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# Green Infrastructure Planning Principles: Identification of Priorities Using Analytic Hierarchy Process

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**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 professional 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 Lisbon Metropolitan Area, in order to prioritize the green infrastructure planning principles influencing GI design and development in urban areas. Experts were asked to prioritize eight primary green infrastructure planning principles: connectivity, multi-functionality, applicability, integration, diversity, multiscale, governance, and continuity. The results show that the most important green infrastructure planning principle for practitioners 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

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## 1. Introduction

Green and blue areas—green-blue infrastructure—have been highlighted by several authors as important assets that contribute to sustainable development [1–3]. 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 wellbeing. 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 local level [4,5].

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 [6], 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. [7]: 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.

## 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 [8–11]. 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 [10,12,13]. 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 [14]. 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 [9,11].

According to Wright [9], 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 [4,15]. In addition, the geographical location and culture dynamics in which green infrastructure is being used also influences the different concepts found in the literature [7,13]. 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 the North American planning practices; and another that highlights the role of green and blue spaces in providing a wide range of ecosystem services [7,12,13]. 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) [15,16].

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 a 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" [17]. This definition not only captures the role that green and blue spaces take regarding ecosystem services provision at different spatial scales [18], but takes into consideration the connections that exist between urban and rural areas and the component of planning and management [16]. As a concept for strategic spatial planning through the provision of ecosystem services, green infrastructure is able to respond to a wide range of environmental, social and economic challenges [2,3]. These include climate change mitigation and adaptation, wildlife habitat protection, air pollution mitigation, social inclusion or increase of recreation opportunities [4,19–21], among others. Green infrastructure is, thus, extremely relevant for quality of life, not only in urban areas, but in all regions [2].

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 [4,22]. However, according to Campagna et al. [4], there is still no global 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 [19]. 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 [23–26], limited studies have studied in depth the integration of green infrastructure principles in spatial planning [25,27] 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 [6]. 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 [6,27]. 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. [7] 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 to 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. [28,29] 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 and Mell [6] go further and propose more principles, including evidence-based approach, importance of scale, and a long-term approach, among others. Gradinaru and Hersperger [27] 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 [19] 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. [7], 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 1.

**Table 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. [7].

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 [25,28–31]. 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. Materials and Methods

### *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 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 [7] 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.

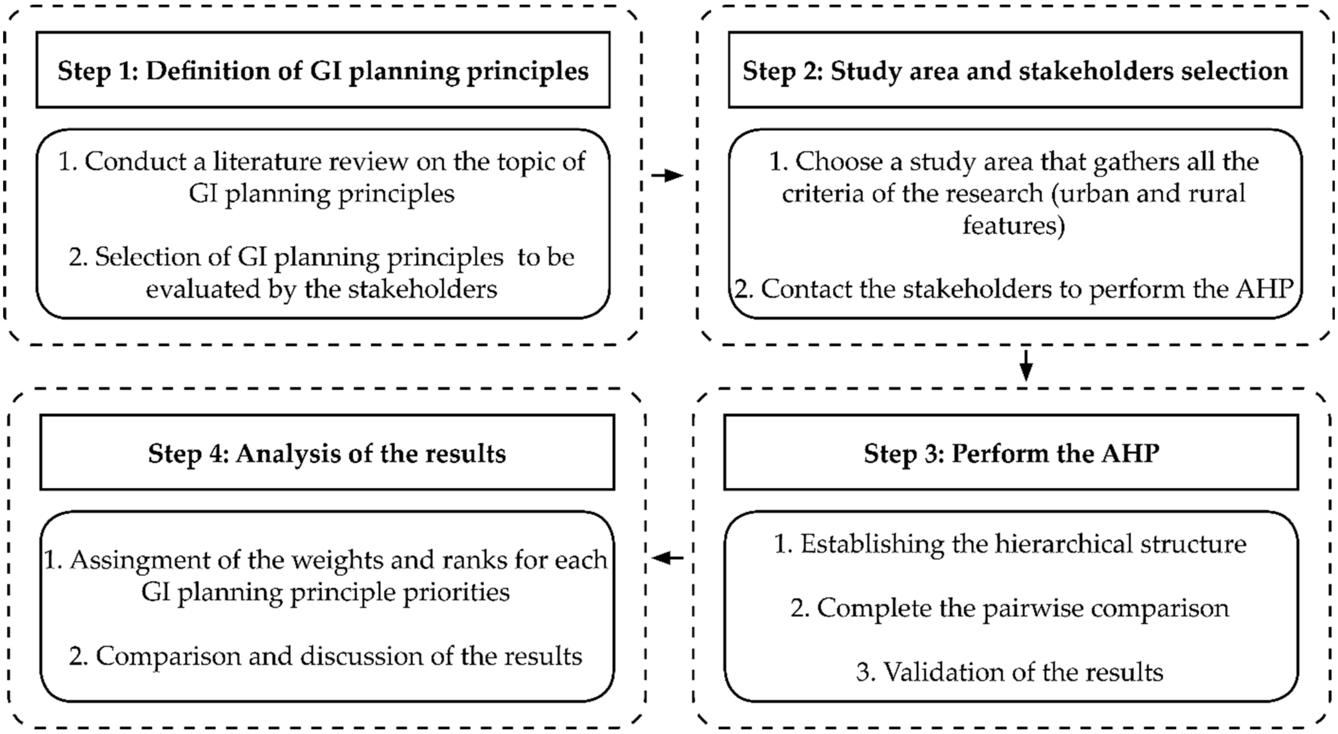


**Figure 1.** Research methodological framework.

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 afterwards and send the results a few days later. Interviewees were experts in the fields of urban planning and landscape architecture and included architects, environmental engineers, geographers, and landscape architects and 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), 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.

### *3.2. 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 [32]. 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 [33]. According to the preliminary results of Census 2021, LMA had about 2,870,770 inhabitants, around 27.7% of the Portuguese population, the most densely populated metropolitan area in the country [34]. 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 [33], as seen in Figure 2.

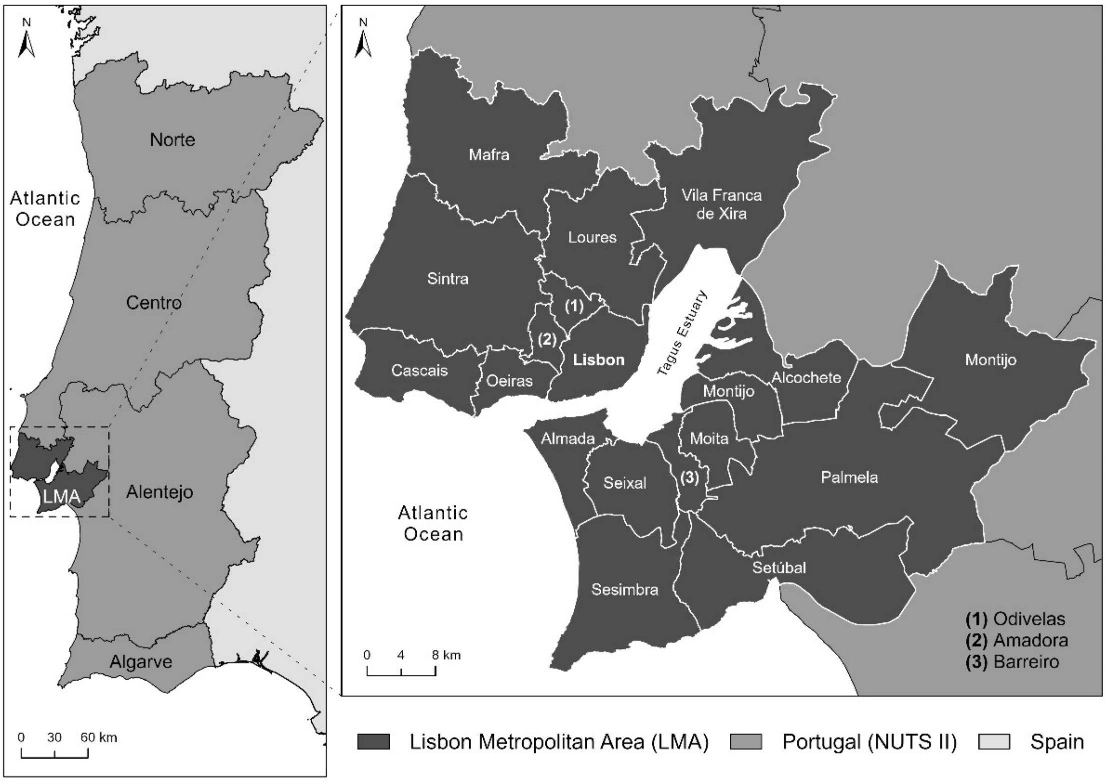


**Figure 2.** Lisbon Metropolitan Area (Data from: CAOP 2012).

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 2, only one out of six municipalities with more than 50% of their territory dedicated to urban areas is 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 [35], as well as nine national protected areas, covering around 15% of the region's area [32,36]. LMA climate is classified as Mediterranean (Csa, according to the Köppen-Geiger classification), having dryer and warmer summers and mild and wet winters.

### *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, for 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 [37,38].

**Table 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.

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 at the preservation of biodiversity and the 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 the 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.

### 3.4. 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 [39,40], used to organize and analyze complex problems and unpredictable situations that require multiple evaluation standards and understandings [41]. 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 [41–45].

The AHP contemplates the numerous layered dimensions of the decision-making processes [41] 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 [46], 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 [44]. 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 [47].

The AHP provides an easy applicable decision-making method that helps the decision maker to precisely make decisions and judgments regarding a specific problem, and both objective or subjective considerations play an important role during the decision process [47]. 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 [39,41].

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 [43]. 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).

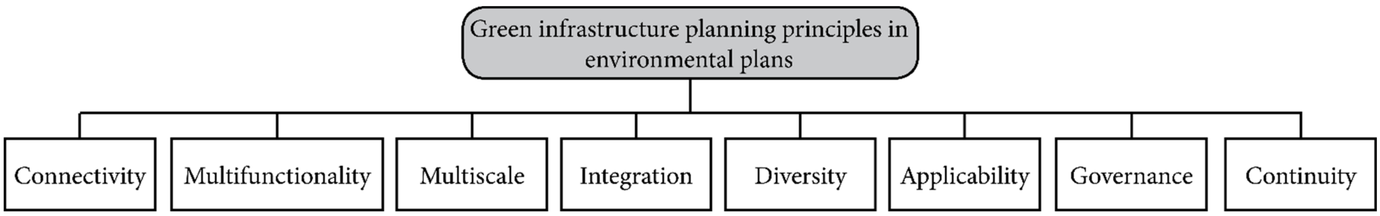


**Figure 3.** Analytic hierarchy process (AHP) hierarchical structure (Source: created by the authors).

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 [39] (Table 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 1. The result of comparing the elements can be obtained with the comparison matrix $A = (a_{ij})$, in Equation (1).

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

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

**Table 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 Saaty 1994 [39].

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 [43,48]. To do this, the consistency index (*CI*) and consistency ratio (*CR*) are employed. If the *CR* is smaller than 0.2, the results are considered reasonable and acceptable [41,43], although the smaller the *CI*, the more consistent are the stakeholders' responses. The *CI* and *CR* can be obtained by Equations (2) and (3), and *RI* (Table 4) is the random consistency index which depends on the number of elements compared.

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (2)$$

$$CR = \frac{CI}{RI} \quad (3)$$

**Table 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 |

Adapted from Saaty 1994 [39].

The $\lambda_{max}$ corresponds to the maximum eigenvalue of the matrix and is given by Equation (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 $(\overline{W}_i)$, and normalize it using Equation (5) [48,49]. After that, if the answers are valid, the elements are ranked based on the results obtained.

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \quad (4)$$

$$W_i = \frac{\overline{W}_i}{\sum_{j=1}^{n} \overline{W}_j} \quad (5)$$

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

After each stakeholder comes to his independent AHP based ranking, the resulting individual priorities ($W_a$) are aggregated using a (weighted) arithmetic mean [50,51], given by Equation (6).

$$W_a = \sum_{i=1}^{n} \frac{W_i}{n} \quad (6)$$

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

## 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 innumerous contacts, did not respond to any of our attempts. Some of the received AHPanalyses had inputs 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 5.

**Table 5.** Outcome of the Analytic Hierarchy Process analysis.

| | | Municipalities | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Alcochete** | **Almada** | **Amadora** | **Barreiro** | **Cascais** | **Lisboa** | **Loures** | **Mafra** | **Moita** | **Montijo** | **Odivelas** | **Oeiras** | **Palmela** | **Seixal** | **Sesimbra** | **Setúbal** | **Sintra** | **Vila Franca de Xira** | **Overall** |
| GI Planning Principles | 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** |
| | Multifunctionality | 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. [7], 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 [52–54]. In addition, an assessment of green infrastructure planning principles integration into strategic planning in European regions, developed by Grădinaru and Hersperger [27], also showed how connectivity and multifunctionality are at the core of planning strategies across Europe, in which Lisbon Metropolitan Area in included. Results from a study from Shin et al. [41], where the AHP methodology was applied to examine the decision criteria of GI experts in terms of design priorities, showed that ecological functions (connectivity) were also considered by most experts 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 and Barão [55], 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 [56,57], 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 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 multi-functionality 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. [58], the first greenway plans in Portugal were mainly destined to ecological and recreational purposes, which included river systems. These plans' approaches were initiated by universities and NGOs in co-operation 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" [59], 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 is, 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 deal with climate change and other risks in urban areas [60,61]. 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 [62].

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 a substantial urban area, 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 [7]. However, it is, surprisingly, one of the most relevant principles for the spatial planners included in this study. This may be explained be the limited attention in the literature regarding practical procedures and implementation strategies for green infrastructure [63], and the lack of detailed action strategies or policies, as well as implementation approaches, in existing plans [19]. This creates concerns regarding the applicability of green infrastructure at 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 to 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 the green infrastructure planning by some authors [25,28], 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 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 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 as 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 a continuous monitorization. Funding is extremely important to guarantee the preservation, restauration, and development of green infrastructure. Nevertheless, according to a study by Slätmo et al. [22], 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 afterwards. This creates enormous pressures among local authorities who have limited financial resources to continue to monitor green infrastructure projects. Second, the fact that local authorities have elections regularly (ever four years), which may result in a change of local governments, leading to an 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 in coherent with the findings of Monteiro et al. [7], 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 Silva [64], 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 sort of reasons explain why citizen participation has been predominantly passive in Portugal, and why the governance principle may be seen 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 as a fundamental principle for green infrastructure planning.

## 5. Conclusions

Green infrastructure planning has been increasing worldwide since the end of 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 its 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 about 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.

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