analysed, which demonstrates that there is an increasing concern among planners regarding the development and implementation of green infrastructure at the local level.

Table 5.1 - Ranks of green Infrastructure planning principles in each method used in the research

Rank	Literature review	AHP	Local plans analysis
1	Multifunctionality	Connectivity	Connectivity
2	Governance	Multifunctionality	Diversity
3	Connectivity	Applicability	Applicability
4	Multiscale	Governance	Integration
5	Diversity	Integration	Multifunctionality
6	Integration	Multiscale	Multiscale
7	Continuity	Continuity	Governance
8	Applicability	Diversity	Continuity

Although there is no pattern in the results in each of the chapters, all in all, the theoretical contribution of this thesis is the transdisciplinary approach taken. By establishing a connection between the theory and practices of green infrastructure planning in local public administrations, this research exemplifies and adds value to land management research. The transdisciplinary theoretical approach used in this thesis paves the way for new efforts to include green infrastructure planning principles into upcoming planning strategies and perhaps even aid to improve already successful sustainability performance outcomes. This research is able to bring together several subjects that had previously been addressed separately into one picture or framework while also stressing the significance of external factors including political, geographic, and institutional contexts.

Furthermore, a comprehensive in-depth case study is also used as part of this thesis' overall methodological contribution to produce empirical data on the complex phenomenon of green infrastructure planning principles integration in local spatial planning, which has previously gone overlooked in the literature. A mixed methods approach was used in this research to gather data, which is essential for obtaining a variety of information from various perspectives on the phenomenon in one specific setting. The set of methods, which included document analysis, literature reviews, and interviews, has validated information and enhanced the data sources in this study. It has opened the door for follow-up research to adopt this methodological approach in different settings or for complementary studies to use different, yet unexplored approaches.

5.2 Recommendations for practitioners

The conceptual framework presented in chapter 2 can help practitioners to view green infrastructure planning as a means toward a more sustainable spatial planning in order to contribute to more resilient communities. It can help bring awareness of a broader scope of green infrastructure as well as help practitioners and decision-makers during the conceptualization and planning of green infrastructure at the local level. The framework highlights the green infrastructure planning principles that should be considered in spatial planning in the implementation of nature-based solutions. This framework can be used by public sector practitioners as a support tool in land management for proactive and conscious green Infrastructure implementation at the local level.

Similarly, the two empirical chapters (Chapters 3 and 4) have the potential to support decision-making processes for public practitioners in defining priorities for the design, implementation, and monitoring of green infrastructure. The views of practitioners in chapter 3 on this topic and the evaluation of local spatial plans in chapter 4 could be used in prioritization exercises to build a vision and a strategic plan for the municipalities in which public sector practitioners identify, choose, and prioritize which are the best green infrastructure principles and planning practices with the most potential to implement. In addition, the results of these both chapters demonstrated the urgency of implementing more sustainable planning solutions, such as green infrastructure practices, in order to tackle the upcoming environmental, social, and economic challenges in the next few decades.

Despite the great potential for further implementation of green infrastructure, the rigid nature of spatial plans, the complexity of concepts on the topic, and the different political agendas are some of the barriers to the implementation of green infrastructure planning principles at the local level. Plus, the lack of human capital as well as financial resources creates enormous pressures among local authorities, leading to a shortage of investment in green infrastructure. Therefore, it is recommended for the public sector, in the case of green infrastructure planning and in spatial planning in general, to focus on and rethink the planning policies and the governance dynamics in the local authorities. Also, engaging in more employee empowerment initiatives and increasing employee training, participation, and collaboration between academia, private sectors, industry and leadership, and other employees regardless of hierarchy, represent a major opportunity to accelerate green infrastructure implementation.

5.3 Limitations of the study

This research presents two overall limitations that are important to acknowledge. Firstly, the amount of case studies considered in the research. Because only a few municipalities were considered in the study (17 in chapter 3 and 11 in chapter 4), there was little basis for generalization and, because of that, there was a limited external validity. The inclusion of more municipalities in the study could have resulted in more generalized results. However, the aim of this thesis was to get a deeper understanding of the integration of green infrastructure planning principles into spatial planning, and the use of such case studies allowed an in-depth, holistic view of a phenomenon that still can be instructive about other similar cases.

Secondly, this research was conducted over a period of four years from conceptualization to writing this dissertation. Therefore, data collection processes had to be performed in a relatively limited amount of time. In addition, because the case study involved local authorities, the process of collecting data and testimonials is, sometimes, hampered by bureaucratic procedures, confidentiality, lack of Interest by the local authorities, and, even, conflict of agendas. Research on policymaking, land management, and changes involving individuals with behaviours and habits require long-term analysis. Thus, having the opportunity to observe the change or the resistance to change regarding this topic over time could benefit this research. Plus, because the green infrastructure planning in Portuguese local authorities is at a low maturity stage as a research field, more time to conduct the research could also bring new insights to this study. Nevertheless, this research answered the research questions initially proposed and presented interesting, viable, and innovative results that may help shape future studies.

5.4 Future research needs

This research contributes to the literature by answering three important research questions in the field of green infrastructure planning in local government authorities. However, many other relevant questions to the field remain open and need to be addressed in future research. This research can serve as a departure point for future contributions.

First, although it has improved over the past few decades, the majority of practitioners in the public sector still find green infrastructure planning to be exceedingly complex and ambiguous. As a result, green infrastructure implementation procedures are frequently insufficient and poorly executed. Additionally, the implementation of such nature-based projects is made more challenging by the fact that decision-makers are frequently faced with a wide range of topics and concepts, particularly in the context of sustainable development. Therefore, to drive green infrastructure implementation at the local level, it is crucial to comprehend strategies for putting and keeping this topic on the agenda of local authorities as well as how to raise it up in their priorities.

Second, it's crucial to comprehend how planning strategies for green infrastructure from the research are applied in actual organizational practice at the local level and what difficulties practitioners encounter. Similar to the current study, many of the previously published works on this subject analyse, create, and implement single case studies that are geographically restricted. Therefore, it is crucial to carry out additional empirical studies that analyse and assess how green infrastructure planning principles are implemented in practice, including more case studies with a wider geographical distribution.

Finally, it is crucial to ensure that the increasing implementation of ecosystem services and green infrastructure practices result in overall sustainable development as well as an improvement in community resilience and quality of life. Although it was not the focus of this investigation, ecosystem services are intrinsically linked to green infrastructure. Even so, although it is a concept that has gained a lot of relevance in the literature in recent years, the concept of ecosystem services is still scarce in policies and land use plans. For this reason, it is necessary for municipalities to invest in new planning approaches at different scales that consider the relationship between green infrastructure and ecosystem services.

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A

APPENDIX A - AHP INDIVIDUAL SCORES OF EACH MUNICIPALITY (CHAPTER 3)

Table A1 - Individual scores of pairwise comparison of GI planning principles (Alcochete)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	1,00	3,00	5,00	3,00	5,00	1,00	5,00
Multifunctionality	1,00	**1,00**	5,00	5,00	3,00	5,00	1,00	5,00
Multiscale	0,33	0,20	**1,00**	3,00	0,50	5,00	0,20	1,00
Integration	0,20	0,20	0,33	**1,00**	2,00	1,00	0,20	0,50
Diversity	0,33	0,33	2,00	0,50	**1,00**	1,00	0,17	0,33
Applicability	0,20	0,20	0,20	1,00	1,00	**1,00**	0,17	0,25
Governance	1,00	1,00	5,00	5,00	6,00	6,00	**1,00**	5,00
Continuity	0,20	0,20	1,00	2,00	3,00	4,00	0,20	**1,00**

Table A2 - Individual scores of pairwise comparison of GI planning principles (Almada)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	1,00	5,00	3,00	7,00	9,00	7,00	9,00
Multifunctionality	1,00	**1,00**	5,00	3,00	7,00	9,00	7,00	9,00
Multiscale	0,20	0,20	**1,00**	3,00	5,00	7,00	5,00	7,00
Integration	0,33	0,33	0,33	**1,00**	5,00	7,00	5,00	7,00
Diversity	0,14	0,14	0,20	0,20	**1,00**	3,00	1,00	3,00
Applicability	0,11	0,11	0,14	0,14	0,33	**1,00**	3,00	1,00
Governance	0,14	0,14	0,20	0,20	1,00	0,33	**1,00**	3,00
Continuity	0,11	0,11	0,14	0,14	0,33	1,00	0,33	**1,00**

Table A3 - Individual scores of pairwise comparison of GI planning principles (Amadora)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	1,00	5,00	5,00	7,00	1,00	3,00	1,00
Multifunctionality	1,00	**1,00**	7,00	7,00	3,00	1,00	3,00	1,00
Multiscale	0,20	0,14	**1,00**	1,00	5,00	1,00	3,00	1,00
Integration	0,20	0,14	1,00	**1,00**	7,00	1,00	3,00	1,00
Diversity	0,14	0,33	0,20	0,11	**1,00**	1,00	3,00	1,00
Applicability	1,00	1,00	1,00	1,00	1,00	**1,00**	7,00	3,00
Governance	0,33	0,33	0,33	0,33	0,33	0,11	**1,00**	1,00
Continuity	1,00	1,00	1,00	1,00	1,00	0,33	1,00	**1,00**

Table A4 - Individual scores of pairwise comparison of GI planning principles (Barreiro)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	1,00	1,00	3,00	3,00	1,00	1,00	3,00
Multifunctionality	1,00	**1,00**	3,00	3,00	5,00	1,00	1,00	3,00
Multiscale	1,00	0,33	**1,00**	3,00	1,00	0,33	0,33	0,33
Integration	0,33	0,33	0,33	**1,00**	1,00	1,00	0,33	1,00
Diversity	0,33	0,20	1,00	1,00	**1,00**	1,00	1,00	0,33
Applicability	1,00	1,00	3,00	1,00	1,00	**1,00**	1,00	1,00
Governance	1,00	1,00	3,00	3,00	1,00	1,00	**1,00**	1,00
Continuity	0,33	0,33	3,00	1,00	3,00	1,00	1,00	**1,00**

Table A5 - Individual scores of pairwise comparison of GI planning principles (Cascais)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	3,00	3,00	5,00	1,00	1,00	5,00	1,00
Multifunctionality	0,33	**1,00**	1,00	5,00	1,00	1,00	3,00	1,00
Multiscale	0,33	1,00	**1,00**	5,00	1,00	1,00	5,00	5,00
Integration	0,20	0,20	0,20	**1,00**	1,00	5,00	3,00	1,00
Diversity	1,00	1,00	1,00	1,00	**1,00**	5,00	5,00	3,00
Applicability	1,00	1,00	1,00	0,20	0,20	**1,00**	5,00	3,00
Governance	0,20	0,33	0,20	0,33	0,20	0,20	**1,00**	1,00
Continuity	1,00	1,00	0,20	1,00	0,33	0,33	1,00	**1,00**

Table A6 - Individual scores of pairwise comparison of GI planning principles (Lisboa)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Multifunctionality	1,00	**1,00**	1,00	1,00	3,00	1,00	1,00	1,00
Multiscale	1,00	1,00	**1,00**	1,00	5,00	2,00	1,00	1,00
Integration	1,00	1,00	1,00	**1,00**	6,00	1,00	1,00	1,00
Diversity	1,00	0,33	0,20	0,17	**1,00**	1,00	1,00	1,00
Applicability	1,00	1,00	0,50	1,00	1,00	**1,00**	1,00	1,00
Governance	1,00	1,00	1,00	1,00	1,00	1,00	**1,00**	1,00
Continuity	1,00	1,00	1,00	1,00	1,00	1,00	1,00	**1,00**

Table A7 - Individual scores of pairwise comparison of GI planning principles (Loures)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	2,00	3,00	4,00	3,00	1,00	1,00	5,00
Multifunctionality	0,50	**1,00**	3,00	3,00	5,00	1,00	1,00	5,00
Multiscale	0,33	0,33	**1,00**	5,00	3,00	1,00	1,00	5,00
Integration	0,25	0,33	0,20	**1,00**	3,00	1,00	1,00	5,00
Diversity	0,33	0,20	0,33	0,33	**1,00**	1,00	1,00	2,00
Applicability	1,00	1,00	1,00	1,00	1,00	**1,00**	1,00	3,00
Governance	1,00	1,00	1,00	1,00	1,00	1,00	**1,00**	3,00
Continuity	0,20	0,20	0,20	0,20	0,50	0,33	0,33	**1,00**

Table A8 - Individual scores of pairwise comparison of GI planning principles (Mafra)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	3,00	5,00	3,00	1,00	5,00	3,00	1,00
Multifunctionality	0,33	**1,00**	5,00	1,00	1,00	3,00	3,00	1,00
Multiscale	0,20	0,20	**1,00**	1,00	1,00	1,00	1,00	1,00
Integration	0,33	1,00	1,00	**1,00**	1,00	3,00	3,00	1,00
Diversity	1,00	1,00	1,00	1,00	**1,00**	1,00	1,00	1,00
Applicability	0,20	0,33	1,00	0,33	1,00	**1,00**	3,00	1,00
Governance	0,33	0,33	1,00	0,33	1,00	0,33	**1,00**	1,00
Continuity	1,00	1,00	1,00	1,00	1,00	1,00	1,00	**1,00**

Table A9 - Individual scores of pairwise comparison of GI planning principles (Moita)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	1,00	5,00	1,00	3,00	1,00	1,00	1,00
Multifunctionality	1,00	**1,00**	3,00	3,00	1,00	3,00	1,00	1,00
Multiscale	0,20	0,33	**1,00**	3,00	1,00	3,00	1,00	1,00
Integration	1,00	0,33	0,33	**1,00**	2,00	2,00	2,00	1,00
Diversity	0,33	1,00	1,00	0,50	**1,00**	3,00	2,00	1,00
Applicability	1,00	0,33	0,33	0,50	0,33	**1,00**	2,00	3,00
Governance	1,00	1,00	1,00	0,50	0,50	0,50	**1,00**	5,00
Continuity	1,00	1,00	1,00	1,00	1,00	0,33	0,20	**1,00**

Table A10 - Individual scores of pairwise comparison of GI planning principles (Odivelas)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	3,00	3,00	1,00	3,00	0,20	3,00	1,00
Multifunctionality	0,33	**1,00**	1,00	0,20	1,00	0,20	3,00	3,00
Multiscale	0,33	1,00	**1,00**	1,00	3,00	0,20	1,00	1,00
Integration	1,00	5,00	1,00	**1,00**	1,00	1,00	1,00	1,00
Diversity	0,33	1,00	0,33	1,00	**1,00**	0,20	0,33	0,33
Applicability	5,00	5,00	5,00	1,00	5,00	**1,00**	1,00	1,00
Governance	0,33	0,33	1,00	1,00	3,00	1,00	**1,00**	1,00
Continuity	1,00	0,33	1,00	1,00	3,00	1,00	1,00	**1,00**

Table A11 - Individual scores of pairwise comparison of GI planning principles (Oeiras)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	7,00	5,00	1,00	5,00	1,00	8,00	1,00
Multifunctionality	0,14	**1,00**	5,00	0,20	1,00	0,14	5,00	0,13
Multiscale	0,20	0,20	**1,00**	0,14	1,00	0,14	1,00	0,14
Integration	1,00	5,00	7,00	**1,00**	5,00	0,14	3,00	0,14
Diversity	0,20	1,00	1,00	0,20	**1,00**	0,14	1,00	0,14
Applicability	1,00	7,00	7,00	7,00	7,00	**1,00**	7,00	1,00
Governance	0,13	0,20	1,00	0,33	1,00	0,14	**1,00**	0,14
Continuity	1,00	8,00	7,00	7,00	7,00	1,00	7,00	**1,00**

Table A12 - Individual scores of pairwise comparison of GI planning principles (Palmela)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	1,00	5,00	5,00	3,00	1,00	9,00	9,00
Multifunctionality	1,00	**1,00**	5,00	1,00	1,00	1,00	9,00	9,00
Multiscale	0,20	0,20	**1,00**	1,00	5,00	1,00	9,00	9,00
Integration	0,20	1,00	1,00	**1,00**	1,00	1,00	9,00	9,00
Diversity	0,33	1,00	0,20	1,00	**1,00**	2,00	1,00	9,00
Applicability	1,00	1,00	1,00	1,00	0,50	**1,00**	9,00	9,00
Governance	0,11	0,11	0,11	0,11	1,00	0,11	**1,00**	9,00
Continuity	0,11	0,11	0,11	0,11	0,11	0,11	0,11	**1,00**

Table A13 - Individual scores of pairwise comparison of GI planning principles (Seixal)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	1,00	3,00	5,00	4,00	7,00	2,00	3,00
Multifunctionality	1,00	**1,00**	2,00	3,00	1,00	1,00	5,00	3,00
Multiscale	0,33	0,50	**1,00**	1,00	1,00	1,00	1,00	1,00
Integration	0,20	0,33	1,00	**1,00**	5,00	2,00	1,00	5,00
Diversity	0,25	1,00	1,00	0,20	**1,00**	1,00	1,00	3,00
Applicability	0,14	1,00	1,00	0,50	1,00	**1,00**	1,00	5,00
Governance	0,50	0,20	1,00	1,00	1,00	1,00	**1,00**	1,00
Continuity	0,33	0,33	1,00	0,20	0,33	0,20	1,00	**1,00**

Table A14 - Individual scores of pairwise comparison of GI planning principles (Setúbal)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	5,00	5,00	1,00	3,00	1,00	1,00	1,00
Multifunctionality	0,20	**1,00**	3,00	1,00	1,00	0,20	1,00	1,00
Multiscale	0,20	0,33	**1,00**	1,00	1,00	0,20	1,00	1,00
Integration	1,00	1,00	1,00	**1,00**	1,00	0,20	1,00	1,00
Diversity	0,33	1,00	1,00	1,00	**1,00**	0,20	1,00	1,00
Applicability	1,00	5,00	5,00	5,00	5,00	**1,00**	1,00	3,00
Governance	1,00	1,00	1,00	1,00	1,00	1,00	**1,00**	3,00
Continuity	1,00	1,00	1,00	1,00	1,00	0,33	0,33	**1,00**

Table A15 - Individual scores of pairwise comparison of GI planning principles (Sesimbra)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	1,00	5,00	3,00	3,00	5,00	5,00	5,00
Multifunctionality	1,00	**1,00**	5,00	3,00	3,00	1,00	1,00	1,00
Multiscale	0,20	0,20	**1,00**	1,00	1,00	1,00	1,00	1,00
Integration	0,33	0,33	1,00	**1,00**	3,00	1,00	1,00	1,00
Diversity	0,33	0,33	1,00	0,33	**1,00**	1,00	1,00	1,00
Applicability	0,20	1,00	1,00	1,00	1,00	**1,00**	1,00	3,00
Governance	0,20	1,00	1,00	1,00	1,00	1,00	**1,00**	1,00
Continuity	0,20	1,00	1,00	1,00	1,00	0,33	1,00	**1,00**

Table A16 - Individual scores of pairwise comparison of GI planning principles (Sintra)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	1,00	5,00	1,00	5,00	0,20	1,00	1,00
Multifunctionality	1,00	**1,00**	3,00	0,14	1,00	0,33	0,33	0,20
Multiscale	0,20	0,33	**1,00**	0,14	0,33	0,20	1,00	0,20
Integration	1,00	7,00	7,00	**1,00**	1,00	1,00	1,00	1,00
Diversity	0,20	1,00	3,00	1,00	**1,00**	0,33	0,33	1,00
Applicability	5,00	3,00	5,00	1,00	3,00	**1,00**	1,00	1,00
Governance	1,00	3,00	1,00	1,00	3,00	1,00	**1,00**	1,00
Continuity	1,00	5,00	5,00	1,00	1,00	1,00	1,00	**1,00**

Table A17 - Individual scores of pairwise comparison of GI planning principles (Vila Fraca de Xira)

Principles	Connectivity	Multifunctionality	Multiscale	Integration	Diversity	Applicability	Governance	Continuity
Connectivity	**1,00**	1,00	5,00	7,00	7,00	5,00	1,00	5,00
Multifunctionality	1,00	**1,00**	5,00	7,00	7,00	7,00	2,00	7,00
Multiscale	0,20	0,20	**1,00**	0,25	2,00	5,00	0,14	2,00
Integration	0,14	0,14	4,00	**1,00**	2,00	1,00	0,14	0,50
Diversity	0,14	0,14	0,50	0,50	**1,00**	1,00	0,14	0,50
Applicability	0,20	0,14	0,20	1,00	1,00	**1,00**	0,20	0,25
Governance	1,00	0,50	7,14	7,14	7,14	5,00	**1,00**	7,00
Continuity	0,20	0,14	0,50	2,00	2,00	4,00	0,14	**1,00**

B

APPENDIX B - INDIVIDUAL SCORES OF THE PLAN EVALUATION FOR EACH GI PLANNING PRINCIPLE (CHAPTER 4)

Table B1 – Individual scores for the connectivity principle by municipality and plan component (connectivity)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Amadora	3	3	2	1	3	**12**
Cascais	0	0	1	3	1	**5**
Lisboa	2	2	2	3	2	**11**
Mafra	0	1	1	0	1	**3**
Moita	1	1	1	0	1	**4**
Odivelas	1	2	2	1	2	**8**
Oeiras	2	3	3	1	2	**11**
Seixal	1	2	1	0	2	**6**
Setúbal	2	3	2	1	2	**10**
Sintra	1	2	2	1	1	**7**
Vila Franca de Xira	1	2	1	0	1	**5**

Table B2 – Individual scores for the connectivity principle by municipality and plan component (multifunctionality)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Amadora	2	2	1	0	0	**5**
Cascais	0	0	2	1	0	**3**
Lisboa	0	2	2	1	0	**5**
Mafra	0	1	0	0	0	**1**
Moita	0	0	1	0	0	**1**
Odivelas	0	2	2	1	0	**5**
Oeiras	0	2	2	1	0	**5**
Seixal	0	1	1	0	0	**2**
Setúbal	3	3	3	0	0	**9**
Sintra	0	3	2	0	0	**5**
Vila Franca de Xira	0	2	1	1	0	**4**

Table B3 – Individual scores for the connectivity principle by municipality and plan component (multiscale)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Amadora	2	1	2	1	1	**7**
Cascais	1	1	1	2	1	**6**
Lisboa	0	1	0	2	1	**4**
Mafra	1	1	0	1	0	**3**
Moita	0	0	0	0	0	**0**
Odivelas	1	0	0	0	1	**2**
Oeiras	3	1	0	0	1	**5**
Seixal	0	1	0	0	0	**1**
Setúbal	2	3	2	1	2	**10**
Sintra	0	2	0	0	0	**2**
Vila Franca de Xira	0	2	1	0	2	**5**

Table B4 – Individual scores for the connectivity principle by municipality and plan component (Integration)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Amadora	1	2	1	0	1	**5**
Cascais	1	1	2	1	0	**5**
Lisboa	0	2	1	1	1	**5**
Mafra	1	1	1	1	0	**4**
Moita	1	1	1	0	0	**3**
Odivelas	1	1	2	1	1	**6**
Oeiras	0	1	1	0	1	**3**
Seixal	1	1	1	0	0	**3**
Setúbal	1	2	2	0	1	**6**
Sintra	0	2	0	0	1	**3**
Vila Franca de Xira	0	2	2	1	1	**6**

Table B5 – Individual scores for the connectivity principle by municipality and plan component (Diversity)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Amadora	3	2	1	1	2	9
Cascais	0	0	1	2	3	6
Lisboa	1	2	2	3	2	10
Mafra	2	1	1	1	0	5
Moita	1	0	1	1	0	3
Odivelas	1	2	2	1	2	8
Oeiras	2	2	2	0	2	8
Seixal	1	1	2	1	0	5
Setúbal	3	4	3	2	3	15
Sintra	0	2	2	1	1	6
Vila Franca de Xira	0	3	1	1	2	7

Table B6 – Individual scores for the connectivity principle by municipality and plan component (Applicability)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Amadora	1	1	2	1	0	**5**
Cascais	1	1	2	3	0	**7**
Lisboa	0	1	2	3	0	**6**
Mafra	0	0	1	3	0	**4**
Moita	2	0	2	2	0	**6**
Odivelas	1	1	3	3	0	**8**
Oeiras	2	1	3	2	0	**8**
Seixal	1	2	2	3	0	**8**
Setúbal	0	3	3	3	0	**9**
Sintra	0	2	2	3	0	**7**
Vila Franca de Xira	0	2	3	2	0	**7**

Table B7 – Individual scores for the connectivity principle by municipality and plan component (Governance)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Amadora	0	0	0	0	0	**0**
Cascais	3	3	1	3	0	**10**
Lisboa	0	2	0	2	0	**4**
Mafra	0	0	0	0	0	**0**
Moita	2	2	0	0	0	**4**
Odivelas	1	2	2	3	0	**8**
Oeiras	0	2	0	0	0	**2**
Seixal	1	1	1	0	0	**3**
Setúbal	0	1	0	0	0	**1**
Sintra	0	1	0	1	0	**2**
Vila Franca de Xira	0	1	0	0	0	**1**

Table B8 – Individual scores for the connectivity principle by municipality and plan component (Continuity)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Amadora	1	0	0	0	0	**1**
Cascais	1	1	1	1	0	**4**
Lisboa	0	1	1	1	0	**3**
Mafra	0	1	0	0	0	**1**
Moita	0	0	0	0	0	**0**
Odivelas	0	1	1	1	0	**3**
Oeiras	0	4	2	0	0	**6**
Seixal	0	1	0	1	0	**2**
Setúbal	0	3	1	0	0	**4**
Sintra	0	0	1	4	0	**5**
Vila Franca de Xira	0	0	0	0	0	**0**

C APPENDIX C - INDIVIDUAL SCORES OF THE PLAN EVALUATION FOR EACH MUNICIPALITY (CHAPTER 4)

Table C1 – Individual scores for each municipality by GI planning principle and plan component (Amadora)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Connectivity	3	3	2	1	3	**12**
Multifunctionality	2	2	1	0	0	**5**
Multiscale	2	1	2	1	1	**7**
Integration	1	2	1	0	1	**5**
Diversity	3	2	1	1	2	**9**
Applicability	1	1	2	1	0	**5**
Governance	0	0	0	0	0	**0**
Continuity	1	0	0	0	0	**1**

Table C2 – Individual scores for each municipality by GI planning principle and plan component (Cascais)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Connectivity	0	0	1	3	1	**5**
Multifunctionality	0	0	2	1	0	**3**
Multiscale	1	1	1	2	1	**6**
Integration	1	1	2	1	0	**5**
Diversity	0	0	1	2	3	**6**
Applicability	1	1	2	3	0	**7**
Governance	3	3	1	3	0	**10**
Continuity	1	1	1	1	0	**4**

Table C3 – Individual scores for each municipality by GI planning principle and plan component (Lisboa)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Connectivity	2	2	2	3	2	**11**
Multifunctionality	0	2	2	1	0	**5**
Multiscale	0	1	0	2	1	**4**
Integration	0	2	1	1	1	**5**
Diversity	1	2	2	3	2	**10**
Applicability	0	1	2	3	0	**6**
Governance	0	2	0	2	0	**4**
Continuity	0	1	1	1	0	**3**

Table C4 – Individual scores for each municipality by GI planning principle and plan component (Mafra)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Connectivity	0	1	1	0	1	**3**
Multifunctionality	0	1	0	0	0	**1**
Multiscale	1	1	0	1	0	**3**
Integration	1	1	1	1	0	**4**
Diversity	2	1	1	1	0	**5**
Applicability	0	0	1	3	0	**4**
Governance	0	0	0	0	0	**0**
Continuity	0	1	0	0	0	**1**

Table C5 – Individual scores for each municipality by GI planning principle and plan component (Moita)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Connectivity	1	1	1	0	1	**4**
Multifunctionality	0	0	1	0	0	**1**
Multiscale	0	0	0	0	0	**0**
Integration	1	1	1	0	0	**4**
Diversity	1	0	1	1	0	**3**
Applicability	2	0	2	2	0	**6**
Governance	2	2	0	0	0	**4**
Continuity	0	0	0	0	0	**0**

Table C6 – Individual scores for each municipality by GI planning principle and plan component (Odivelas)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Connectivity	1	2	2	1	2	**8**
Multifunctionality	0	2	2	1	0	**5**
Multiscale	1	0	0	0	1	**2**
Integration	1	1	2	1	1	**6**
Diversity	1	2	2	1	2	**8**
Applicability	1	1	3	3	0	**8**
Governance	1	2	2	3	0	**8**
Continuity	0	1	1	1	0	**3**

Table C7 – Individual scores for each municipality by GI planning principle and plan component (Oeiras)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Connectivity	2	3	3	1	2	**11**
Multifunctionality	0	2	2	1	0	**5**
Multiscale	3	1	0	0	1	**5**
Integration	0	1	1	0	1	**3**
Diversity	2	2	2	0	2	**8**
Applicability	2	1	3	2	0	**8**
Governance	0	2	0	0	0	**2**
Continuity	0	4	2	0	0	**6**

Table C8 – Individual scores for each municipality by GI planning principle and plan component (Seixal)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Connectivity	1	2	1	0	2	**6**
Multifunctionality	0	1	1	0	0	**2**
Multiscale	0	1	0	0	0	**1**
Integration	1	1	1	0	0	**3**
Diversity	1	1	2	1	0	**5**
Applicability	1	2	2	3	0	**8**
Governance	1	1	1	0	0	**3**
Continuity	0	1	0	1	0	**2**

Table C9 – Individual scores for each municipality by GI planning principle and plan component (Setúbal)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Connectivity	2	3	2	1	2	**10**
Multifunctionality	3	3	3	0	0	**9**
Multiscale	2	3	2	1	2	**10**
Integration	1	2	2	0	1	**6**
Diversity	3	4	3	2	3	**15**
Applicability	0	3	3	3	0	**9**
Governance	0	1	0	0	0	**1**
Continuity	0	3	1	0	0	**4**

Table C10 – Individual scores for each municipality by GI planning principle and plan component (Sintra)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Connectivity	1	2	2	1	1	**7**
Multifunctionality	0	3	2	0	0	**5**
Multiscale	0	2	0	0	0	**2**
Integration	0	2	0	0	1	**3**
Diversity	0	2	2	1	1	**6**
Applicability	0	2	2	3	0	**7**
Governance	0	1	0	1	0	**2**
Continuity	0	0	1	4	0	**5**

Table C11 – Individual scores for each municipality by GI planning principle and plan component (Vila Franca de Xira)

	Information base	Vision, objectives and strategy	Management Regulation	Actions and Implementation	Visual Representation (Maps)	**Total**
Connectivity	1	2	1	0	1	**5**
Multifunctionality	0	2	1	1	0	**4**
Multiscale	0	2	1	0	2	**5**
Integration	0	2	2	1	1	**6**
Diversity	0	3	1	1	2	**7**
Applicability	0	2	3	2	0	**7**
Governance	0	1	0	0	0	**1**
Continuity	0	0	0	0	0	**0**