Megaron, Vol. 18, No. 4, pp. 499–519, December 2023

Megaron
https://megaron.yildiz.edu.tr - https://megaronjournal.com
DOI: https://doi.org/10.14744/megaron.2023.70962

Article

The importance of geographical information systems in urban and landscape planning: A bibliometric analysis

Kadir Tolga ÇELİK[1], Ahmet ŞEKEROĞLU[2*]

[1]Department of Urban Design and Landscape Architecture, Amasya University Faculty of Architecture, Amasya, Türkiye
[2]Department of Urban and Regional Planning, Amasya University Faculty of Architecture, Amasya, Türkiye

ARTICLE INFO

Article history
Received: 19 July 2023
Revised: 17 December 2023
Accepted: 18 December 2023

Key words:
Bibliometric analysis; geographic information systems (GIS); urban planning; spatial planning; landscape planning.

ABSTRACT

Since the 1970s, Geographic Information Systems (GIS) have gained increasing recognition in the literature, drawing the attention of numerous scientific disciplines, particularly within technical and environmental sciences. What initially began as computerized map production in the 1970s has evolved with advancements in computer processing power and capacity, supported by various software packages. This study aims to reveal the general tendencies in research studies conducted in the fields of urban planning, spatial planning, and landscape planning. To identify these trends, a bibliometric analysis was conducted by examining literature on studies published worldwide, including Türkiye. For this purpose, 2,354 research and review articles published between 1990 and 2022 and indexed in the Web of Science database were analyzed using VOSviewer software, which is suitable for scientific mapping and bibliometric analysis. The analysis focused on the most frequently published journals, highly-cited authors and countries, collaborative authorship relationships, and the most cited authors, journals, and research topics in Türkiye. As a result, it has been observed that, considering the emergence of modern GIS concepts in the late 1970s and subsequent development based on spatial data from the 1980s, studies in the fields of Urban and Regional Planning, Urban Design, and Landscape Architecture have gained momentum since the 1990s. Research establishing the relationship between GIS and planning in Türkiye has been increasing since 2004, with the primary focus of these studies being categorized into three clusters: site selection, spatial mapping, and mathematical modeling.

Cite this article as: Çelik KT, Şekeroğlu A. The importance of geographical information systems in urban and landscape planning: A bibliometric analysis. Megaron 2023;18(4):499–519.

INTRODUCTION

A Geographic Information System (GIS) is a tool that defines space as points, lines, or areas and reveals its attributes (Dueker, 1979). Unlike other computerized systems, such as spreadsheets, word processors, and database management systems, GIS processes and manages spatial data. While word processors and spreadsheets handle text and numbers, respectively, GIS processes maps, images, and other types of spatial data with specific references to locations on Earth's surface (Zhu, 2016). Modern concepts of GIS were first introduced in the late 1970s (Dueker, 1979). In the following decades, definitions of GIS began

***Corresponding author**
*E-mail adres: ahmet.sekeroglu@amasya.edu.tr

to expand and diversify. Marble et al. (1984) described GIS as a set of tools for the input, storage, organization, and analysis of spatial data, while Cowen (1988) defined it as a decision support system utilized in the problem-solving and decision-making processes involving spatial data. Chrisman (1999) broadened the definition to include not only spatial data but also social phenomena as integrated tools within the system. Goodchild (2004) delineates GIS as a tool that combines nomothetic elements in its software and algorithms with idiographic elements in its databases. Since the 2000s, modern GIS has provided two-dimensional (2D) and 2.5-dimensional (2.5D) map representations using traditional cartographic approaches, as well as visualization techniques that enable users to navigate the real world in virtual reality with three-dimensional (3D) maps. It has also facilitated the creation of maps that can be presented and distributed through various media (hard copy papers, computer screens, mobile devices, etc.) (Zhu, 2016). For centuries, maps have served as data storage tools to fulfill societal needs. Prior to the computer revolution, maps were produced mainly by hand or through photochemical procedures known as photomechanical map generation (Robinson et al., 1995). The feasibility of computer-aided GIS emerged with the development of microcomputers and operating systems. The history of computer-aided GIS implementation began in the mid-1960s with the development of the Canadian Geographic Information System (CGIS), which aimed to assist the Canadian Federal Government in managing rural Canada's natural resources and land capacity (Tomlinson, 1967). The CGIS introduced new approaches such as digitization and classification (Waters, 2017).

In the 1970s, GIS evolved into a computer-aided process that automated map production. Various cartographic data structures were developed to encode map data (Peuquet, 1984; Zhu, 2016). The ODYSSEY GIS, developed by the Computer Graphics and Spatial Analysis Laboratory at Harvard University, was a pioneer in data structuring for digitally encoding line and area features on maps (Peucker & Chrisman, 1975). These structures laid the foundation for the development of data models and management systems for spatial data in modern GIS. However, this period's GIS had shortcomings, such as inflexible spatial data entry, poor data management, limited cartographic representation, and simple map processing, all managed on large host computers in batch mode. The first GIS applications were mainly used for land and natural resource inventories, such as CGIS, the Minnesota Land Management Information System (MLMIS), and the Land Use and Natural Resources Inventory System (LUNR) (Coppock & Rhind, 1991).

The 1980s marked an upswing for GIS. As computing power increased, basic spatial data management and analysis functions evolved, integrating with computer mapping, database management, and analytical capabilities. The introduction of hardware such as X-Windows, Microsoft Windows, and Apple's Macintosh simplified the use of GIS software. A notable development was the release of ARC/INFO, the first commercial GIS software package for microcomputers in the 1980s. Additionally, positional query functions were developed, allowing users to retrieve information from GIS databases based on geographic locations or perform geo-queries to create maps. This period experienced a rapid demand for spatial data, leading to the emergence of the spatial data industry and a market for digital spatial data. Medium-resolution digital remote sensing, particularly through the Landsat Earth observation satellite program, became a significant source of digital spatial data for GIS. Advances in spatial data management and techniques such as digitization, map creation, map scale transformation, geometric measurement, buffer creation, overlay analysis, and digital terrain modeling were introduced in most GIS (Berry, 1987; Dangermond, 1983). Map algebra concepts and techniques were also developed, enabling the processing of maps as variables through mathematical operations. However, GIS of the 1980s lacked spatial analytics and modeling capabilities (Goodchild, 1990). With the advent of the Internet in the 1990s, GIS applications expanded from computerized mapping and natural resource inventories to environmental analysis, modeling, and decision-making. Yet, GIS lacked the spatial analysis and modeling features required for complex environmental modeling and decision-making tasks. With GIS software like IDRISI, the range of spatial analysis applications supporting environmental modeling expanded. Links between statistical packages (e.g., S-Plus, ArcView) and GIS were established to enhance GIS-based statistical modeling (Openshaw, 1998). By the late 1990s, remote sensing images were being integrated with GIS.

Also, in the late 1990s, Light Detection and Ranging (LIDAR) technology marked an important milestone in the collection of high-resolution and highly sensitive digital surface and digital terrain models. The availability of very high-resolution remote sensing images and LIDAR data has enabled the development of a new level of GIS analytical capability in the 2000s, allowing for more accurate and detailed environmental analysis and modeling.

Since 2006, a series of online mapping platforms have emerged, providing an innovative approach to the collection of environmental data by engaging with the wider community (Zhu, 2016).

Since the early 2000s, rapid advancements in computer technologies have been pivotal in the development of spatial query and analysis systems within the field of GIS. Today, this era, known for its lasting impact, has seen an increase in the use of ArcGIS software for spatial decision support systems in numerous studies (Miller & Goodchild, 2014). Access to spatial data and the diversification of

information, alongside spatial databases, computation-based mathematical approaches, spatial analysis, modeling, and visualization methods, have become increasingly prominent within the GIS field (Haining, 2003).

GIS has become a fundamental tool for spatial planning and management, primarily due to its utility in the planning process through the incorporation of multi-criteria decisions regarding land use. Therefore, its applications are crucial not only for visualization and data management but also for evaluating alternative choices based on spatially relevant criteria. This decision support tool is invaluable for assessing and managing various spatial data, integrating the preferences of those involved in the decision-making process, such as decision-makers, planners, stakeholders, and policymakers (Latinopoulos & Kechagia, 2015).

GIS is a technology that caters to the spatial data management needs of users, combining the spatial positions and related attributes of real-world objects. It collects, stores, manages, processes, analyzes, displays, and defines geographic distribution data concerning all or part of Earth's surface. GIS technology enhances the scientific basis of planning and design by ensuring the basic data is detailed, reliable, and accurate. Over the past two decades, spatial planners and designers have increasingly utilized it both for the ease and speed of creating and dynamically updating various plans, tables, and reports (Li & Wang, 2022), and for its use in spatial distribution analysis and map production (Raillani et al., 2022). GIS technology, with its versatile and dynamic structure, enables efficient planning and applications by providing rational and systematic analysis, aiding in swift decision-making. Moreover, GIS assists in understanding what is occurring at a specific location, gathering information about geographical areas that meet certain conditions, detecting anomalies that do not fit the geographical pattern of their location, and determining the outcomes of particular actions (Dekolo & Oguwaye, 2005).

In urban and regional planning, GIS is widely utilized to process spatial data and support decision-making. It provides data and techniques needed at different stages of the process, such as setting goals, conducting resource inventories, analyzing current situations, modeling and projecting, developing and selecting planning options, and implementing, evaluating, monitoring, and providing feedback for the plan (Santos et al., 2021).

In landscape planning, GIS is used to assess location suitability, examine proposal feasibility, allocate uses within an area, and predict the effects of different decisions (Bilous et al., 2021). GIS applications concentrate on the interaction between landscape processes and morphological aspects and address the aesthetic, functional, social, and ecological relationships between natural and human systems. Furthermore, GIS is employed in traffic and transportation models, planning models, economic models, cognitive models, multi-actor models, nature and environmental models, agricultural models, and energy models (Nijhuis, 2016). It is also an analysis method used in landscape ecology to study changes in spatial landscape patterns (Sun Q. et al., 2022). Additionally, GIS is instrumental in incorporating biodiversity knowledge into the planning phase and assessing the potential impact of existing plans on biodiversity conservation in urban green spaces (Yeo et al., 2022).

In the planning and design field, the general potential applications of GIS, which particularly connect maps and attribute data, are as follows (Dekolo & Oguwaye, 2005):

- Natural resource management topics such as vegetation (Islam et al., 2023), forest inventory (Rana et al., 2023), modeling of forest areas (Tiamgne et al., 2022), production forecasting and management (Dunaieva et al., 2019), access planning (Lee et al., 2019), ecosystem change detection (Bhattacharjee et al., 2021), water resources potential and management (Chatterjee & Dutta, 2022), and monitoring the use of water resources (Sun T. et al., 2022).
- Land topics such as land use and inventory (Kang et al., 2021), preparation and management of agricultural inventories (Calina & Calina, 2022), and soil resources inventory and management (Papadopoulos et al., 2017).
- Environmental planning and management topics such as environmental impact assessment (Zarubin et al., 2021), environmental risk management (Filho et al., 2010), and environmental monitoring (Kipkemboi et al., 2023).
- Emergency planning and management topics such as monitoring of natural hazards (Feng et al., 2020), hazard analysis (Pollino et al., 2022), and fire risk analysis and planning (Coşkun & Toprak, 2023).
- Transportation topics such as transportation planning (Waleghwa & Heldt, 2022), network analysis (Moreno-Navarro, 2022), and transportation demand modeling (Lopes et al., 2014). Additionally, this list of potential application areas can be expanded.

The expansion of spatial data systems has unlocked significant potential for big data studies in the fields of GIS and planning. However, the diversity and volume of data present challenges in shaping geographic information and creating accurate, understandable data-driven models (Haining, 2003).

Spatial information and the ability to apply it are crucial in developing complex systems such as cities. The diversification of spatial data and information has propelled the advancement of geographic information science and technology. In this context, GIS is considered an essential tool in urban studies and related disciplines (Cowen, 1988).

In the planning process, maps are invaluable, serving as a reference and a platform to reflect physical decisions in the relationship between settlements and physical space. The creation of these maps during the planning process benefits from various and abundant data layers. Integrating, combining, and preparing data for dynamic querying is essential in processes that involve diverse economic, social, and physical parameters related to space. Comprehensive analyses, establishing relationships between data, and the successful execution of processes necessitate the use of specialized software programs. These programs are critical not only in the analysis and evaluation stages but also throughout the planning process. GIS, as computer-based software, plays a significant role in the planning discipline by acting as a source of information, a tool, and an evaluation platform in the preparation and decision-making processes.

This study aims to highlight the importance of GIS in the disciplines of City and Regional Planning, Urban Design, and Landscape Architecture, which are actively involved in spatial analysis, evaluation, and modeling processes, based on scientific research. To this end, a bibliometric analysis was performed using statistical techniques to evaluate the scientific literature published through the Web of Science database. The study, spanning the years 1990-2022, examined articles and review articles indexed in the Social Sciences Citation Index (SSCI), Science Citation Index Expanded (SCI-E), Emerging Sources Citation Index (ESCI), and Arts & Humanities Citation Index (AHCI). It evaluated the general trends first in the international literature and then in Türkiye.

The study primarily seeks to address two questions:

- How do advancements in the field of GIS impact the planning disciplines?
- In which areas have studies focusing on planning related to the development of GIS in Türkiye concentrated?

By doing so, this study underscores the influence of GIS on planning disciplines and emphasizes the significance of research in the literature on planning and design. Moreover, it provides a more detailed analysis of GIS's contribution to the planning disciplines and the research trends in Türkiye, thus serving as a guide for future studies.

METHODOLOGY

Although GIS-based analysis and evaluation methods vary, there are studies covering many scientific disciplines and fields. In this study, a bibliometric analysis was carried out to reveal the research carried out on disciplines such as urban planning and urban design and landscape architecture, which mostly work on spatial analysis. The process, which started with revealing the general situation in the dimension of international literature in the analysis, evolves into Türkiye and reveals the place of GIS in planning and design disciplines. The process of "search criteria", "selection", "analysis" and "evaluation of the results" is shown in Figure 1.

Bibliometric Analysis

Bibliometrics is the quantitative analysis of the bibliographic properties of literature (Hawkins, 2001; Kokol et al., 2020). Bibliometric analysis (BA) represents a new form of meta-analytical research or meta-review of literature (Harsanyi, 1993; Kim & McMillan, 2008; Fetscherin et al., 2010). It is a statistical technique used to assess the quality and quantity of published scientific literature and analyze trends in a particular area (Sweileh et al., 2017; Buber & Koseoglu, 2022). As an objective and rational tool, it is employed to analyze the impact and value of research achievements (Ying et al., 2023).

It is also utilized to observe and assess the growth, trends, and knowledge structures of different fields across various academic disciplines (Priovashini & Mallick, 2021; Ghosh et al., 2022).

Bibliometric methods are frequently employed to reveal trends in research publications. The foundation of bibliometric methods can be traced back to Campbell's (1896) statistical methods for determining subject distributions. Subsequently, bibliometric analyses, which found application in diverse fields and methods, expanded to different stages with the development of computer programming and software.

Scientific mapping, or BAs, aims to illustrate the structural or dynamic aspects of scientific research. Presently, there are various databases such as Web of Science (WoS), Scopus, and Google Scholar, which store scientific studies, documents, and their citations. These databases aid in the search and acquisition of information about scientific fields and studies. However, databases do not uniformly cover all scientific fields and journals.

BAs commonly employ descriptive terms and phrases, authors, citation numbers, and topics such as cited authors, journals, and countries. Subject headings are derived through titles, abstracts, or combinations of these. Depending on the chosen analysis units, different facets of the research area can be analyzed (Börner et al., 2003; Shamsi et al., 2020; Radu et al., 2021).

In conducted studies, the social structure of the field (Gänzel, 2001), the international dimensions of the institutions to which authors are affiliated, the conceptual structure and prevalent concepts they address through descriptive terms and words, and the intellectual structure of the research area can be analyzed through citation structure (Cobo et al., 2011). Software is used for bibliometric analyses to ensure quantitative and accurate conclusions are drawn without deviations from subjectivity (di Montanara et al., 2022).

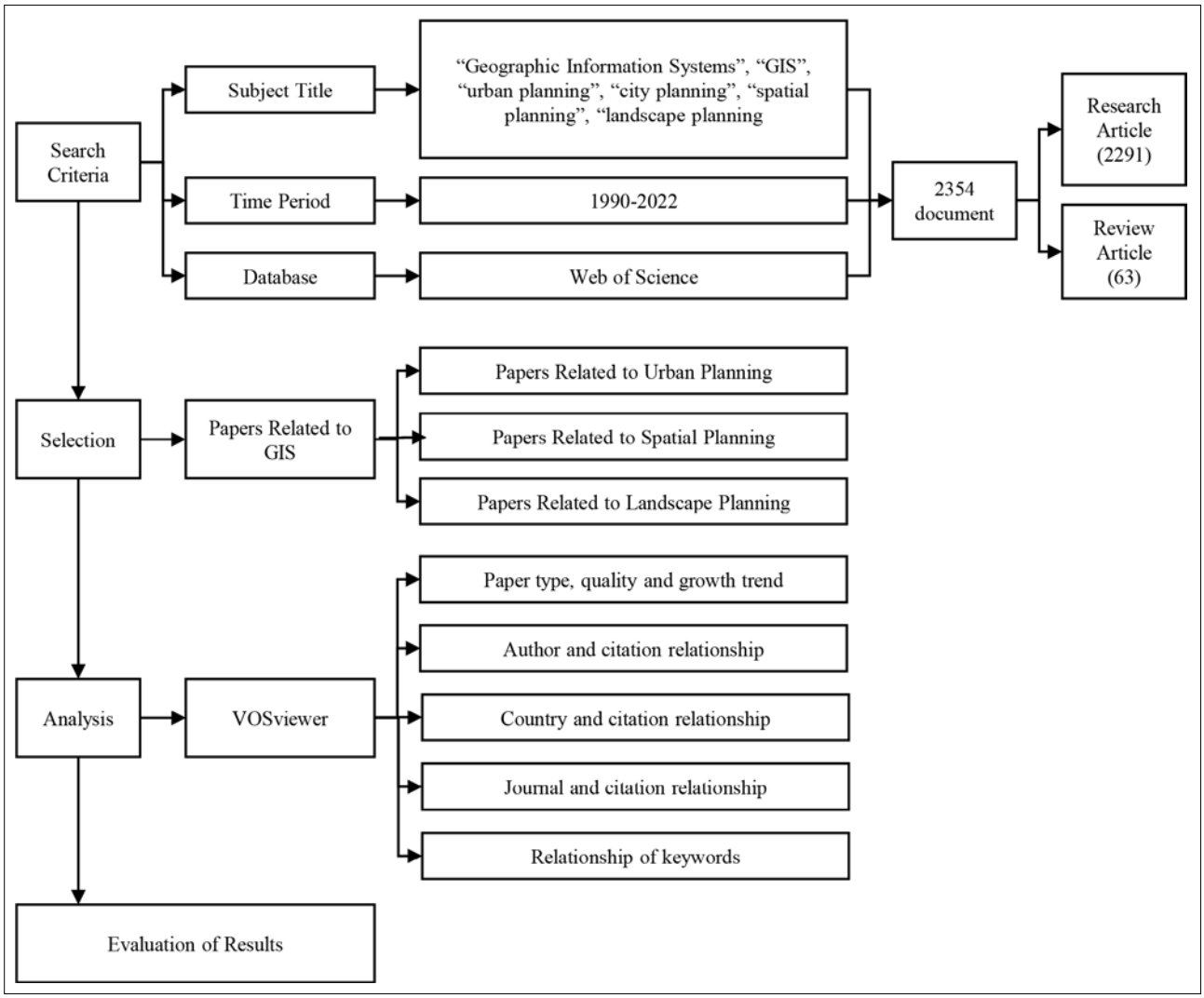

Figure 1. Stages of the Study Method.

Research Rules

Bibliometric analyses consist of various steps, including database selection, determination of subject categories, identification of search keywords, data preprocessing, selection of analyses to be used, visualization techniques, and interpretation of results.

The databases selected for bibliometric analysis data include citation indexes provided by Web of Science (WoS), namely, SSCI, SCI-E, ESCI, and AHCI. There are two key reasons for selecting these citation indexes. The first is that since the 1900s, these databases have indexed the most significant and influential research outputs across various disciplines. The second reason is their comprehensive reference information, which facilitates tracking the developmental process of research in various fields (Wang & Liu, 2014; Kiriyama & Kajikawa, 2014).

In this study, articles published from 1990 to 2022 were retrieved from the Thomson Reuters' Web of Science database, which encompasses SSCI, SCI-E, ESCI, and AHCI indexes.

When determining subject categories, the initial goal is to uncover the use of GIS across different disciplines in the international literature and its role in the planning, urban design, and landscape architecture disciplines in Türkiye. Documents retrieved from the WoS database were evaluated using VOSviewer, a software program developed by Nees Jan van Eck and Ludo Waltman of Leiden University for creating and displaying bibliometric maps (van Eck & Waltman, 2010). VOSviewer is instrumental for generating network maps and analyzing document types, years, authors, co-cited authors, countries, institutions, journal sources, co-cited journals, keywords, and co-citations (Zhang et al., 2020).

This study utilized bibliometric indicators at the document level (number of documents, document type, number of citations, highly cited documents, average citations, h-index, and number of publications by countries) and author level (number of authors, average authors per document, most productive and most cited authors, and authors' countries). Additionally, the information structure

of this dataset was analyzed, and networks were visualized at the levels of social structure (co-authorship network and international collaboration network) and conceptual structure (co-occurrence network for keywords).

Within the scope of this study, the research rules in the WoS database are defined as follows:

Topic Search = ("Geographical Information System" OR "GIS") AND ("urban planning" OR "city planning" OR "spatial planning" OR "landscape planning"), with the wildcard character (*) used to broaden search terms. The study spans the years 1990-2022.

The selection of key concepts, including City and Regional Planning, Urban Design, and Landscape Architecture disciplines, is based on two important considerations. Firstly, subject headings such as revealing existing land uses, preparing and mapping inventories for agriculture, forests, and pasture areas; environmental risk assessment and impact analysis; transportation-oriented analysis, planning, and modeling; functional use access analyses; and current city situations and future projections (such as population, energy, employment) are related to keywords in planning, urban planning, city planning, spatial planning, and landscape planning. Secondly, these two professional disciplines' studies, which pertain to physical space, require software to perform various visualization and mapping studies during the analysis, evaluation, and planning creation process. Within these software programs, GIS-based applications offer various spatial visualization and evaluation techniques. As a result, GIS enables the presentation of various space-based evaluation techniques with speed and objectivity. Therefore, to elucidate the approaches discussed in these two disciplines utilizing GIS, the relationship between GIS and planning was established from the subject search criteria in the study.

ANALYSIS

Overview

Based on the established criteria, a total of 2,354 articles were identified. The distribution of articles published in prominent journals is detailed in Table 1. Of the 2,354 articles, 2,291 (97.32%) were research articles, while 63 (2.68%) were review articles. Publications spanned across a total of 713 journals, with the most frequent appearances in journals such as 'Sustainability,' 'Landscape and Urban Planning,' 'ISPRS International Journal of Geo-Information,' 'Land Use Policy,' and 'Land.'

Table 1. List of journals with the most articles published.

	Journal Title	Number of Papers
1	Sustainability	135
2	Landscape and Urban Planning	103
3	ISPRS International Journal of Geo Information	57
4	Land Use Policy	48
5	Land	34
6	Computers Environment and Urban Systems	33
7	Ecological Indicators	32
8	Environment and Planning B Planning Design	29
9	International Journal of Geographical Information Science	28
9	Remote Sensing	28
9	Sustainable Cities and Society	28
Total		555

The trend of changes in the number of articles published from 1990 to 2022 is depicted in Figure 2. Since 2004, there has been a consistent upward trend, with the peak number of publications occurring in 2020 and 2021.

Countries and Regions

While authors from 115 countries or regions have contributed to the study, the top 10 countries with the highest number of contributors are listed in Table 2. Notably, the majority of the studies were conducted in the People's Republic of China and the United States.

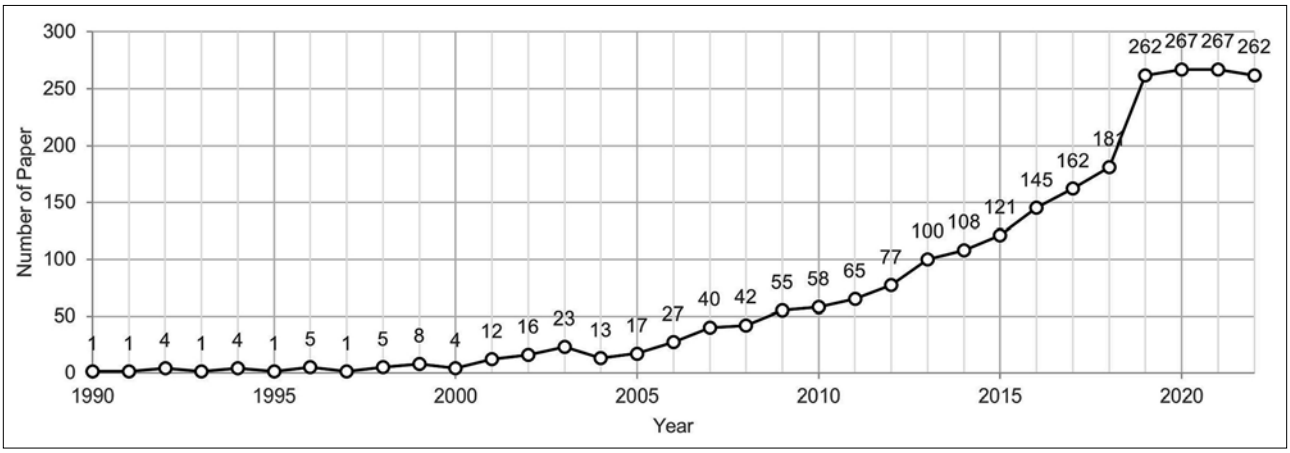

Figure 2. Number of published papers from 1990 to 2022.

Table 2. List of countries that have produced the most studies by authors

	Country	Total Number of Papers	Percentage of All Papers (%)
1	People's Republic of China	383	16,3
2	United States of America	304	12,9
3	Italy	184	7,8
4	Germany	141	6,0
5	Türkiye	129	5,5
6	England	123	5,2
7	Spain	111	4,7
8	Australia	107	4,5
8	Netherlands	107	4,5
10	Indian	91	3,9
Total		1680	71,3

Other significant contributors include Italy, Germany, Türkiye, England, Spain, Australia, the Netherlands, and India.

When examining the co-authorship between countries, there is a parallel between the countries with a high number of articles and those with evaluations based on at least 5 publications and 5 citations. As depicted in Figure 3, according to the co-authorship relationship, the People's Republic of China and the United States of America are the most prominent in terms of publication volume. In contrast, Germany, the United States, the United Kingdom, the Netherlands, and Canada stand out in terms of average citations. Thus, as indicated in Table 2, the People's Republic of China and the United States of America are observed to have the most substantial international collaboration in the field of GIS.

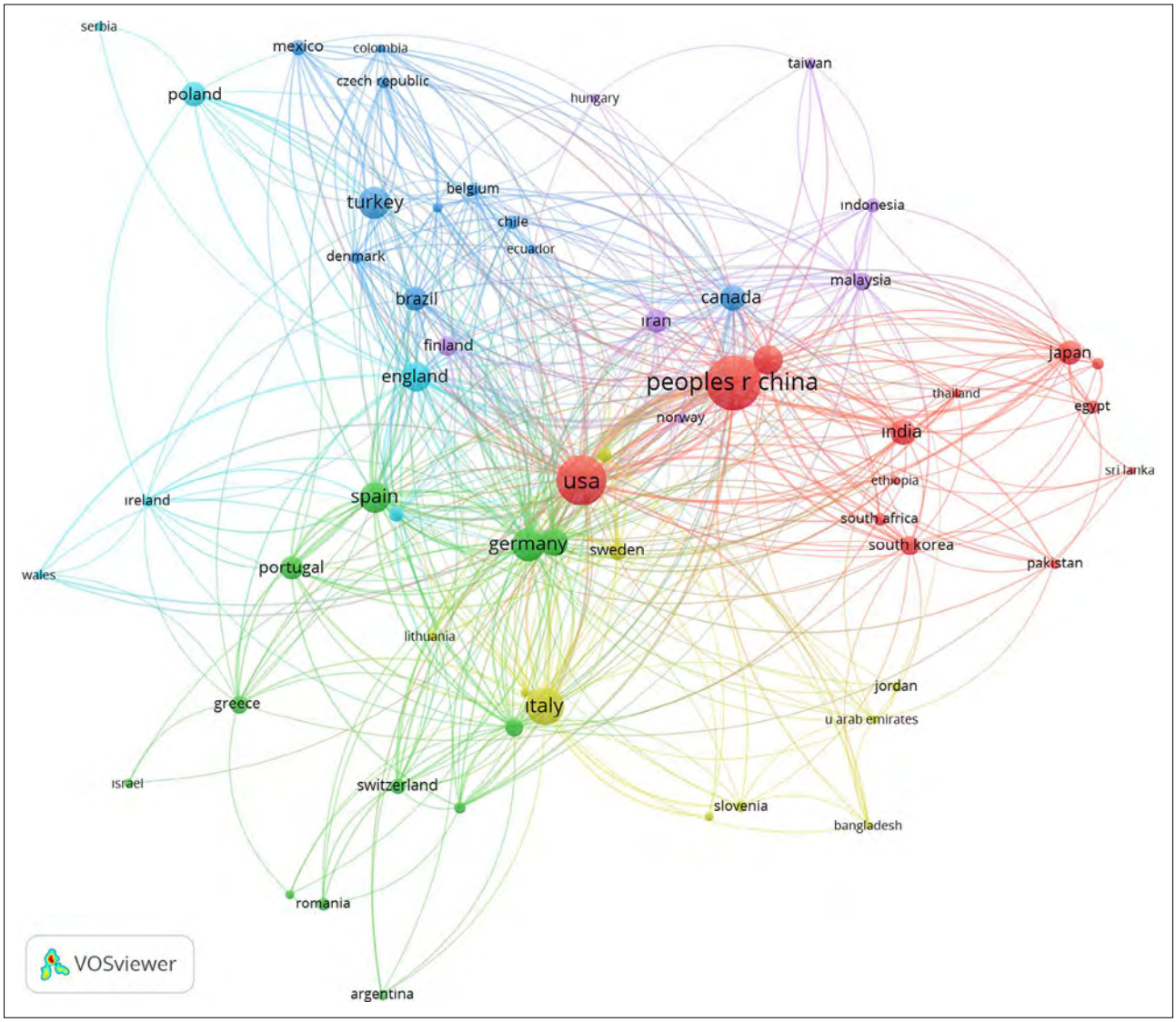

Figure 3. Network visualization showing co-author and country relationships.

Authors

A total of 7,360 authors have contributed to studies on urban planning, city planning, spatial planning, and landscape planning. When evaluated based on a threshold of at least 2 publications and 2 citations, Çetin, M. (12 publications), Murayama, Y. (12 publications), and Pradhan, B. (11 publications) are leading in terms of the number of publications. In terms of total citations, Li, X. (805 citations), Liu, X. (790 citations), and Çetin, M. (750 citations) have made significant contributions to the literature. The top 10 most-cited authors, in terms of citation count, are listed in Table 3.

In determining the most influential authors, the 'cited authors' analysis was utilized in the form of 'co-citation' analysis. The criteria for this analysis required a minimum of 50 citations, leading to the identification of 75 authors. Their interconnections are presented in Figure 4. According to the results of the co-citation network analysis, Malczewski, J., Batty, M., Li, X., Brown, G., and Saaty, T. L. emerge as the most influential authors. The analysis discerned 6 distinct clusters, illustrated in Figure 4 with purple, green, yellow, blue, red, and turquoise.

In the purple cluster, featuring authors such as Malczewski, J. and Halpern, B. S., GIS and multi-criteria decision-making are highlighted. The green cluster, which includes Brown, G. and Goodchild, M. F., brings GIS studies related to public participation and landscape planning to the forefront. The yellow cluster, with authors like Saaty, T. L. and Çetin, M., is associated with studies on the Analytic Hierarchy Process (AHP) and GIS. The blue cluster, where authors such as Batty, M. and Li, X. are featured, focuses on GIS and network modeling. In the red cluster, formed by authors like Seto, K. C. and Bhatta, B., topics related to remote sensing, urban growth, and landscape metrics are

Table 3. List of authors featured in terms of the number of citations.

	Author	Number of Citations	Number of Papers
1	Lee, X.	805	9
2	Liu, X.	790	9
3	Çetin, M.	750	12
4	Ng, E.	691	6
5	Ren, C.	662	5
6	Chen, L.	580	3
7	Bathrellos, G.	552	4
7	Skilodimou, H.	552	4
9	Pradhan, B.	550	11
10	Haase, D.	495	4
Total		6427	67

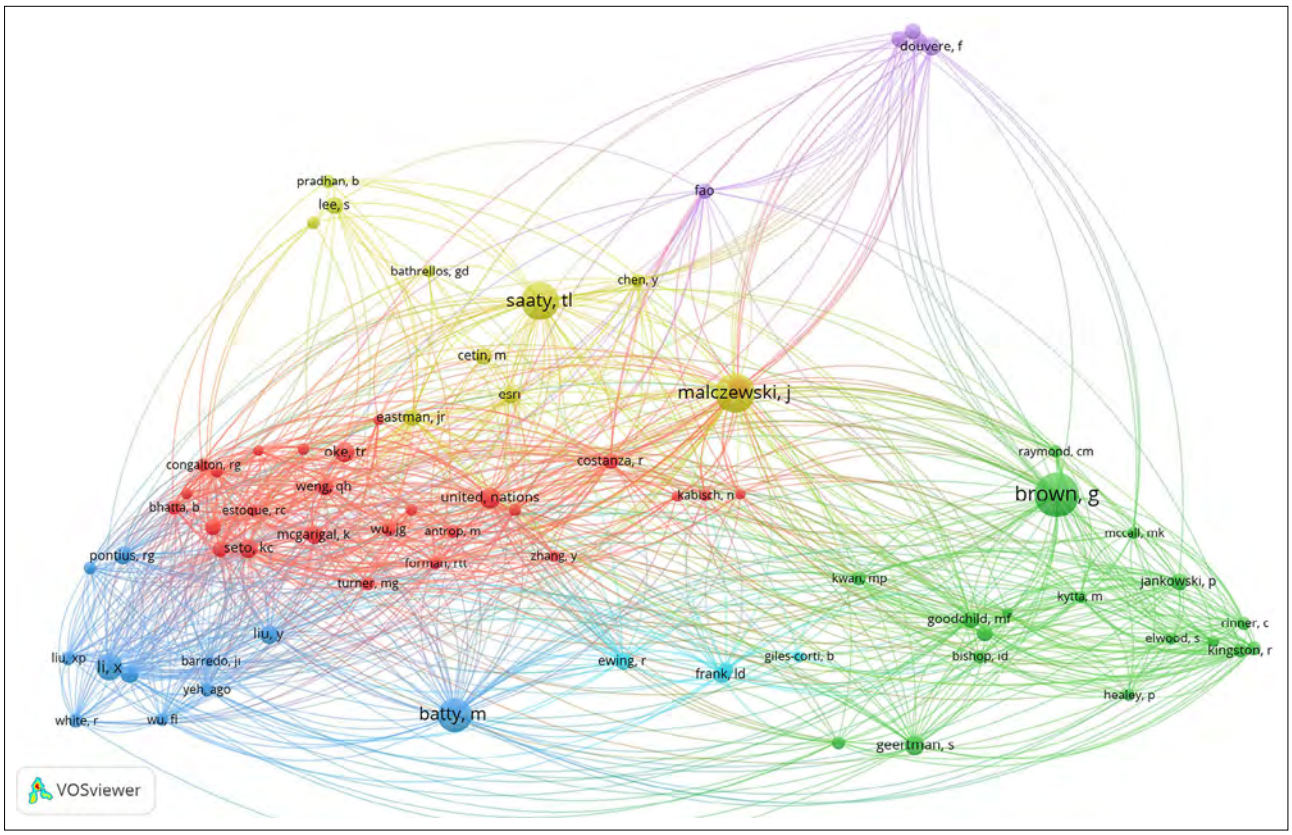

Figure 4. The common network relationship of the most influential authors.

emphasized, while the turquoise cluster includes Frank, L. D. and Ewing, R., who conduct studies on urban form and meta-analysis.

Co-occurrence Analysis

The relationships among keywords used by authors are illustrated in Figures 5 and 6. Larger circles represent the

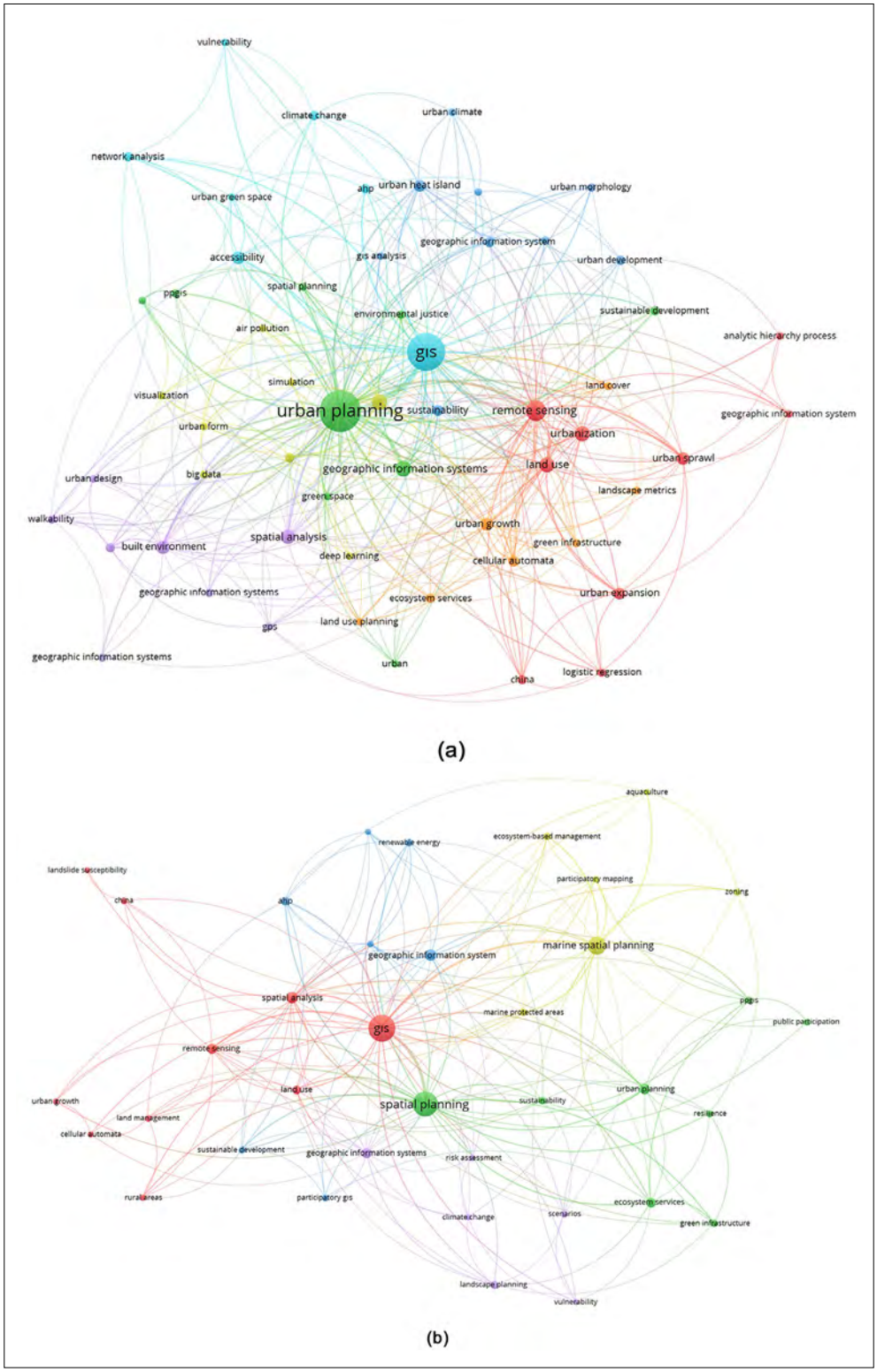

Figure 5. The network that shows the relationships of words in the fields of **(a)** urban planning and **(b)** spatial planning that the authors use most together.

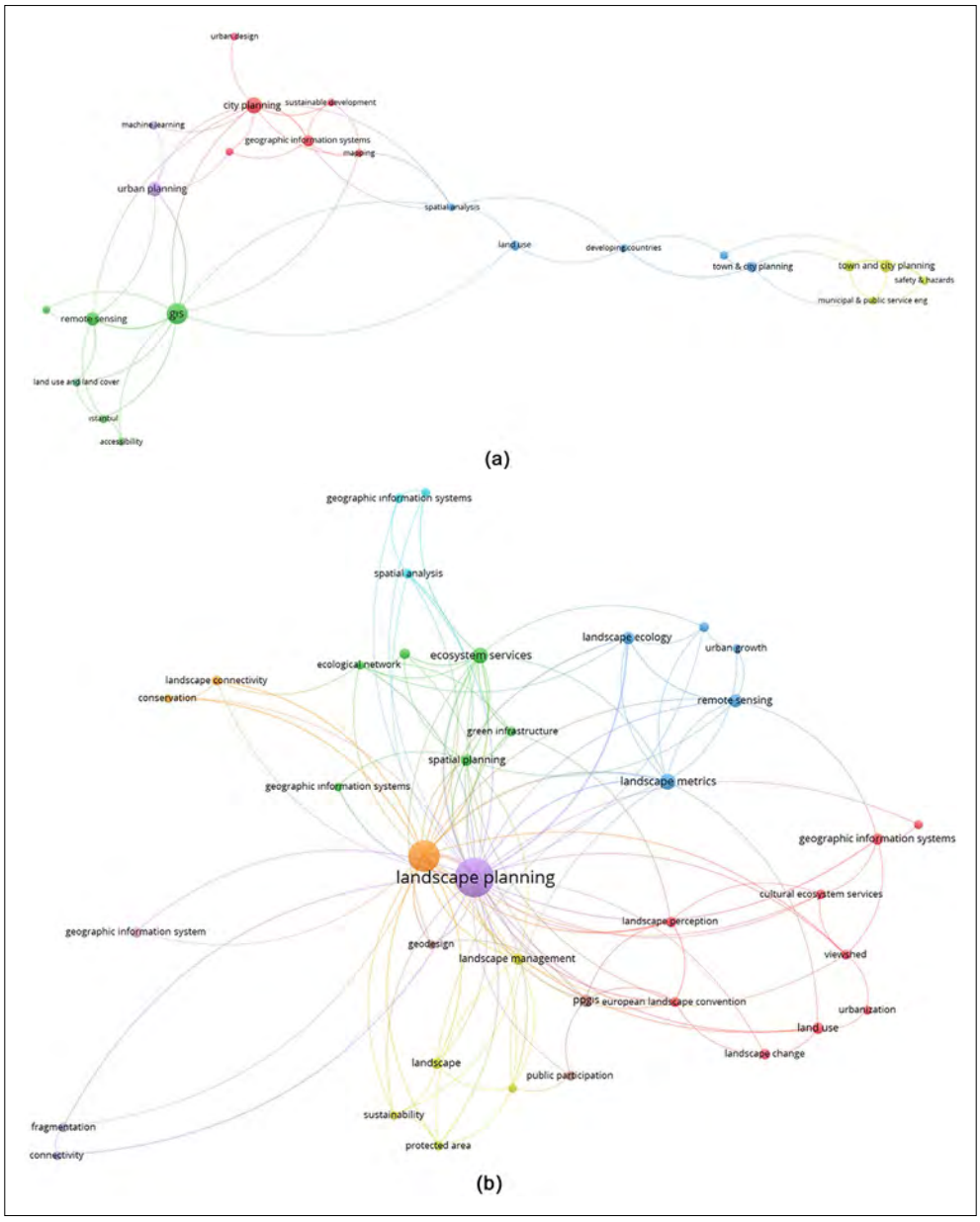

Figure 6. The network that shows the relationships of words in the fields of **(a)** city planning and **(b)** landscape planning that the authors use most together.

most frequently used words within these relationship networks, while studies that are interconnected are denoted by the same color.

Accordingly, urban planning, remote sensing, and spatial planning are prominent in the context of GIS. As we approach the present day, it is evident that there is a growing research interest in concepts such as urban sprawl, accessibility, the Analytic Hierarchy Process (AHP), urban design, urban morphology, multi-criteria decision-making, renewable energy, green infrastructure, and walkability. Additionally, land use planning, public participation, landscape metrics, climate, logistic regression, and landscape ecology are among the most frequently interconnected concepts.

In the realm of urban planning, the following concepts are particularly noteworthy: land use, climate change, sustainable development, urban morphology, resilience, sustainability, renewable energy, ecosystem services, green infrastructure, GIS, and spatial analysis. In spatial planning, a distinct emphasis is found on concepts like urban growth, GIS, AHP, sustainability, multi-criteria decision analysis, spatial analysis, and resilience. For landscape planning,

certain clusters revolve around concepts such as landscape ecology, ecosystem services, network analysis, spatial analysis, and sustainability. These clusters represent the core areas of research and inquiry within the respective planning disciplines.

CONCLUSION

This study aims to elucidate the relationship between GIS and planning through bibliometric analysis, referencing the Web of Science (WoS) database. Research and review articles indexed in SSCI, SCI-E, ESCI, and AHCI from 1990 to 2022 were scrutinized. Initially, the international literature was appraised, followed by an exploration of general trends in Türkiye.

The study's first research question asks, "How do the advancements in the field of GIS impact the planning disciplines?" The developments in GIS have expedited the integration of various methods and approaches within planning disciplines. Notably, the surge of big data in data-driven studies has established GIS as a pivotal element in the objective decision-making process.

In countries leading in the interplay between GIS and planning, analyses and evaluations predominantly cover urban planning. Country-specific study distributions are as follows:

- In the People's Republic of China, 74% of the total studies focus on urban planning, with 17% on spatial planning and 9% on landscape planning.
- In the USA, 69% of studies center on urban planning, 19% on spatial planning, and 12% on landscape planning.
- In Italy, 55% of the work is dedicated to urban planning, 28% to spatial planning, and 17% to landscape planning.
- In Germany, 47% of work pertains to urban planning, 38% to spatial planning, and 15% to landscape planning.

The People's Republic of China, which leads in publication volume, predominantly publishes in urban planning, with topics such as remote sensing, urbanization, urban sprawl, and land use frequently associated with GIS. While analysis and evaluation methods are prominent in the GIS-planning nexus, the employment of GIS based on mathematical or statistical evaluations appears limited. In leading countries like the United States, Italy, and Germany, there is a marked inclination toward urban planning, though the number of publications in spatial planning and landscape planning has risen recently. Topics like ecosystem services, accessibility, landscape planning metrics, and spatial analysis have gained increasing attention in the planning literature and are being linked to GIS in Italy and the USA (Figures 7 and 8).

Reflecting on the advent of modern GIS concepts in the late 1970s and their evolution based on spatial data since the 1980s, it is evident that studies in City and Regional Planning, Urban Design, and Landscape Architecture have found significant traction since the 1990s. As planning disciplines are fundamentally reliant on spatial data and as data diversity and complexity grow, there is a burgeoning necessity for interpretive decision analysis and evaluation systems that encompass multifaceted and dynamic processes. GIS fulfills this need by offering a crucial rational and systematic decision-making framework (Murayama & Thapa, 2011; Latinopoulos & Kechagia, 2015). Literature reviews indicate that GIS is predominantly utilized as a visualization tool in urban planning and landscape planning for spatial mapping. Moreover, analyses and evaluations incorporating statistical and mathematical models generally remain secondary (Maness & Farrell, 2004; Lee & Sambath, 2006). It appears that the most influential authors on topics bridging GIS and planning tend to concentrate on multi-criteria decision-making methods for site selection studies and their relationship with GIS. The process involves overlay analyses in spatial mapping, beginning with the AHP (Saaty, 1980), to finalize site selection. Recently, there has been a growing focus on topics such as renewable energy (Baban & Parry, 2001; Wiginton et al., 2010; Sánchez-Lozano et al., 2013), urban growth (Herold et al., 2003; Cheng & Masser, 2003; Moghadam & Helbich, 2013), land use changes (Guan et al., 2011; Palomo et al., 2013; Liping et al., 2018), and landscape metrics (Kong et al., 2007; Fichera et al., 2012; Liu & Yang, 2015).The second research question of the study asks, 'In which areas have studies focused on planning related to the development of GIS in Türkiye?'

In Türkiye, planning and GIS studies commenced later than in the international literature, but a surge in research activity in recent years has placed it among the most influential countries. Consequently, GIS has been increasingly utilized in planning studies. Since 2005, pioneering studies have begun to establish the relationship between spatial planning and GIS. By the end of 2022, 60% of the total works in Türkiye were in urban planning, with 20% in spatial planning and 20% in landscape planning.

The main thrust of the studies conducted in Türkiye falls under three clusters: site selection, spatial mapping, and mathematical modeling. Site selection studies

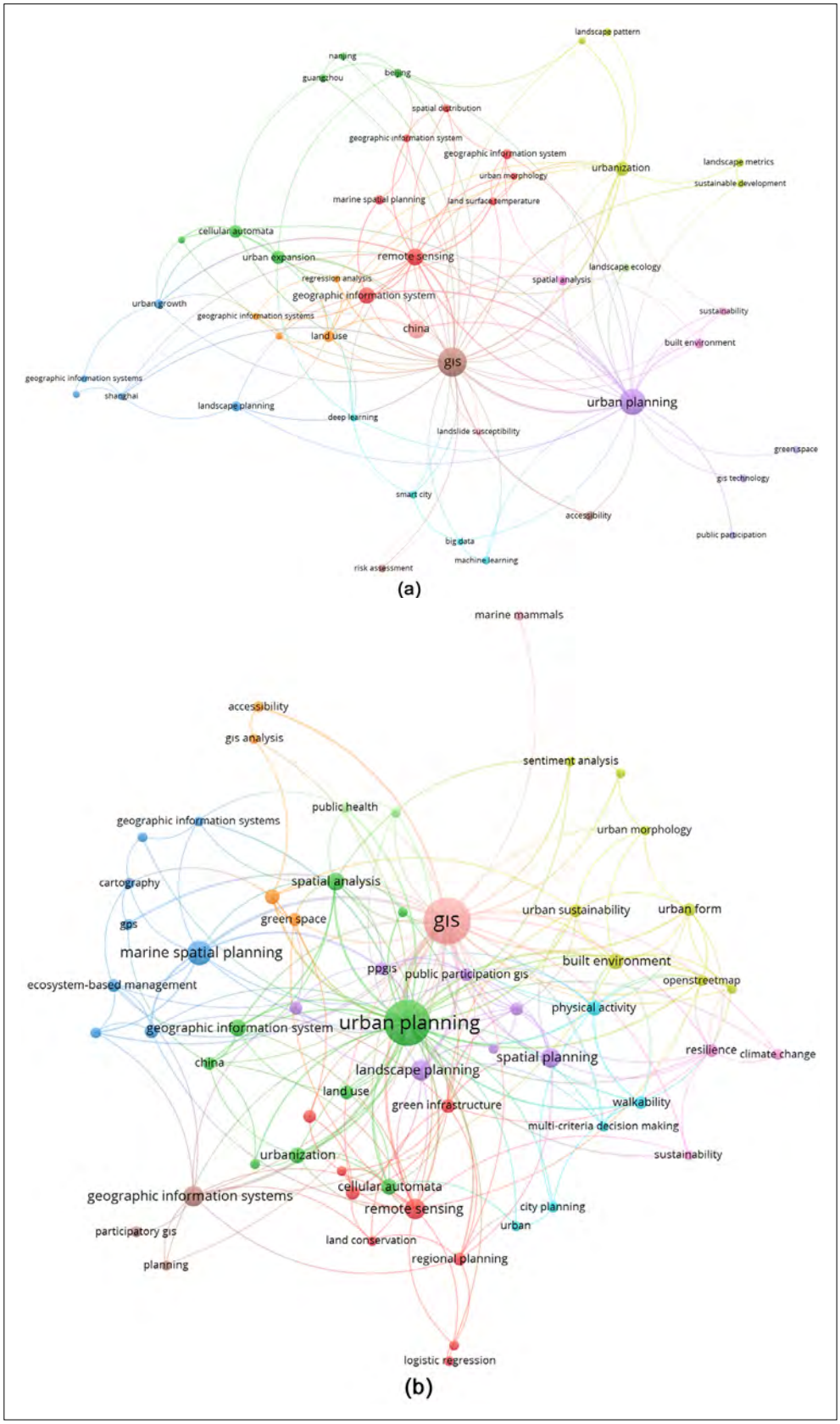

Figure 7. Key concepts that come to the fore in the relationship between GIS and planning **(a)** The People's Republic of China and **(b)** United States.

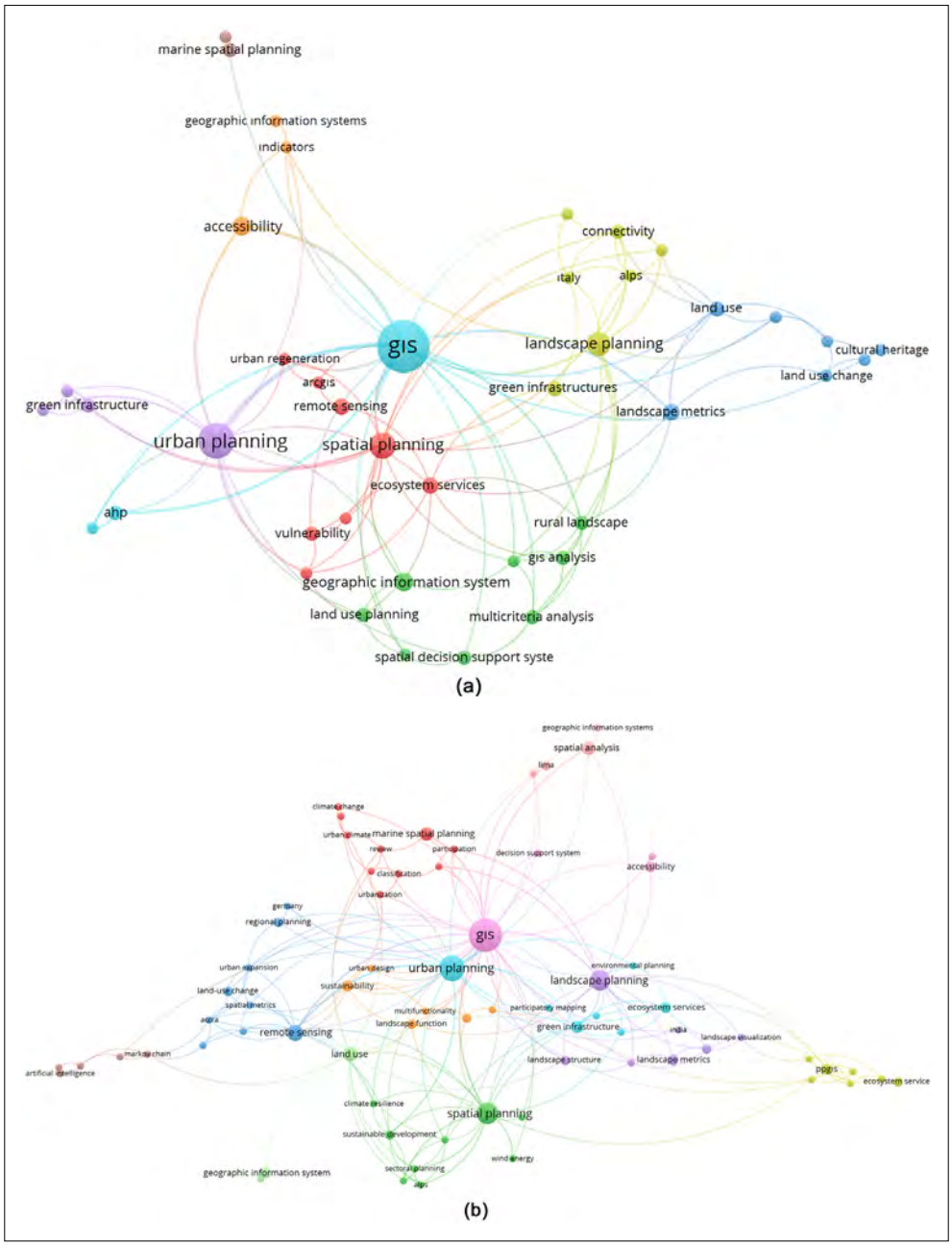

Figure 8. Key concepts that come to the fore in the relationship between GIS and planning **(a)** Italy and **(b)** Germany.

predominantly involve mapping various criteria over renewable energy resources within a GIS environment, using overlay analysis. Spatial mapping studies are primarily focused on mapping spatial data, with a process that often relies on remote sensing and land use analysis. Although studies on mathematical modeling are scarce, the primary approach is centered on optimization studies (Table 4).

The general profile of researchers in the fields of urban planning, spatial planning, and landscape planning tends to consist of scientists who favor a technical mapping perspective over a planning discipline approach. It is observed that authors predominantly publish their studies in planning-related journals. Given that planning disciplines operate on the basis of cumulative effects in spatial evaluations and regard GIS applications as methodological tools, there is a growing need for researchers with expertise in planning to contribute more significantly to this body of work.

Consequently, future research should encourage planning experts to adopt GIS as a significant methodological approach in various land use processes for multi-criteria and multi-objective decision strategies.

Table 4. Purpose of the most influential authors working in Türkiye to use GIS and clustering list (WoS database, date of last access: 10.06.2023)

Cluster	Authors - Year	Journal	Citation	The Purpose of the Use of GIS
Site Selection	Aydin, N. Y.; Kentel, E; Duzgun, S. (2010)	Renewable & Sustainable Energy Reviews	200	Determination of the location selection of wind energy facilities by GIS and AHP (weighted overlay analysis)
Mathematical Modeling	Baskent, E. Z.; Keles, S. (2005)	Ecological Modelling	170	Use of mathematical optimization and meta-heuristic techniques in GIS in solving the spatial forest management problem
Site Selection	Çetin, M. (2015)	Environmental Monitoring and Assessment	146	Demonstration of areas based on bioclimatic comfort with GIS
Site Selection	Çetin, M.; Adıgüzel, F.; Kaya, Ö. F.; Sahap, A. (2018)	Environment Development and Sustainability	129	Demonstration of areas based on bioclimatic comfort with GIS
Site Selection	Çetin, M. (2019)	Air Quality Atmosphere and Health	109	Assessment of the impact of bioclimatic comfort zones on urban planning using GIS and remote sensing
Spatial Mapping	Çetin, M.; Zeren, I.; Şevik, H.; Çakir, C.; Akpinar, H. (2018)]	Environmental Monitoring and Assessment	109	Determination of natural parks with GIS within the sustainability of tourism potential
Spatial Mapping	Yilmaz, I. (2007)	Engineering Geology	104	Identification of geologically objectionable areas using remote sensing data with GIS
Site Selection	Uyan, M. (2014)	Environmental Earth Sciences	91	Determination of the location of solid waste facilities by AHP and GIS
Spatial Mapping	Çetin, M.; Şevik, H. (2016)	Environmental Monitoring and Assessment	83	Determination of the potential of recreation areas with GIS
Site Selection	Torkayesh, A. E.; Zolfani, S. H.; Kahvand, M.; Khazaelpour, P. (2021)	Sustainable Cities and Society	57	Determination of landfill facilities by GIS
Spatial Mapping	Karakus, C. (2019)	Asia-Pacific Journal of Atmospheric Sciences	45	Determination of land use changes by GIS and remote sensing
Site Selection	Kılıçoğlu, C.; Çetin, M.; Arıcak, B.; Sevık, H. (2021)	Theoretical and Applied Climatology	45	Location selection of residential areas using GIS and MCDM methods
Site Selection	Adıgüzel, F.; Çetin, M.; Kaya, E.; Şimşek, M.; Güngör, Ş.; Sert, E. B. (2020)	Theoretical and Applied Climatology	39	Identification of suitable areas for bioclimatic comfort in land management and planning with GIS
Site Selection	Baz, İ.; Geymen, A.; Er, S. N. (2009)	Advances in Engineering Software	37	Suitability analysis according to natural thresholds using GIS
Spatial Mapping	Çetin, M.; Önaç, A. K.; Sevık, H.; Cantürk, U.; Akpinar, H. (2018)	Arabian Journal of Geosciences	37	Demonstrating the sustainability of natural and cultural resources with GIS

Table 4. Purpose of the most influential authors working in Türkiye to use GIS and clustering list (WoS database, date of last access: 10.06.2023) (Cont.)

Cluster	Authors - Year	Journal	Citation	The Purpose of the Use of GIS
Spatial Mapping	Yanar, T.; Kocaman, S.; Gökçeoğlu, C. (2020)	ISPRS International Journal of Geo-Information	31	Creation of hazard sensitivity maps by GIS and fuzzy AHP method
Spatial Mapping	Yilmaz, I.; Marschalko, M.; Bednařík, M. (2011)	Carbonates and Evaporites	31	Mapping of areas in danger of collapse with GIS
Spatial Mapping	Güngör, Ş.; Çetin, M.; Adıgüzel, F. (2021)	Air Quality Atmosphere and Health	30	Determination of the development of thermal perceptions over time by GIS
Mathematical Modeling	Erener, A. (2013)	International Journal of Applied Earth Observation and Geoinformation	29	Evaluation of the performance and accuracy of the classification algorithms obtained with GIS
Spatial Mapping	Arca, D.; Kutoğlu, Ş. H.; Bęcek, K. (2018)	Environmental Monitoring and Assessment	28	Evaluation based on GIS and multi-criteria decision-making method in determining landslide sensitivity in mining areas
Spatial Mapping	Coşkun, H. G.; Algancı, U.; Usta, G. (2008)	Sensors	28	Determination of land use changes by GIS and remote sensing
Spatial Mapping	Marschalko, M; Yilmaz, I; Kubecka, K; Bouchal, T; Bednarik, M; Drusa, M; Bendova, M. (2015)	Arabian Journal of Geosciences	25	Creation of maps using GIS to identify new areas for settlements affected by collapses in underground mining
Site Selection	Tercan, E.; Eymen, A.; Urfalı, T.; Saraçoğlu, B.Ö. (2021)	Land Use Policy	24	Evaluation of conformity analysis of solar power plants using GIS and multi-criteria decision-making techniques
Site Selection	Adıgüzel, F.; Sert, E.B.; Dinç, Y.; Çetin, M.; Güngör, S.; Yuka, P.; Doğan, O.S.; Kaya, E.; Karakaya, K.; Vural, E. (2022)	Theoretical and Applied Climatology	23	Developing a GIS-based decision-making strategy to identify the most appropriate areas in tourism activities
Spatial Mapping	Uzun, O.; Müderrisoğlu, H. (2011)	African Journal of Agricultural Research	21	Visualization of landscape quality in landscape planning with GIS
Site Selection	Tercan, E.; Tapkın, S.; Latinopoulos, D.; Dereli, M.A.; Tsiropoulos, A.; Ak, M.F. (2020)	Environmental Monitoring and Assessment	19	Determination of the location selection of offshore wind energy facilities by GIS and MCDM method
Site Selection	Günen, M.A. (2021)	Renewable Energy	18	Performing conformity analysis using GIS and MCDM method
Site Selection	Nyimbili, P.H.; Erden, T. (2020)	ISPRS International Journal of Geo-Information	18	Performing conformity analyses of urban emergency facilities with GIS and multi-criteria decision-making methods

Table 4. Purpose of the most influential authors working in Türkiye to use GIS and clustering list (WoS database, date of last access: 10.06.2023) (Cont.)

Cluster	Authors - Year	Journal	Citation	The Purpose of the Use of GIS
Mathematical Modeling	Öztürk, D. (2017)	Journal of Environmental Engineering and Landscape Management	17	Fractal analysis based on GIS and remote sensing systems
Spatial Mapping	Das, H.O.; Sönmez, H.; Gökçeoğlu, C.; Nefeslioğlu, H.A. (2013)	Landslides	16	Demonstrating the impact of seismic activity on landslide areas with GIS
Spatial Mapping	Demir, G. (2018)	Natural Hazards	14	Determination of landslide sensitivities using GIS and MCDM method
Spatial Mapping	Alphan, H.; Güvensoy, L. (2016)	Journal of Environmental Engineering and Landscape Management	13	Demonstrating land use change using GIS
Site Selection	Peker, F.; Kurucu, Y.; Tok, H.H.; Saygılı, E.; Tok, E. (2013)	Journal of Environmental Protection and Ecology	13	Conformity analysis with GIS in determining ecological thresholds
Spatial Mapping	Soycan, A.; Soycan, M. (2009)	Arabian Journal for Science and Engineering	13	Creation of digital high models with GIS
Site Selection	Dereli, M.A.; Tercan, E. (2021)	Environment Development and Sustainability	11	Determination of the location of solid waste storage facilities by GIS (weighted linear combination)
Site Selection	Kaya, O.; Alemdar, K.D.; Campisi, T.; Tortum, A.; Codur, M.K. (2021)	Energies	11	Conformity analysis of electric vehicle charging stations using GIS and multi-criteria decision-making methods
Spatial Mapping	Kumlu, KBY; Tudes, S. (2019)	Natural Hazards	10	Evaluation of earthquake risk areas by GIS and MCDM method
Spatial Mapping	Salata, S.; Ronchi, S.; Giaimo, C.; Arcidiacono, A.; Pantaloni, G.G. (2021)	Sustainability	10	Assessment of flood-risk areas with GIS
Spatial Mapping	Uzun, O.; Gültekin, P. (2011)	Scientific Research and Essays	10	Spatial mapping in landscape planning using GIS

ETHICS: There are no ethical issues with the publication of this manuscript.

PEER-REVIEW: Externally peer-reviewed.

CONFLICT OF INTEREST: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FINANCIAL DISCLOSURE: The authors declared that this study has received no financial support.

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