

Article

# Towards Integrated Land Management: The Role of Green Infrastructure

Samanta Bačić <sup>1</sup> , Hrvoje Tomić <sup>2,\*</sup> , Goran Andlar <sup>3</sup>  and Miodrag Roić <sup>2</sup> 

<sup>1</sup> Faculty of Civil Engineering, Architecture and Geodesy, University of Split, Matice Hrvatske 15, 21000 Split, Croatia

<sup>2</sup> Faculty of Geodesy, University of Zagreb, Kačićeva 26, 10000 Zagreb, Croatia

<sup>3</sup> Faculty of Agriculture, University of Zagreb, Svetošimunska Cesta 25, 10000 Zagreb, Croatia

\* Correspondence: htomic@geof.hr

**Abstract:** Today, more than half of the world's population lives in urban areas, and this percentage is increasing every day. Accelerated urbanization leads to overbuilding, air and environmental pollution, climate change, and various other environmental problems. One of the ways to solve these problems is the planning of green infrastructure (GI). The development of GI brings a number of social, ecological, and economic benefits, and it is one of the ways to achieve sustainable development. Therefore, it is important to include GI in land management systems. This study used VOSviewer to analyze 4385 published papers in the field of GI and 110 studies on GI in combination with land management, land administration, LADM, and land use planning from the WoS database for the periods from 1995 to 2022 and from 2007 to 2022, respectively. The current research used the bibliometric method to see what the trends are in GI and how much GI has been researched for the purpose of land management. It was shown that researchers are giving more and more importance to GI, but GI in land management systems is still not sufficiently researched.

**Keywords:** green infrastructure; land management; VOSviewer; land administration; LADM; land use planning; bibliometric method



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## 1. Introduction

Today, 55% of the world's population lives in urban areas, and it is estimated that this number will increase to 68% by 2050 [1]. Every year, more and more people move from rural to urban areas and cities become overpopulated and overbuilt, meaning that the number of green spaces in the cities decreases [2]. The reduction in green areas leads to air and environmental pollution, the consumption of resources and energy, and significant climate changes; for example, an increase in temperature and an increasing number of floods [3]. At the same time, there is consensus that the planning of green infrastructure (GI) can significantly reduce the mentioned problems. GI is 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 in both rural and urban settings [4]. GI sustains clean air and water, and provides many benefits to people and wildlife [5]. Therefore, it is necessary to develop GI in a planned manner. This represents a great challenge, but it is crucial because GI supports natural and ecological processes that bring benefits to both rural and urban environments, and as such is necessary for the healthy development of humans and society as a whole [6].

The problem is recognized at the global level, and in 2015 the Agenda 2030 for Sustainable Development was adopted at the General Assembly of the United Nations (UN), which defines 17 global goals for sustainable development. GI is important for achieving several goals of the Agenda 2030, especially for goal 11. Goal 11 is aimed at the development of inclusive, safe, resilient, and sustainable cities and human settlements, and one of the

priorities of the goal is to provide universal access to green and public spaces. It is also significant for the achievement of goal 9, aimed at building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation. Goal 13 highlights the fight against climate change and its impacts [7]. In July 2022, based on Agenda 2030, the UN Economic Commission for Europe (UNECE) adopted the Regional Action Plan 2030, which integrates the guiding principles of Agenda 2030 and supports an integrated and balanced approach to achieving goal 11 in the UNECE region. The main goal is to support the simultaneous resolution of challenges in achieving sustainable housing and urban development in light of the COVID-19 pandemic, climate change, and housing emergencies, all through clearly defined principles, policies, goals, and actions [8]. At the level of the European Union (EU), in 2020 a European recovery plan was adopted, NextGenerationEU, which is also based on Agenda 2030. The NextGenerationEU plan provides funding for a European green plan that provides guidance for a green transformation and highlights the realization of a sustainable, climate-neutral, and green Europe [9]. Within the framework of NextGenerationEU, the Recovery and Resilience Facility (RRF) was introduced to mitigate the economic and social impacts of COVID-19. The RRF enables member states to use grants and loans through their own national recovery and resilience plans to finance reforms and related investments that accelerate recovery and increase the resilience of the economy and society [10,11]. The importance of GI in Europe was particularly highlighted by the adoption of the strategic document Green Infrastructure. It was adopted by the European Commission and it defines GI as a strategically planned network of natural and semi-natural areas, which together with other elements of the environment are designed and managed to establish a wide range of ecosystem services. The intention of the program is to provide all stakeholders with a framework for the implementation of the development of GI in urban areas in order to achieve the final goal, an increase in GI [12].

For the implementation of any policies related to urban spaces and the environment, such as the development and implementation of GI in space, land management measures aimed at sustainable land use are used. Land management is carried out using a land administration system that enables effective land use and conservation, obtaining income from the land and resolving land disputes [13]. Therefore, in addition to numerous programs emphasizing the importance of GI, it is important to mention the international directives and norms related to land management and land administration that regulate the big spatial data that need to be processed and that support the creation of policies related to the environment, some of which are the INSPIRE directive and the ISO standard Land Administration Domain Model (LADM). The INSPIRE directive was launched in 2007 by the EU to connect national spatial data infrastructure, and its main goal is to make spatial data available among EU member states [14]. The LADM was accepted as an ISO standard in 2012 and represents a conceptual model whose goal is to provide a basis for the development of effective land administration systems, including the legal and spatial aspects [15].

From all of the above, it is evident that the importance of GI is recognized at the global level, so in this research an emphasis will be placed on the GI and its benefits, and the importance of GI in land management will be highlighted. The current research uses the bibliometric method to see what the trends are in GI and how much GI has been researched for the purpose of land management.

## 2. Materials and Methods

The data for this study were collected from the database of the Web of Science (WoS). WoS is the world's most trusted independent global citation database [16], which was published in 2004 by Thomson Reuters. It is an interdisciplinary database with records from several bibliographic databases [17], including Science Citation Index Expanded (SCI-Expanded), the Social Science Citation Index (SSCI), the Arts and Humanities Citation Index (A&HCI), and the Emerging Sources Citation Index (ESCI) [18]. The WoS database contains records of publications from 1900 to the present [17].

For this research, two searches of the scientific literature were made. The first included only the concept of “green infrastructure”, while the second included “green infrastructure” in combination with “land management”, “land administration”, “LADM”, and “land use planning”. The searches were filtered by title, abstract, author keywords, and keywords plus, and only studies in English were selected. The search date was 26 July 2022.

This study used the bibliometric analysis method, a method that began to develop at the beginning of the 20th century [19]. Now, it is a popular and rigorous method for analyzing and exploring large volumes of bibliometric data. The analysis of such data can be done using various bibliometric software [20]. The bibliometric analysis in this study was performed using the VOSviewer software. VOSviewer is a freely available software tool developed by Nees Van Eck and Ludo Waltman of Leiden University in the Netherlands. The software is used for constructing and visualizing bibliometric networks [21]. VOSviewer can display a map in different ways, including in the label view, the density view, the cluster density view, and the scatter view. In the label view, items are displayed with a label and corresponding circle, whereby the more important the displayed item, the larger its label and its circle. In the density view, items are displayed with a label and color, whereby the denser the displayed area around the item, the more important it is. The cluster density view is similar to the density view, except that here the items are assigned to clusters. In the scatter view, items are displayed with a circle and color, and this view does not provide detailed information [22].

Next, scientific publications were downloaded from the WoS database, followed by a quantitative analysis using VOSviewer. The downloaded WoS database files were input in VOSviewer by selecting different types of analyses and maps were created using the VOS mapping technique.

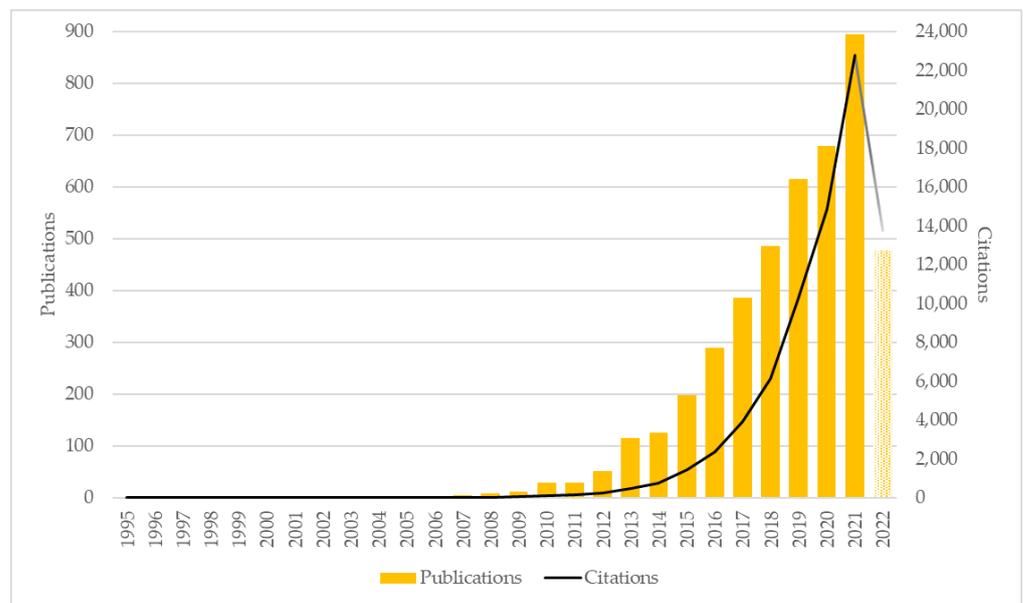
### 3. Results

As stated previously, two searches were conducted in WoS. The first search included only the term “green infrastructure”, and 4385 papers were obtained from the WoS database. The first studies on “green infrastructure” included in the WoS database were published in 1995, in July by Hauserman [23] and in October by Walmsley [24]. Therefore, the search time range was from 1995 to 2022.

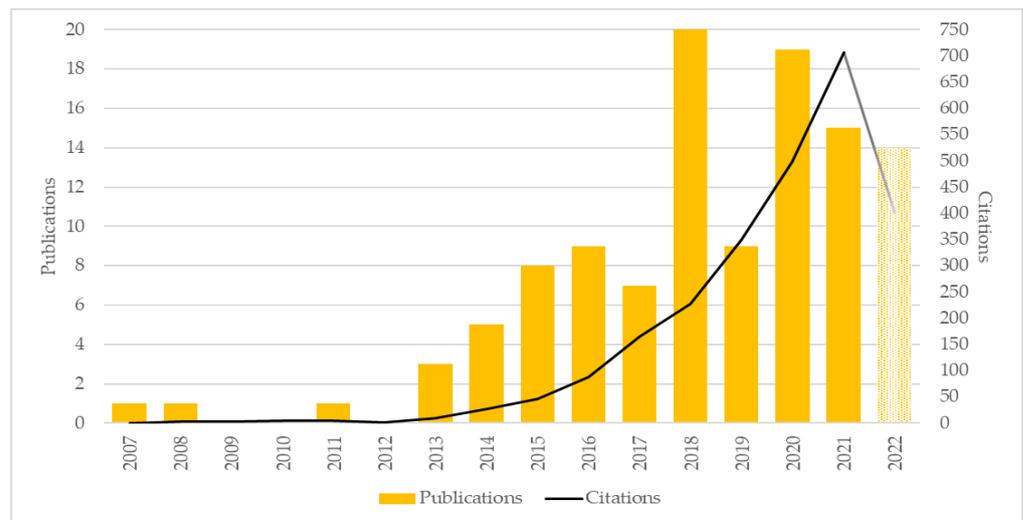
According to the statistical analysis of the literature search results, relatively few studies on GI were published from 1995 to 2012. However, since 2013 there has been an increase, and more and more studies on GI are published every year. Additionally, as the number of publications increased, so did the number of citations (Figure 1). It is obvious that GI is one of the topics that scientists and experts are increasingly interested in and that GI is given a lot of importance in various fields of science and research.

The second search included the term “green infrastructure” in combination with “land management”, “land administration”, “LADM”, and “land use planning”, and 110 papers were obtained from the WoS database. The first study on these topics included in the WoS database was published in 2007, a study about land use planning of the rural–urban fringe in the north of England by Gallent and Shaw [25]. Therefore, the search time range was from 2007 to 2022.

According to the statistical analysis of the literature search results, few studies were published from 2007 to 2013, at either one or none per year. Most studies were published in 2018, and since that year we can say that more and more experts have started to deal with these topics. Additionally, as the number of publications increased, so did the number of citations, with the highest number of citations in 2021 (Figure 2). Evidently, there is not much scientific research on GI within land management practices and there is a gap in this research field.



**Figure 1.** The number of publications and citations on “green infrastructure” collected in the WoS database.



**Figure 2.** The numbers of publications and citations on “green infrastructure” in combination with “land management”, “land administration”, “LADM”, and “land use planning” collected from the WoS database.

### 3.1. Distribution of Publications by Country

The number of published publications in a country related to the given topics reflects the degree of the country’s contribution to the research in this field [17]. From 1995 to date, most studies on GI (1275) were published in the United States of America (USA), accounting for 29.08% of the global total. In second place is China with 12.70% of publications out of the global total, followed by England (11.31%), Italy (7.37%), Germany (7.32%), and Australia (7.07%). All other countries have less than 5% of the published papers on GI, as seen in Table 1. In Croatia, only 17 papers (0.39% of the total number of papers) were published on the topic of GI in the period from 1995 to 2022.

**Table 1.** Numbers of publications and their percentages for countries researching GI.

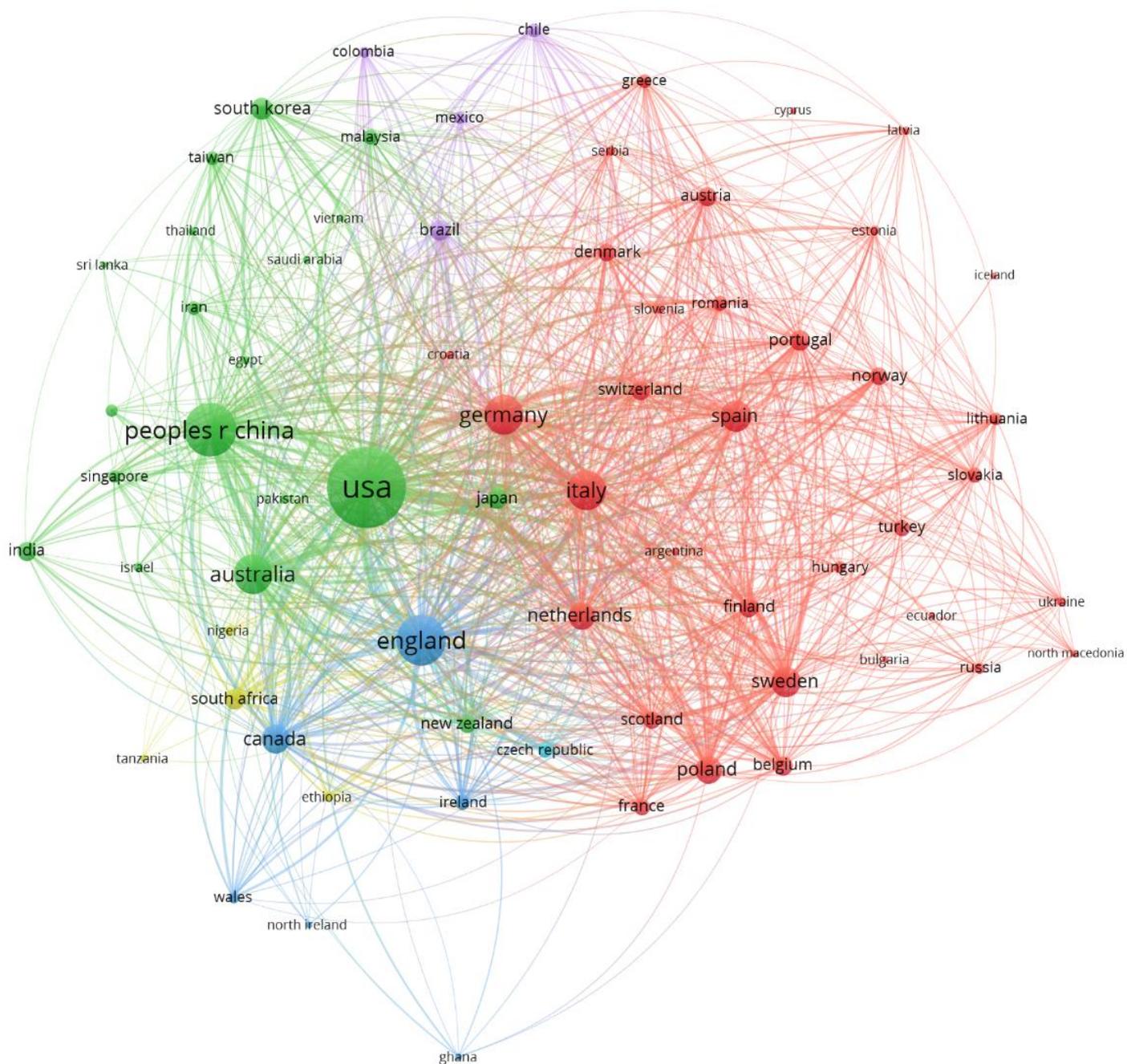
Country	Count	Percentage [%]
USA	1275	29.08
China	557	12.70
England	496	11.31
Italy	323	7.37
Germany	321	7.32
Australia	310	7.07
Spain	195	4.45
Sweden	187	4.26
Canada	174	3.97
Netherlands	155	3.53
Poland	154	3.51
South Korea	104	2.37
Portugal	90	2.05
Brazil	89	2.03
Others	1961	44.72

The numbers of publications published in which countries were also analyzed in VOSviewer. In total, 111 countries recorded publications on GI between 1995 and 2022. The country distribution map of the GI literature is displayed in Figure 3. These results also showed that the USA published the most publications about GI. Figure 3, created in VOSviewer, also reveals the cooperation among countries; that is, it shows that authors from different countries collaborate on the same article. Countries that are connected by lines of the same color cooperate the most.

Table 2 and Figure 4 show which countries research the most topics related to the second search in the WoS database (“green infrastructure” in combination with “land management”, “land administration”, “LADM”, and “land use planning”). Most studies on these topics were published in the USA, with 21.82% of the global total, followed by Italy (13.64%), Spain (12.73%), and China (10.91%). All other countries have less than 10% of the published papers, as seen in Table 2. Between 2007 and 2022, a total of 44 countries researched these topics. A map showing those countries that published studies in this research field was created in VOSviewer and is shown in Figure 4. In Croatia, no research on this topic has been published yet.

**Table 2.** Numbers of publications and their percentages for countries researching GI in combination with land management, land administration, LADM, and land use planning.

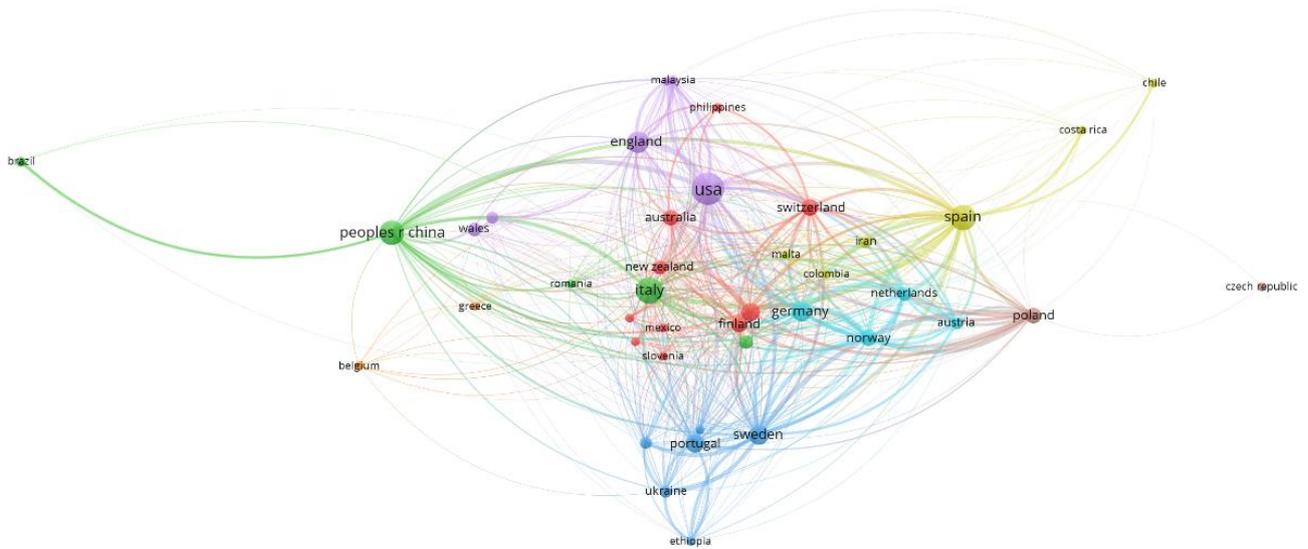
Country	Count	Percentage [%]
USA	24	21.82
Italy	15	13.64
Spain	14	12.73
China	12	10.91
England	9	8.18
Germany	7	6.36
Sweden	7	6.36
Canada	6	5.45
Portugal	6	5.45
Norway	5	4.55
Switzerland	5	4.55
Australia	4	3.64
Finland	4	3.64
Poland	4	3.64
Others	43	39.09



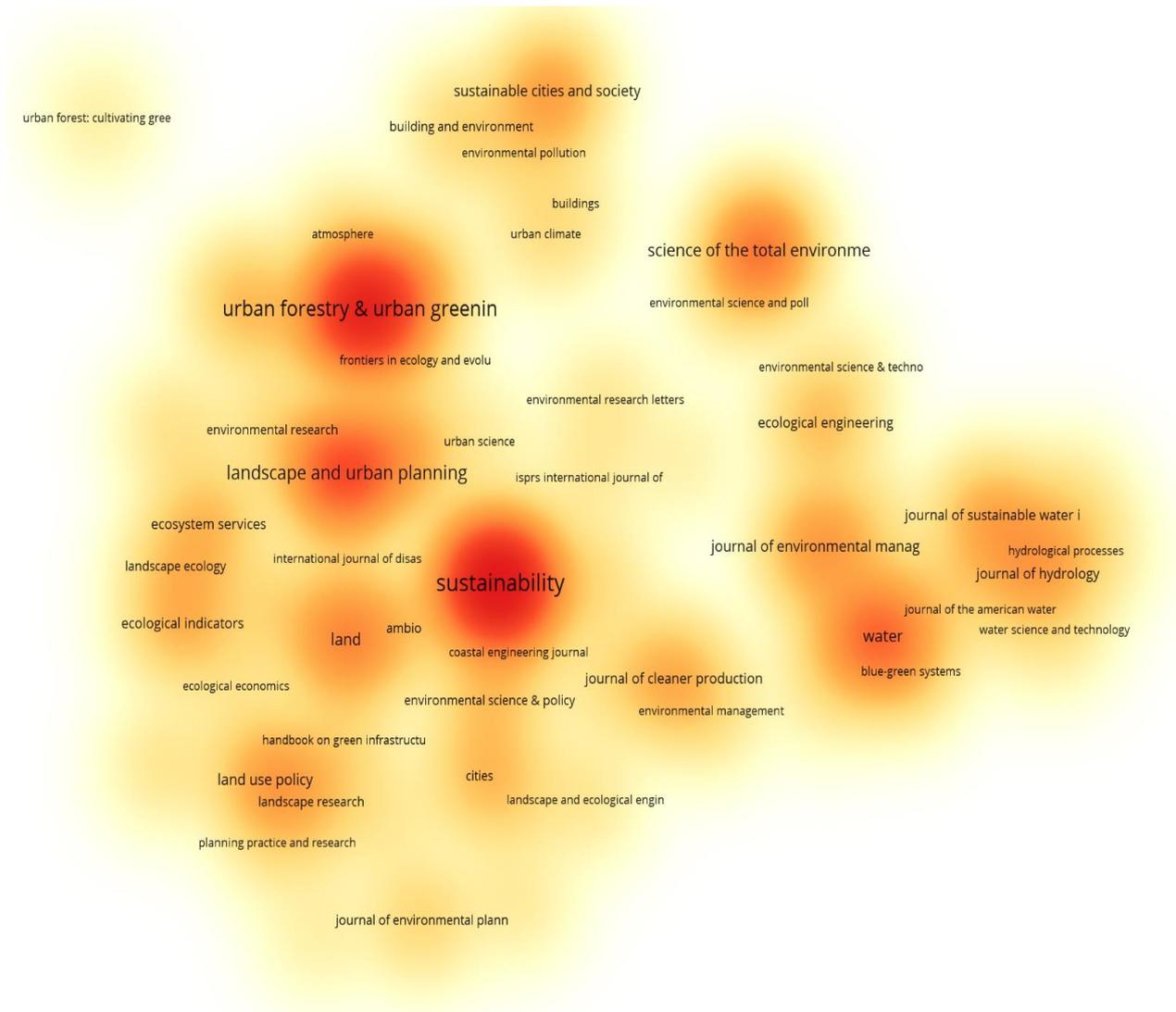
**Figure 3.** Map of the countries studying GI, created in VOSviewer.

### 3.2. Distribution of Publications by Journal

Using density maps, it is shown which journals published the most papers related to the searched topics in the WoS database. Figure 5 shows that most papers on GI were published in the journal Sustainability (350 papers), followed by Urban Forestry and Urban Greening (266 papers), Landscape and Urban Planning (159 papers), and Science of the Total Environment (119 papers). On the other hand, Figure 6 shows that most papers related to the term GI in combination with “land management”, “land administration”, “LADM”, and “land use planning” were published also in the journal Sustainability (19 papers), followed by Land Use Policy (11 papers), Ecosystem Services (7 papers), and Landscape and Urban Planning (6 papers).



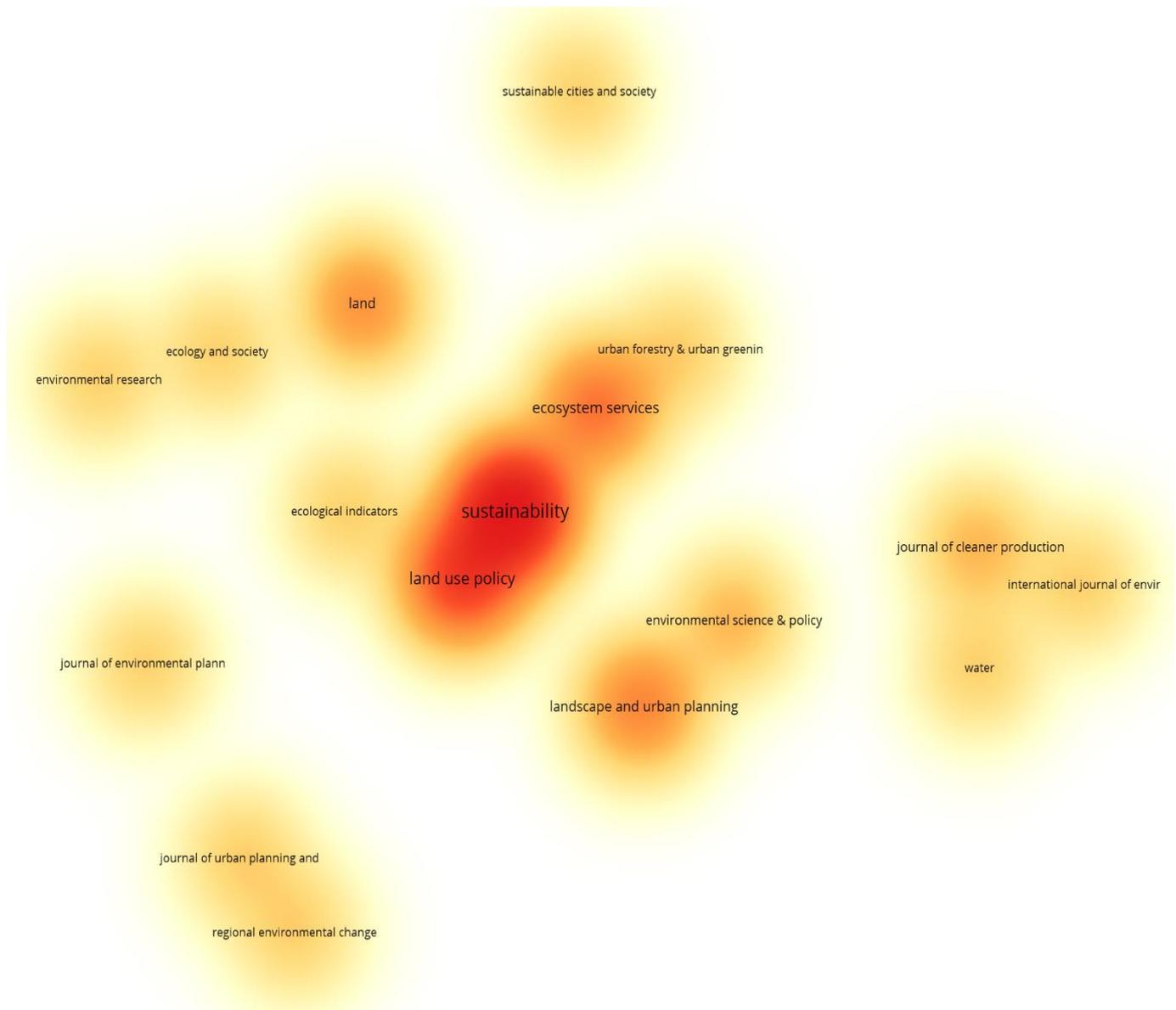
**Figure 4.** Map of the countries studying GI in combination with land management, land administration, LADM, and land use planning, created in VOSviewer.



**Figure 5.** The density map of the journals studying GI, created in VOSviewer.

### 3.3. Keyword Analysis

Keywords are some of the most important elements in an analysis, which tell us which topics are represented in the publications and which are the research trends, while the analysis examines the actual content of the publication itself [20].



**Figure 6.** The density map of the journals studying GI in combination with land management, land administration, LADM, and land use planning, created in VOSviewer.

Analyzing the term GI in VOSviewer, 12,854 keywords were identified via a co-occurring keyword analysis. The top 50 frequency keywords and connections between them are visualized in Figure 7. On the other hand, when analyzing the term GI in combination with “land management”, “land administration”, “LADM”, and “land use planning”, in total 801 keywords were identified via the co-occurring keyword analysis in VOSviewer. The top 20 frequency keywords and connections between them are visualized in Figure 8. In Figures 9 and 10, the colors are defined by the average publication per year of each keyword in the period between 2018 and 2020. Yellow indicates the most recent research, while dark blue indicates the oldest research. According to the keyword analysis in VOSviewer, it is evident that the most represented keyword in both cases is GI, followed by ecosystem services and management. This indicates that GI has a relationship with many scientific fields, and especially that GI is closely related and brings benefits to ecosystem services, biodiversity, and climate change and is important for sustainable development. In Figure 10, it can be seen that in the recent research new keywords appear, such as land use and land use planning. This indicates that recently the importance of GI in land management has been increasingly recognized.

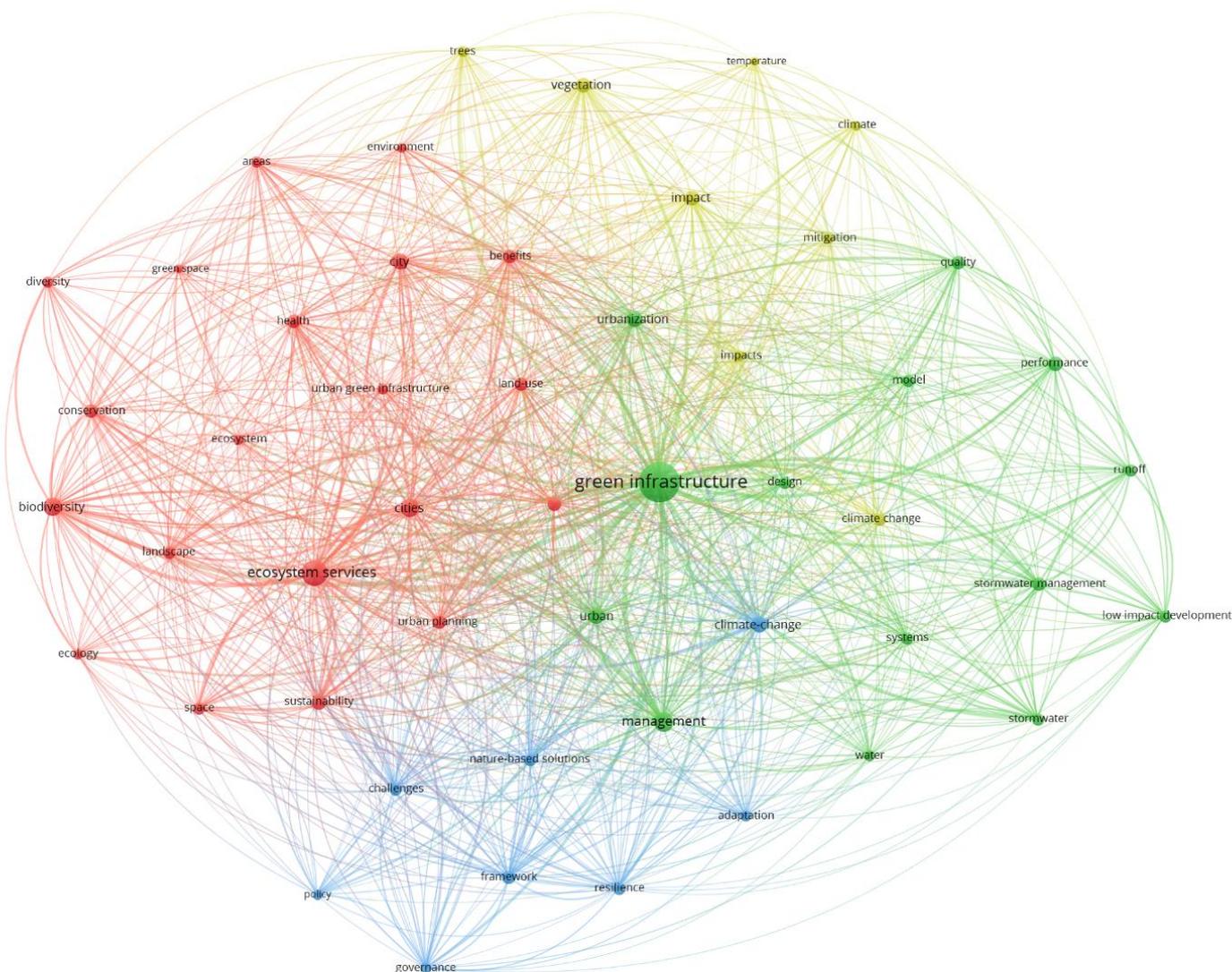
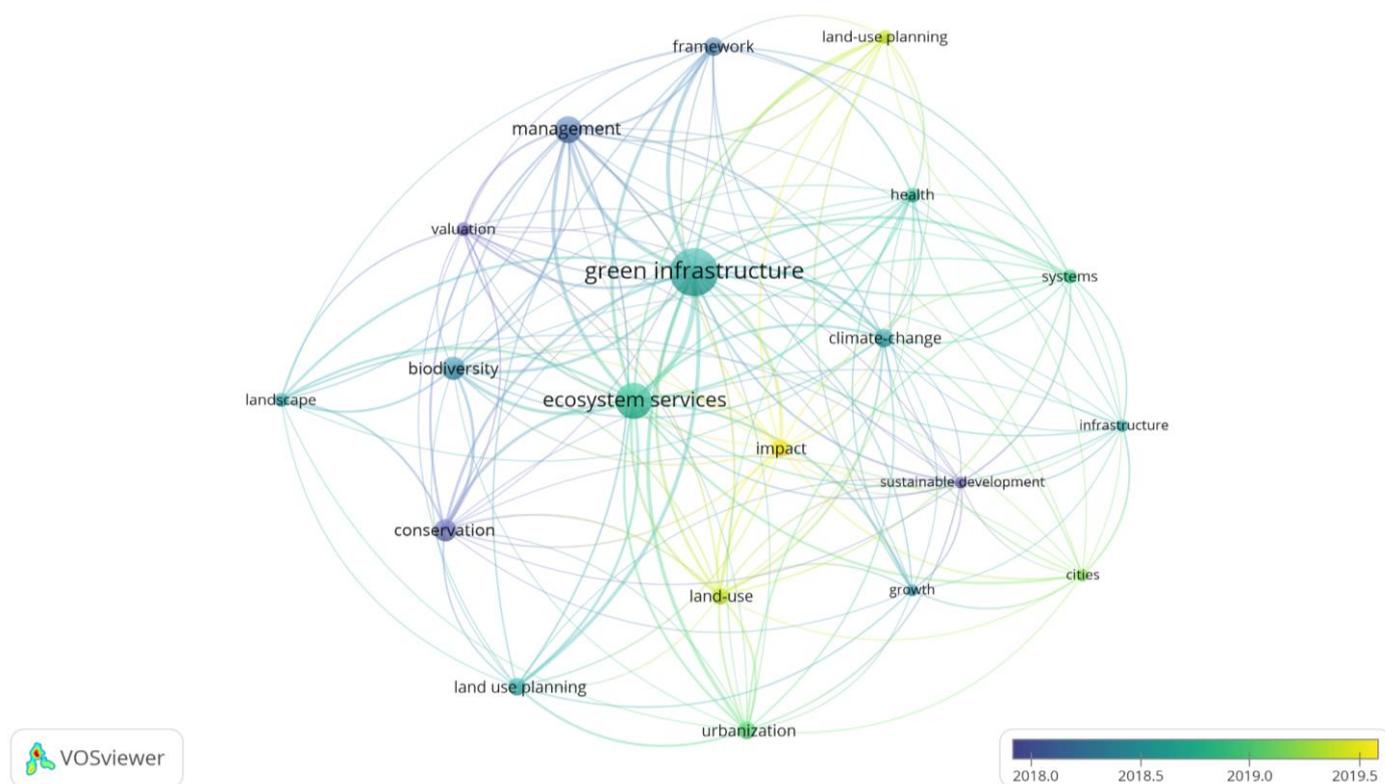


Figure 7. The top 50 frequency keywords on GI, created in VOSviewer.





**Figure 10.** Time periods of the keywords on GI in combination with land management, land administration, LADM, and land use planning, created in VOSviewer.

#### 4. Discussion

In this research, we analyzed and interpreted 4385 studies on GI and 110 studies on GI in combination with land management, land administration, LADM, and land use planning. All studies were collected from the WOS database for the period between 1995 and 2022 and for the period between 2007 and 2022, respectively. We analyzed how this field has been researched and activated over the years, and which countries and journals publish the most papers in this field of research. An analysis of keywords was also carried out, which showed the current topics in this research area and the direction in which the recent research has been going.

The results obtained after the conducted analysis showed that since 2015 there has been a significant increase in the number of studies published on GI. Additionally, since 2015, there has been an increase in the number of studies on GI in combination with land management, land administration, LADM, and land use planning, but the number of studies in this research area is still significantly small compared to the total number of studies on GI, representing only 2.5%. However, the positive growth trend in the number of studies on GI shows that more and more researchers are dealing with this field of research and that GI has become one of the important tools for solving problems caused by excessive urbanization. From the distribution of publications by country, it was found that most papers were published in developed countries. Most of the publications were published in the USA, with 29.08% (Table 1) and 21.82% (Table 2) of the total number, and North America leads in the number of publications on GI. It is followed by European countries, which do a lot of research on GI and sustainable development, and recently also on GI in land management systems. In Asian countries, most papers were published in China. In African countries, significantly less research has been conducted on these topics compared to other regions. From the obtained results, it is clear that developed countries lead in the number of studies. However, there are also a number of other factors besides the development of

the country that influence the number of studies in each individual country, which should be further analyzed.

From the analysis of the journals, it was found that the researchers for the topics about GI and land management mostly choose journals that are focused on sustainable development, the planning of urban and rural land uses, environmental issues, and other similar topics. Therefore, it can be said that these are some of the main topics of most papers about GI. The current topics in this field of research are best demonstrated by the keyword analysis. The analysis of the top 50 keywords and the top 20 keywords indicated that the researchers are mostly dealing with topics about ecosystem services, biodiversity, sustainable development, and the impacts of climate change on the environment, especially in urban areas. According to the most frequent words from the keyword analysis, it was found that the majority of papers deal more with environmental and social benefits and less with economic benefits. The same conclusion was reached by several other authors in their systematic literature reviews of GI [26–28]. The three most cited publications about GI are “Promoting Ecosystem and Human Health in Urban Areas Using Green Infrastructure: A Literature Review” by Tzoulas et al. [29], “Nature and Health” by Hartig et al. [30], and “Classifying and Valuing Ecosystem Services for Urban Planning” by Gomez-Baggethun and Barton [31]. Given that these publications deal with the problems of ecosystem services and the impacts of GI on human health and well-being, this also confirms the previously stated claim that a smaller number of studies refer to the economic benefits of GI. Andersson and others also argue that land management and land use planning are rarely taken into account in urban ecosystem services planning [32].

Although GI has been studied intensively, especially in the last few years, with the number of publications in this field of research growing daily, the fact is that GI in land management systems has not been researched as much.

## 5. Conclusions

This bibliometric analysis provides insights into GI research and its importance in land management procedures. The studies show that GI has been gaining more and more importance, especially after the adoption of the UN Agenda 2030 on sustainable development. There has since been a large number of studies on GI emphasizing its benefits and advantages, such as in the fight against climate change and in maintaining biodiversity, as well as its good impacts on human health and well-being [33–35]. Considering that the big problems for cities are overbuilding and insufficient green spaces, green roofs and walls could play a significant role in sustainable urban development [36–38]. Some of their benefits are temperature, urban air pollution, and building energy consumption reductions [36,37]. It can be concluded that GI is important for achieving the goals of sustainable development, but it is also important to pay attention to sustainable land management. According to the UN, sustainable land management is the use of land resources for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions [39]. Selecting the right land uses for the given biophysical and socio-economic conditions and implementing sustainable land management are essential aspects in minimizing land degradation, rehabilitating degraded land, and ensuring the sustainable use of land resources [39,40]. Therefore, when planning GI, it is necessary to pay more attention to land management in order to achieve more benefits from the land on which GI is planned.

In this study, it was found that there is a large amount of research on GI, but also that there is a lack of studies dealing with GI for the purpose of land management, and this creates a serious gap in this field of research. The reason for the lack of research in this field is not because it is not significant but because there is no adequate spatial data infrastructure and software capabilities for analyzing large amounts of data for this purpose. Therefore, it would be good if, among other things, the future research focused on GI in land management systems in order to be able to better plan GI in both urban and rural

areas. When planning GI, it is important to pay attention to land management in order to find out what the benefits and possibilities of the land are and what it is suitable for. For future research, we suggest the inclusion of numerical analyses in land planning for GI in order to obtain a universal land valuation model for the purpose of GI planning.

On the other hand, this study has some limitations. This study analyzed only publications based on the WoS database, so some research results may be left out because the WoS database does not contain all publications and documents on this topic. Furthermore, the free software VOSviewer was used for the bibliometric analysis, which also has some shortcomings. Therefore, it might be good to also collect data from other databases and make a comparative analysis with some other software programs in future research studies.

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