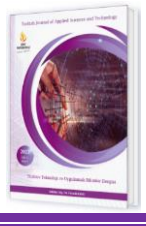
Türkiye Teknoloji ve Uygulamalı Bilimler Dergisi



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Reuse of Solid Waste in Landscape Architecture: A Bibliometric Analysis

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Abstract

This study aims to systematically examine the scientific literature on the reuse of solid waste in landscape architecture using the bibliometric method. In the face of problems such as global resource depletion, environmental pollution, and climate change, the integration of waste into sustainable design processes is becoming increasingly important. The discipline of landscape architecture has the potential to offer nature-based solutions by evaluating waste in functional, aesthetic, and environmental terms. Within the scope of the study, publications between 1995-2025 were obtained from the Web of Science database and analyzed with the Biblioshiny tool running in the R Studio environment. Creating keyword matches, conceptual clusters, and international collaboration maps determined trends in the literature, prominent institutions, and thematic densities. The findings reveal that publications on green infrastructure, ecosystem services, and climate change-compatible urban design have increased significantly since 2017. It is seen that institutions based in the USA, China, and South Korea stand out in terms of publications and collaborations. The prominent studies show that interdisciplinary sustainability approaches are gaining strength. The study maps the academic structure in the field, reveals current research gaps, and offers suggestions to increase Türkiye's international visibility in this field. Future research should focus on experimental applications, cost-effectiveness analyses, and policy integration.

Keywords: Reuse of Waste, Organic Waste, Industrial Waste, Sustainable Urban Design, Landscape Architecture

1. Introduction

Today, rapidly increasing population, industrialization, and consumption habits have made solid waste management a global problem. Millions of tons of solid waste are produced worldwide, a significant portion of which harms the environment, threatens ecosystems, and leads to the depletion of natural resources (1-3). This situation creates serious economic and social problems and environmental impacts (4;5). Therefore, reshaping waste management and implementing environmentally friendly strategies have become one of the basic elements of sustainable development (6).

Landscape architecture stands out as a discipline with the potential to develop strategies that support environmental sustainability. Landscape designs compatible with the natural environment and aesthetically and ecologically sustainable are considered practical tools for solving environmental

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problems (7;8). Reusing solid waste in landscape projects offers an important opportunity to reduce environmental impacts and provide economic benefits (9). Creative evaluation of waste materials in landscape designs helps protect natural resources, provides economic savings, and offers sustainable solutions (10).

The reuse of solid waste in landscape architecture reduces environmental impacts and provides social and economic benefits. Reuse enables the creation of more environmentally friendly and resilient cities by promoting landscape designs that support biodiversity (11). In addition, the use of waste materials in landscape design contributes to local governments' compliance with environmental policies and the increase of public awareness (12). In order to reduce the environmental impacts of solid waste, the transformation of waste storage areas into landscape projects stands out as an important strategy. It is possible to transform solid waste storage areas into ecological and aesthetic areas with landscape planning. Solid waste storage areas have been transformed into parks and recreation areas in field applications. This process aimed to ensure that the area was in harmony with the natural ecosystem by using local plant species (13). Plastic wastes are used for permeable surfaces and decorative elements in landscape designs. Plastic wastes were used in walking paths and playgrounds in Portland, USA. In this way, rainwater management was provided, reducing the urban heat island effect (14). Glass waste is used for different purposes in landscape design, such as walkways, decorative elements, and water management systems. For example, in London, England, glass waste has been successfully applied as an aesthetic and functional element in landscape projects. This application has reduced the environmental waste load and produced sustainable and aesthetically prosperous designs (15). Composting from organic waste and using compost as a soil improver is frequently used in landscape projects. In Berlin, Germany, compost obtained from organic waste was used in park and garden projects, and thus, soil quality was improved. Mixing compost into the soil at specific rates supports plant growth and improves soil structure, allowing water to be retained in the soil more (16).

Reusing industrial waste in landscape projects reduces the environmental burden and provides economic benefits. In Rotterdam, the Netherlands, waste concrete and brick materials were used to build walkways and seating areas in urban parks. This application reduced the amount of environmental waste and provided a durable and cost-effective solution (17).

The reuse of solid waste in landscape architecture is an important strategy that supports environmental sustainability and the protection of natural resources. Examples presented in the literature show that building elements, walkways, decorative elements, and permeable surfaces produced from waste materials provide positive ecological and economic effects. In addition, integrating waste into landscape projects is critical in protecting natural cycles and supporting urban ecosystems. Focusing on issues such as cost-effectiveness, long-term sustainability, and public awareness in future studies will contribute to more effective implementation of waste management in landscape architecture (18).

Bibliometric analysis systematically examines the literature in a specific field of research and evaluates various metrics such as publication counts, citation rates, collaborations among authors, and

prominent keywords. This method reveals the current state of knowledge in the field and guides future research (19). The Biblioshiny tool, on the other hand, allows the analysis of information obtained from leading databases such as Scopus and Web of Science through its user-friendly interface. This software visualizes research trends, relationships between authors, and prominent themes in the literature, thus revealing the structure of academic production more clearly (20). Biblioshiny facilitates bibliometric calculations through its interface and allows users to analyze data from major databases such as Scopus and Web of Science (21). This method will identify significant trends in the literature, research gaps, and potential areas for future research.

The main purpose of this study is to comprehensively examine the existing literature on the reuse of solid waste in landscape architecture, to reveal research trends, and to identify knowledge gaps in this area. The bibliometric analysis method was applied using bibliophily software in the study. The following basic research questions will be answered in this study: (1) What are the main trends in the existing literature on the use of solid waste in landscape architecture? (2) Which sustainable practices are prominent in the reuse of solid waste in landscape designs? (3) What are the gaps in the literature, and which research areas can fill these gaps? The results of this study will systematically reveal the current trends, challenges, and opportunities for reusing solid waste in landscape architecture projects. In addition, this study will contribute to the spread of sustainable landscape designs by clearly revealing landscape architecture's role in solid waste management. Identifying gaps in the literature will open new research areas for future studies in this field. In conclusion, using solid waste in landscape architecture is important in combating climate change, protecting natural resources, and ensuring environmental sustainability.

2. Materials and Methods

This study was planned according to the quantitative research method, and the analysis process was carried out in line with the bibliometric approach. Bibliometric analysis is a method that allows the systematic examination of publications produced in a specific academic discipline using statistical and mathematical techniques. This approach provides the opportunity to evaluate the dynamics of scientific publishing from a large-scale perspective; it reveals the effects of prominent studies, authors, journals, institutions, and countries in the field over time through numerical data (22;23). Bibliometrics is not only limited to making the current state of the literature visible but also provides strategic direction for future research. In this context, bibliometric analyses were implemented using the Biblioshiny interface running in the R Studio environment. The program allows the analysis of basic trends, collaboration relationships, and conceptual clusters in research areas numerically and visually. The methodological process of the research consists of three main stages. In the first stage, the general framework of the study was determined, and the Web of Science (WOS) database was preferred as the data source. By the scope of the study, bibliometric analysis criteria were clarified, keywords were defined, and the scanning range was structured according to time and subject title. In the second stage, studies published between

1995 and 2025 were considered in the data collection process. In this context, a comprehensive literature review was conducted using the "All Fields" option using the WOS database. The scanning process was performed by combining the following two keyword groups with the “AND” logical operator (Group 1 – Waste Management and Reuse Focused Terms: “Solid Waste Reuse” OR “Waste Management Strategies” OR “Green Infrastructure” OR “Sustainable Waste Management” OR “Industrial Waste Reuse” OR “Compost in Urban Design” OR “Organic Waste in Urban Design” OR “Glass Waste in Urban Design” OR “Plastic Waste in Urban Design” OR “Recycling of Waste” OR “Construction Waste in Urban Design” AND Group 2 – Landscape and Urban Design Focused Terms: “Landscape Solutions” OR “Eco-Friendly Landscape Solutions” OR “Sustainable Urban Design” OR “Landscape Architecture” OR “Landscape Design” OR “Urban Resilience” OR “Reclaimed Materials in Landscape”). The records obtained from the scan were exported in .csv format, compatible with BibTeX, using the WOS interface. In this way, the data was organized in a suitable structure for the bibliometric analysis process and ready for the analysis phase. The data analysis and visualization process, which constitutes the third phase of the study, was carried out by comprehensively examining the records obtained from the WOS database through the Biblioshiny tool. In this phase, cooperation networks between countries, scientific productivity levels on a country basis, and conceptual clusters based on keywords were analyzed in detail. The findings were presented using bibliometric techniques such as network visualization, density visualization, and visualization, thus revealing the structural dynamics of the research field from a holistic perspective.

In the first stage of the study, conceptual maps generated through Biblioshiny significantly contributed to identifying prominent thematic trends, influential authors, and key institutional actors within the literature. This phase provided a comprehensive visual overview of the intellectual structure, enabling researchers to explore the relationships and clustering patterns among various research themes.

Building on this foundation, the second stage of the analysis moved beyond merely describing the current state of the literature. It allowed for the identification of emerging or underexplored themes that hold potential for future investigation. This methodological approach thus expanded the analytical scope, offering insights into both well-established domains and gaps that remain unaddressed in the field.

In the final stage, the findings obtained through this bibliometric framework are presented in detail in the subsequent section of the study, titled “Results.” This section includes evaluations grounded in bibliometric indicators, visual representations of data, and key inferences derived from the analysis, providing a robust basis for further academic discussion and interpretation.

3. Findings and Discussion

Within the scope of the study, data on 820 documents covering the period 1995–2025 in the WOS database were analyzed. The examined publications consist of 233 different sources (journals, books, etc.), and the annual average growth rate was calculated as 14.08% (Table 1). This increase shows

that waste management and sustainable landscape themes have started to attract more and more attention in scientific circles in recent years. Similarly, it is stated in the literature that environmental sustainability and circular economy topics are among the rising research areas in recent years (24).

The average document age is 4.49 years, which shows that the research field is developing within the current dynamic. In addition, the average number of citations per document was determined to be 20.83. This value indicates that the scientific impact of the publications in the field is medium-good. Citation rates show academic visibility and the subject being considered by policymakers and practitioners.

A total of 26.77 authors were determined to have contributed to the study; 77 of these authors have single-authored publications. In general, an average of 4.36 authors have co-authored the documents, which shows that multi-authored publishing is dominant in the field. In addition, 29.88% of the publications are produced through international collaboration. This finding reveals that cross-border collaborations are strengthening in waste management, sustainable design, and landscape architecture. Similarly, Mazer et al. (2020) emphasize that international research partnerships in environmentally-based disciplines increase the quality of scientific output and contribute to developing global solution proposals.

In the keyword analysis, 1,385 different terms were identified within the scope of Keywords Plus, and 2,655 different terms were identified within the original keywords defined by the authors (Author's Keywords). This shows that the thematic diversity of the research area is quite broad. The literature also states that a multidisciplinary approach, especially involving waste management and sustainable urban design, has become mandatory (26).

In examining document types, most publications are research articles (n=682). This is followed by 71 reviews and 33 proceedings papers. This distribution reveals that the subject is actively addressed with original research and compilation studies. Indeed, considering that environment-based themes must be constantly re-evaluated in line with current developments, the contribution of studies based on literature reviews to the field cannot be denied (Table 1).

Figure 1 visually demonstrates the relationship between countries, research themes, and universities. The United States, China, and South Korea are among the countries that produce the most publications on sustainable landscapes, green infrastructure, and climate change. These countries are followed by countries such as Poland, Canada, Australia, the United Kingdom, and Türkiye. This finding shows that the search for environmental sustainability and infrastructure-based solutions has intensified on a global scale.

At the keyword level, concepts such as “green infrastructure,” “ecosystem services,” “climate change,” “urban resilience,” and “sustainability” are prominent. It is understood that these themes focus on nature-based solutions and cities' capacity to adapt to the climate crisis (27). Similarly, the importance of nature-based solutions in sustainable urban design is emphasized in the literature, and it is stated that the discipline of landscape architecture plays a guiding role in this process (28). At the same time, it has

been stated that providing urban ecosystem services is a fundamental element in increasing cities' environmental and social resilience (29). These approaches point to the strategic importance of nature-based solutions in developing sustainable urban design strategies, both in local-scale implementation and at the broader urban and international levels (30).

Table 1. Main information about the data set

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1995:2025
Sources (Journals, Books, etc)	233
Documents	820
Annual Growth Rate %	14.08
Document Average Age	4.49
Average citations per doc	20.83
References	39458
DOCUMENT CONTENTS	
Keywords Plus (ID)	1385
Author's Keywords (DE)	2655
AUTHORS	
Authors	2677
Authors of single-authored docs	77
AUTHORS COLLABORATION	
Single-authored docs	92
Co-Authors per Doc	4.36
International co-authorships %	29.88
DOCUMENT TYPES	
article	682
article; book chapter	2
article; data paper	1
article; early access	11
article; proceedings paper	1
book review	6
correction	2
editorial material	10
proceedings paper	33
review	71
review; early access	1

At the university level, Seoul National University, Swedish University of Agricultural Sciences, Texas A&M University, Tongji University, and the University of Arizona have studied the topic the most. Research outputs come mainly from universities with interdisciplinary work and environmentally focused strategies (Figure 1).

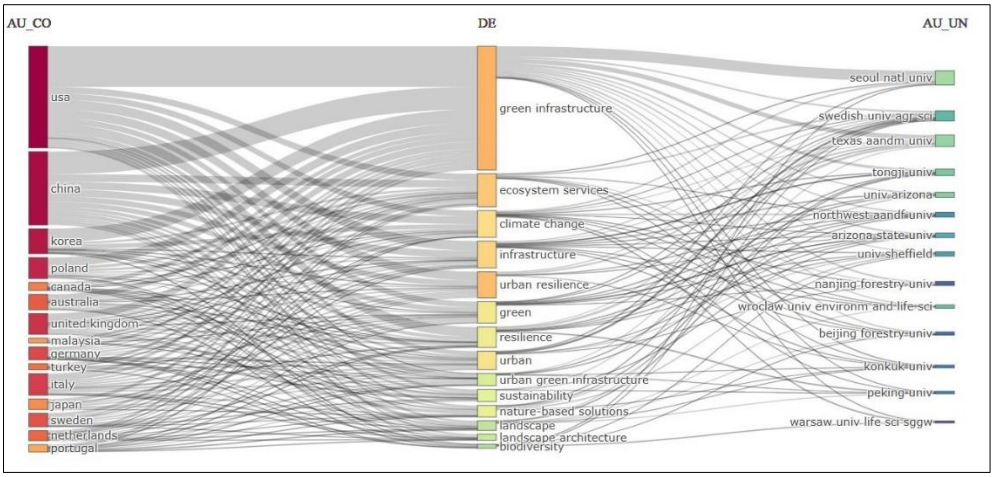

Figure 1. Country-Keyword-Institution relationship map

There has also been an increase in studies conducted in the fields of sustainable waste management and landscape architecture in Türkiye. Zero waste management is a fundamental part of sustainable environmental policies in Türkiye that aim to prevent waste production, recycle, and protect nature. Özel (2018) examined the environmental impacts of solid waste areas in Türkiye and evaluated the relationships between waste management and environmental protection. Gül and Yaman (2021) evaluated the waste management and zero waste project in Ankara and stated that the data obtained within the framework of this project should be integrated with other applications across Türkiye. Saraç et al. (2023) emphasized that the effectiveness of zero waste management for metropolitan cities in Türkiye was evaluated through data envelopment analysis and that significant results were obtained regarding environmental sustainability within this framework. Tunç and Yıldız (2024), who provide a historical perspective on the waste management approach in Türkiye, analyze the effects of the implemented financial measures. These policies, which are offered as solutions to environmental problems in various regions of Türkiye, should be reinforced with international collaborations of local universities. However, it is still seen that a limited number of institutions from Türkiye are represented in the literature. Integrating local universities into international networks is important in increasing scientific visibility (35).

Among the publications examined, the institution with the highest scientific production is Seoul National University, which stands out by far with 232 publications. This university is followed by Texas A&M University (71 publications), the University of Arizona (53 publications), Tongji University (43 publications), and Wroclaw University of Environmental and Life Sciences (30 publications). The fact that different universities from Sweden, China, the USA, and England are included in the list shows that the research area has a geographically multi-centered structure (Figure 2). This situation indicates that the themes of sustainable landscaping, waste management, and green infrastructure have a strong academic response in the West and East Asian countries. The prominence of institutions from countries such as South Korea, China, and Poland, in particular, shows that environmental planning and nature-based solution approaches are also developing academically in these countries. The fact that no

university from Türkiye was included in the top 10 in the study indicates that scientific visibility in this field needs to be increased (Figure 2). As emphasized in the literature, environmental and sustainability-themed topics especially create more impact with international partnerships. This requires more active participation of universities in global research networks (36).

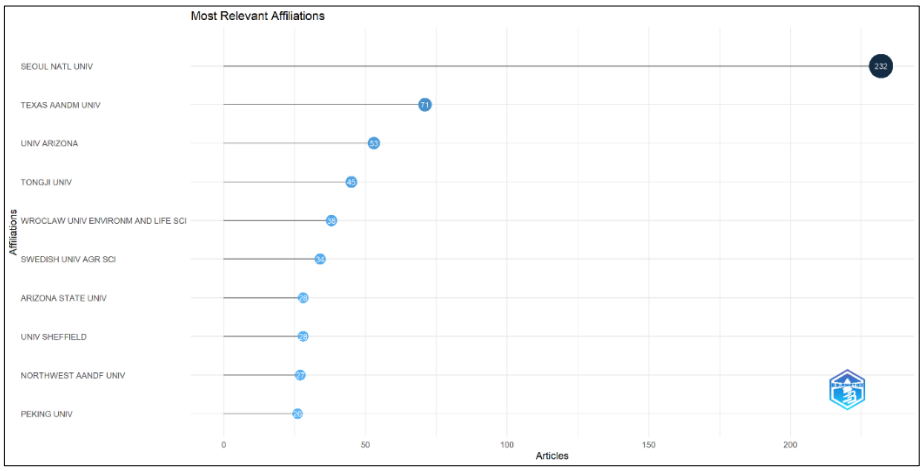

Figure 2. Featured institutions by number of publications

Tuan (2019) emphasizes the importance of sustainability reports and states that institutions should be more visible for internationalization and effective sustainability practices. In addition, Özel (2018) argues that research on waste management in Türkiye should be addressed in a broader context on environmental impacts and sustainability. Such research is important to ensure that Türkiye becomes more effective in the international arena regarding environmental and sustainability issues. While it is known that Türkiye has an increasing publication production on similar themes, encouraging qualified and visible academic collaborations will strengthen contributions in this area.

As a result of the bibliometric analysis, the most frequently encountered keywords in the literature are “green infrastructure” and “ecosystem services” (Figure 3). These terms are repeated 143 and 109 times, indicating that the research field is strongly oriented towards nature-based solution approaches. These findings reveal that the fields of landscape architecture, urban design, and environmental planning focus on aesthetic and functional design and ecological sustainability. The use of these terms has increased significantly, especially since 2017. Concepts such as green infrastructure, ecosystem services, climate change, and resilient cities have gained rapid momentum in the post-2020 period. This trend shows that academic interest in nature-based solution strategies has increased in recent years as the impact of climate change and environmental crises has increased. Especially after the COVID-19 pandemic, the need for environmental resilience and open green spaces in cities has led to such concepts being addressed more frequently in the academic field. In the word cloud visual, concepts such as “green infrastructure,” “ecosystem services,” “cities, urban,” “climate change,” “resilience,” and “biodiversity” are seen to stand out in terms of both frequency and context. This shows that the topics

addressed in the studies are not limited to urban spaces; they are also associated with multidimensional factors such as climate, ecosystem, and human health (Figure 3).

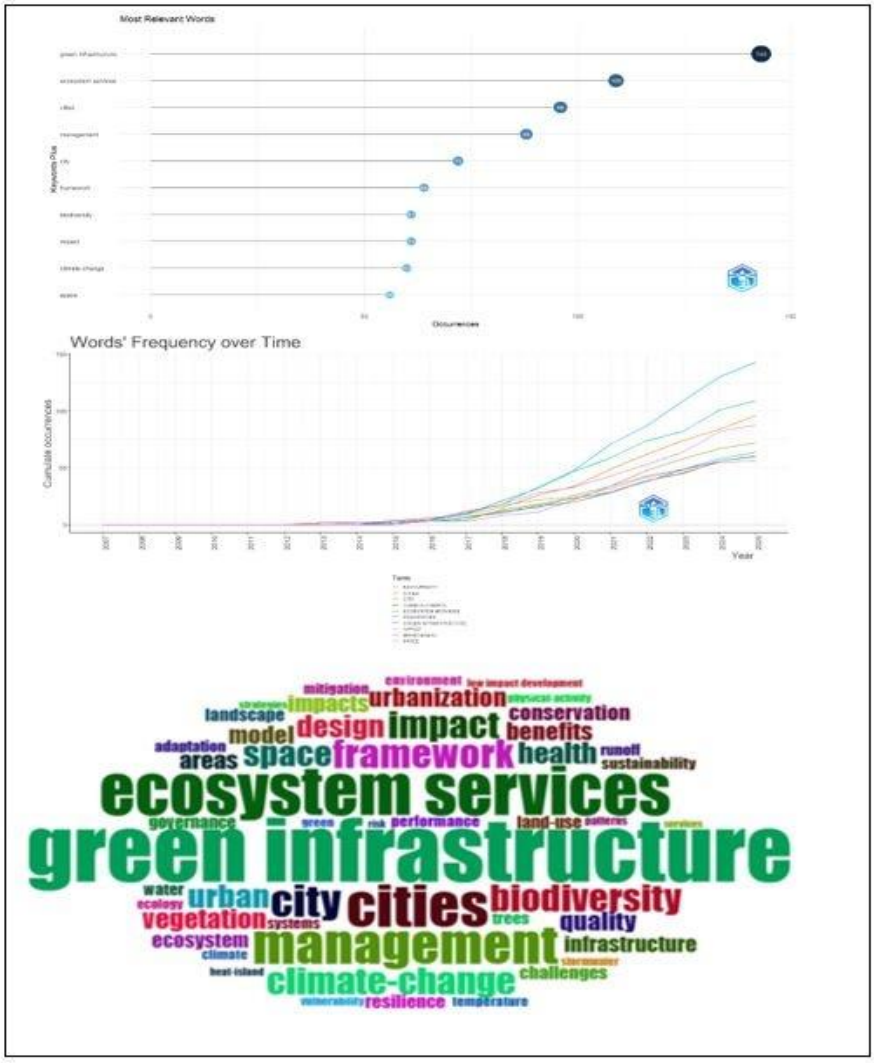

Figure 3. Most used keywords

The co-occurrence network presented in Figure 4 reveals the themes around which the strongest relationships between keywords in the literature are shaped. According to the network, the concept of "green infrastructure" is positioned at the center of the network by establishing intense relationships with different concept clusters such as "ecosystem services," "cities," "management," and "framework." This shows that the green infrastructure approach is addressed holistically, not only with its environmental but also with its administrative, spatial, and systemic dimensions.

The network is observed to have three main clusters: green (nature-based), blue (management/planning-based), and red (climate-focused). The green cluster includes concepts such as ecosystem services, biodiversity, space, and conservation; this structure shows that nature-based approaches have become an important reference framework in urban planning. The blue cluster represents studies that analyze urban-scale strategies and policies through concepts such as cities, management, and framework. The red cluster expresses environmental threats and spatial strategies

developed against these threats through concepts such as “climate, vegetation, design, and impact” (Figure 4).

This network structure reveals that interdisciplinary connections in landscape architecture and sustainable planning are intensifying and that concepts are increasingly being addressed. In particular, the common use of concepts such as “green infrastructure and ecosystem services” in both nature-based and administrative fields demonstrates the discipline's scientific richness and multidimensional development.

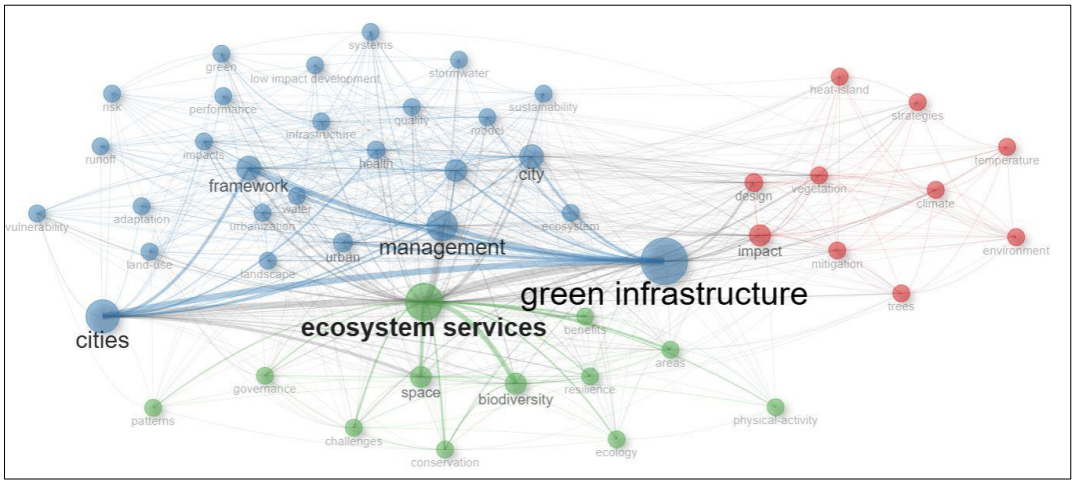

Figure 4. Co-occurence network analysis

The density map in Figure 5 shows the countries with the highest publication production in the field of research. According to the map, the USA and China are the leading countries contributing to the literature. These two countries are followed by the United Kingdom, Germany, the Netherlands, South Korea, and Italy, respectively. Türkiye is also in the central cluster, increasing its contribution to academic production in this field.

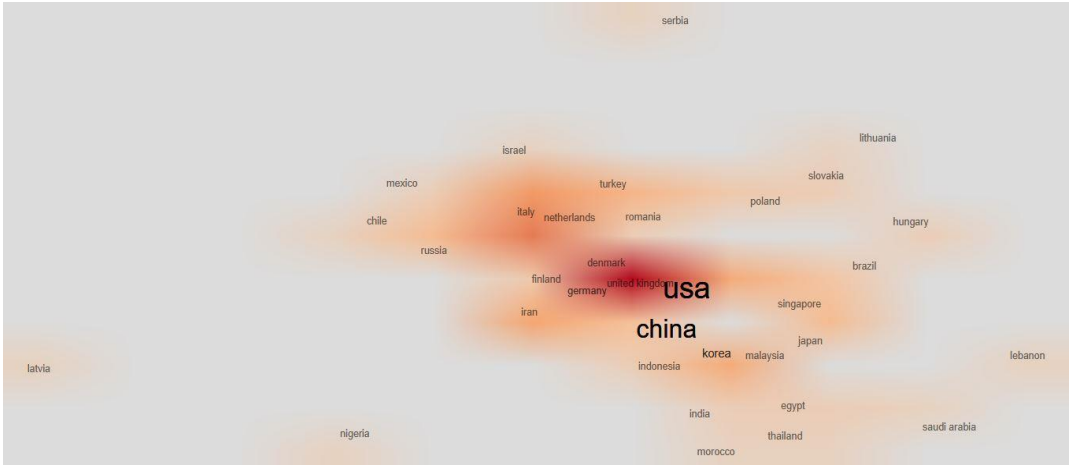

Figure 5. Country scientific production density map

Figure 6 presents the structure of scientific cooperation between countries. According to this network, the USA and China are positioned at the center of the network thanks to their

productivity and the cooperation they have established with many countries. While the USA has established strong cooperation with countries such as Germany, the United Kingdom, and Finland, China has developed more intense relations with Korea, Malaysia, Japan, and Indonesia. Türkiye, on the other hand, is particularly involved in cooperation with European countries and is positioned within the regional scientific interaction network.

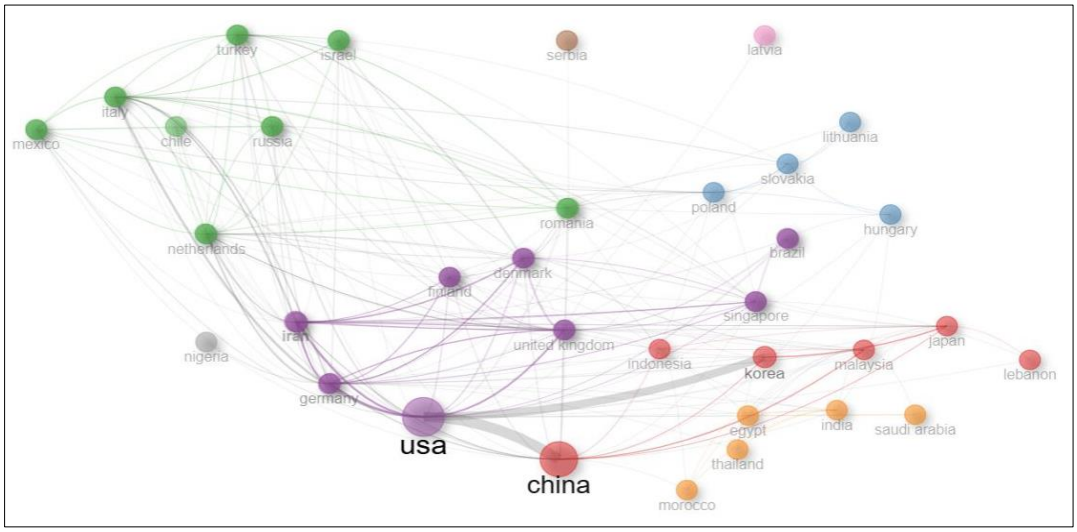

Figure 6. Country collaboration network

These findings reveal that international partnerships are increasingly important in environmentally-based and sustainability-focused research areas and that issues such as nature-based solutions, green infrastructure, and ecosystem services, in particular, require cross-disciplinary and transnational collaboration. It is emphasized in the literature that the vast majority of studies with high scientific impact consist of international joint publications (38).

4. Results

This study systematically examined the scientific literature on the reuse of solid waste in landscape architecture using a bibliometric approach. The analyses conducted using the Biblioshiny interface running in the R Studio environment revealed the main trends in the field, institutional and international collaborations, and thematic research clusters. The findings show that there has been a significant increase in the themes of sustainable urban design, green infrastructure, and ecosystem services, especially after 2017, and this increase coincides with the increasing interest in issues such as climate change and urban resilience on a global scale.

Keywords such as “green infrastructure, ecosystem services, and climate change” stand out as central themes, reflecting the discipline's multidimensional and interdisciplinary nature. Conceptual clusters and collaboration networks reveal that ecological, managerial, and spatial perspectives are addressed together; this indicates a strong research agenda supported by international collaborations.

As a result, the reuse of solid waste in landscape architecture supports environmental sustainability and resource efficiency. It contributes to developing innovative, economical, and ecologically sensitive

urban design solutions. This study provides a general framework for academic production, identifies current research gaps, and guides future studies linking waste reuse to resilient cities. In the future, further empirical research, design practices, and policy integration efforts are critical to transforming academic knowledge into field-applicable, scalable, and community-supported strategies.

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