

Article

Green Infrastructure Planning Principles: An Integrated Literature Review

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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.

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

1. Introduction

In 2018, more than 4 billion people lived in urban areas, and, according to the United Nations [1], the urban population will increase by 2.5 billion by 2050. This, however, creates enormous social, economic and environmental pressures in cities [2,3], 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 [4], 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 [5–9], 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 [6,10–12]. 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 [13–15], and can be grouped in four categories, namely provision, regulation, support and cultural [11,16,17]. 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 [18]. 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 the double accounting when valuing the ecosystem services [19]. 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 last century [20,21]. 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 [22–24], 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 to promote 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. 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 [25]. Nevertheless, this concept can have different definitions, depending on which context is used [25–28] and by whom the concept is used. Even though its historical roots go back to the 19th and 20th centuries [29,30], the “green infrastructure” concept is widely considered new [31].

The green infrastructure idea is based on much earlier concepts like parkways, green belts or garden cities [6,23,29,32]. 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 [33], but also among environmental groups, ecologists [34], and politicians [34–36].

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 [29,32,37,38] 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 [34]. Furthermore, numerous greenway-type projects were implemented [29,39] 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 [40] 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 President's Commission on Americans Outdoors in 1987 that started that movement [34].

The President's Commission [41] 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 [30,33,34,39,42]. Nevertheless, Little [43] 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, [34], 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 in 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 meant to be protected, but also areas and places that could have a recreational, educational, and scenic use. Ahern [31] 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 [29]. But what were exactly the arguments that supported this greenway movement and why was it so important at that time? According to Searns, [29], in the second half of the 20th century, the increase of 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 [44,45] 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 [29,39,46], along with cultural and social ones [47].

Although the greenway movement was starting to spread around the globe, due to different geographical, political, and scientific systems [37], different definitions of this concept have arisen. In Europe, for example, the term ecological networks was prevalent [36,37]. Ecological networks were defined by Jongman [36] 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, Steingröver, & Rooij [48] 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 [49,50]. 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 [6].

In fact, according to Ignatieva et al. [6] and Walmsley [32], 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 [10] 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 [51] 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 [32] 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 [52]. 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 [53]. 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 [12]. However, according to the United States Environmental Protection Agency [54], “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 [55–57] 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., [17] 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 [58].

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 in people’s health [59] 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 [28]. Apart from that, due to a decrease in health expenses, the capacity of attracting skilled workers and tourists and the increase of property value [28,60], green infrastructure can promote economic growth in urban areas [59,61]. However, to fulfill these multifunctional purposes, both the quantity and quality of urban and peri-urban green spaces must be addressed in planning processes [59] 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 [62]. 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 green infrastructure. Understanding the mechanisms between urban design and human actions on ecological functions are significant to achieve sustainability, at a time where 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.

3. Methods

There are several methods used for literature reviews processes that are helpful to address new or already known issues, and each provides different insights for knowledge creation, text development, and individuation [63]. 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 [64]. To do so, this research focuses on an integrative literature review on 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 [65]. 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 [66,67].

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, [66,68–72], that assure the quality and effectiveness of the review. As presented in Figure 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.

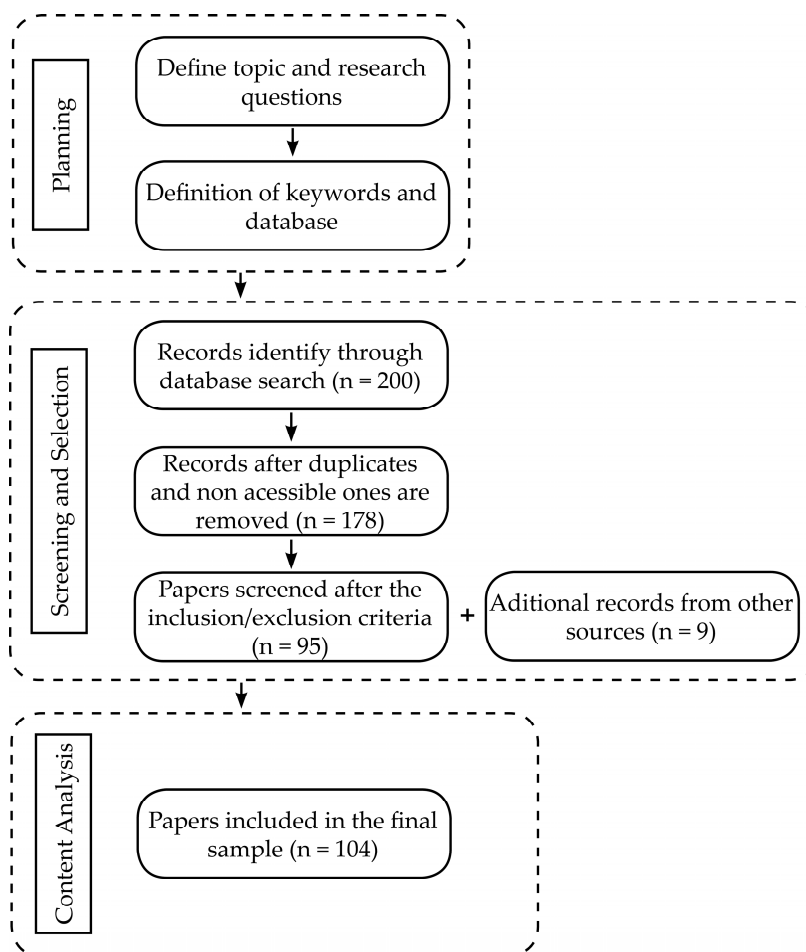


Figure 1. Overview of the methodological approach adapted from Klein et al. [66].

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 [69]. Since the focus of the research question is what principles green infrastructure planning must consider to promote sustainability and resilience at the local scale, a combination of two sets of terms were 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 that all 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 [66,73]. The titles, abstracts, and the full text of the resulting sample were screened for relevance according to the criteria presented in Table 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 for 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 on this integrative literature review is to understand what the principles that should be considered in green infrastructure planning are, 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 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 evidences from practical application
Inclusion of explicit or implicit green infrastructure planning principles	The paper contains explicit information regarding green infrastructure planning principles or may briefly describe a green infrastructure planning principle without using the word “principle”

After the screening and selection of the final sample, the 104 documents were scrutinized through a qualitative content analysis to summarize the content of the selected data [74]. 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 [75]. 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, evidences, 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 appear 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 existing words that were being searched. Through a careful interpretation of the documents and the all the resulting categories, the authors were, then, able to identify the most common green infrastructure planning principles in the literature.

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 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” [76]); (3) some principles were too simplistic and the information provided was not sufficient to understand what that principle refer to, as for example “promote natural resources and open space” [77]; (4) others were rather too complex to understand and did not align with the scope of the paper (e.g., “coordination” [64]), 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 include 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 are: connectivity; multifunctionality; multiscale; integration; diversity; applicability; governance; and continuity.

Table 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, a 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.	[10,21,22,24,28,31,51,59,64,76,78–113]
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 possess 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 this spaces, spatially in urban areas where space is limited and scarce.	[11,21,24,28,31,59,64,76,78–80,82,85–96,98,99,101–105,107,108,110–134]
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.	[6,10,11,21–24,31,51,64,79,80,82–84,88,91,95,98,99,103–105,107,111–114,124,129,132,135–141]
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 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.	[21,77,79,80,85–87,91,102–104,111,113,120,124,128,134,136,142–144]
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.	[6,59,64,77,79,80,82,89,92,97,99,101,103,105,108,110,111,113,115,120,125,134,138,141,145–151]
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.	[23,77,80,85,91,95,97,117,120,126,128,140,147,150,152–154]

Table 2. Cont.

Principles	Interpretation	References
Governance	Governance aims at the collaboration between the government actors and the 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 which will not be appreciated and supported by the local population and its objectives and goals will not be accomplished.	[10,21,24,77,79,80,84–88,90,91,94–96,100,102–105,107,114,119–124,128,130,131,135,138,139,143,146,150,155–166]
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 with the evolution of the planned green projects.	[21,23,77,78,80,88,90,91,105,114,117,124,128,135,139,140,146,150,154,157,167]

By examining the results, it is possible to identify the 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 analyzed (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 by several authors as the core elements (or principles) of green infrastructure [92,106,125], 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 [10,31], as key principles for green spaces and greenways development. Table 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 on 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 spatial integration of environmental, social, economic, cultural, and aesthetic functions, some concerns and criticisms have been expressed in recent years about their applicability [127]. In reality, there has been an increase of studies that focus on understanding how such theoretical concepts can definitely be implemented and evaluated [81,86,106,111,125], and this research clearly has shown that. The number of studies regarding ecosystem services in spatial planning and biodiversity enhancement in urban areas have 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 analyzed. For these reasons, both diversity and integration were considered key green infrastructure planning principles in this study.

Because the 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 solution 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 with stormwater management and flood control [85,87]. Although it can also be applied to other functions [87], 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 of stormwater management, compared to other regions [55,57], 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 into decision-making, which could be lost in cases where public participation is lacking [156]. Stakeholder engagement in green infrastructure planning is an important issue that is discussed in several studies, as shown in Table 2. In fact, in this study, governance was mentioned in 50 papers out of the 104 analyzed, which is consistent with the findings of Dorst and Davies & Laforteza [21,120], 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 [21].

Although citizen engagement in green spaces 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 policy making, 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 fundamentals 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 [114]. As much as governance may in fact contribute to the success of other principles, for example continuity, governance has gained such an 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 [87] and strengthen green infrastructure resilience. Even though the majority of papers analyzed concerning governance focused on implementation practices, the importance in considering governance in 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, there were two principles in particular that stood out in more than one study and seemed to be mentioned by several authors. Those principles were accessibility [91,100,115,139,147] and evidence-based approaches [10,24,105]. The accessibility principle refers to the guarantee that all people can use, enjoy, and positively contribute to green infrastructure [91], 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 spaces planning, accessibility is something that is already intrinsic in 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. As for the evidence-based approach, some studies defended the idea that green infrastructure planning must be based on robust scientific knowledge gained from a number of different fields [105]. Nonetheless, as much as this is important and crucial for a 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 as a core principle of green infrastructure planning.

Unlike the previous principles (accessibility and evidence-based approach), none of the 104 papers analyzed in this research directly mentioned the applicability or the continuity principles as core green infrastructure principles. Similar to the findings of Lennon and Scott [95], 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 of green infrastructure plans already developed [77], 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) are realistic, can be implemented and developed, and if the solutions presented and adaptable to the considered area or not.

Similar to applicability, the lack of post-implementation monitoring or empirical measurements of the outcomes and benefits of green infrastructure was also referred by several authors as something that damaged the implementation of green infrastructure. As stated by Kim and Tran [77] 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 analyzed, made the authors of this research consider continuity as a core and important principle of green infrastructure planning.

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 in 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 identify, select, and evaluate green infrastructure planning principles, that may be explained by the different priorities in the political agendas, which may be influenced by different geographical locations and cultural dynamics. Still, future research should be conducted to understand the reasons of such different principles presented in the literature and how the principles selected can be evaluated and how can they be put into practice.

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