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# Advances, hotspots, and trends in restorative environment research over the past 30 years: a bibliometric analysis based on the WoS database

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In the face of mounting pressures in modern society, research into restorative environments has emerged as a crucial field addressing issues related to mental health and environmental wellbeing. This study presents a comprehensive bibliometric analysis of 919 publications on restorative environment research, spanning from 1993 to 2024, utilizing VOSviewer and CiteSpace for data visualization, based on the Web of Science database. The main objective of this bibliometric analysis is to provide scholars and researchers with a deeper insight into the current state and evolving trends in restorative environment research, while also pinpointing areas that warrant further investigation. The study examines research patterns across several key dimensions, including publication volume, keywords, journals, academic disciplines, countries, institutions, and individual researchers. The results of this analysis highlight the following key points: (1) Research on restorative environments has experienced significant growth since 2014, with a marked acceleration during the COVID-19 pandemic. (2) The primary research foci include environmental psychology, the relationship between nature and social wellbeing, and urban ecosystems with aesthetic health, with environmental psychology and cognitive restoration emerging as the most interconnected core themes. (3) Leading journals in restorative environment research include the *Journal of Environmental Psychology*, the *International Journal of Environmental Research and Public Health*, and *Frontiers in Psychology*. (4) The main academic fields contributing to this body of research are psychology, public health, landscape architecture, and urban planning. (5) The United States has the highest number of publications on restorative environments (212 papers), followed by China (159 papers), the United Kingdom (90 papers), Sweden (67 papers), and Australia (55 papers). (6) Uppsala University has emerged as the most prolific institution, with 35 publications, followed by the Swedish University of Agricultural Sciences (32 papers) and the University of Exeter (24 papers). Finally, environmental psychology and cognitive restoration, the connection between nature and social wellbeing, and urban ecosystems with aesthetic health are identified as the leading and most dynamic research areas. These findings suggest that restorative environment research has made significant strides over the past 3 decades and is poised to continue expanding in the years ahead.

## KEYWORDS

restorative environment, bibliometric analysis, research progress, VOSviewer, Citespace

## 1 Introduction

The escalating global mental health crisis, exacerbated by rapid urbanization, has increasingly highlighted the impact of living environments on mental wellbeing. The World Health Organization reports that over 1 billion people worldwide are affected by mental health disorders, with the prevalence of conditions like depression and anxiety continuing to rise. At the same time, the United Nations forecasts that by 2050, nearly 70% of the global population will reside in urban areas. The pressures of high-density living, scarce green spaces, and ongoing environmental challenges linked to urbanization have intensified the mental health issues faced by city dwellers. In this context, the concept of restorative environments has attracted growing academic attention, becoming a focal point in research dedicated to promoting psychological restoration, alleviating stress, and enhancing cognitive function (Du et al., 2022; Guo et al., 2023; Masullo et al., 2023). Among the most influential theoretical frameworks for restorative environments are the Attention Restoration Theory (ART) and the Stress Reduction Theory (SRT). ART, developed by Kaplan & Kaplan (Rachel and Stephen, 1989), posits that natural environments can effectively restore attention depleted by sustained cognitive exertion. This theory outlines four essential attributes of restorative environments: being away, extent, compatibility, and fascination. In contrast to ART's emphasis on cognitive restoration, SRT focuses on the emotional regulation and physiological recovery facilitated by exposure to natural settings. Ulrich et al. (1991) suggested that interaction with natural environments can alleviate physiological stress responses, such as lowering heart rate, blood pressure, and cortisol levels, thereby improving mental health and fostering emotional balance.

Extensive research has established that restorative environments positively influence both mental health and cognitive function. Even brief exposure to natural settings, such as parks or forests, has been shown to significantly enhance individuals' performance on cognitive tasks (Backman et al., 2022; Yan et al., 2024; Tundisi, 2024). In contrast to confined urban spaces, individuals show a marked reduction in cortisol levels and a notable improvement in subjective wellbeing when they rest in open green spaces or near waterfronts (Huang B. et al., 2024; Zhu et al., 2024; Moura et al., 2024). Additionally, restorative environments can facilitate social cohesion by promoting more frequent interactions among community members, thus helping to alleviate feelings of loneliness and social isolation (Deemer et al., 2023; Park et al., 2022; Huang J. et al., 2024). These findings not only corroborate the fundamental tenets of the Attention Restoration Theory (ART) and Stress Reduction Theory (SRT), but also underscore the broader social benefits of restorative environments, which extend beyond individual wellbeing. Despite the considerable advancements in restorative environment research in recent years, the findings remain scattered across a variety of disciplines and research streams, with a lack of systematic reviews or knowledge integration. This fragmentation hinders researchers' ability to gain a comprehensive understanding of emerging trends and critical issues within the field. Furthermore, traditional literature review methods face inherent limitations when dealing with large volumes of interdisciplinary research, making it difficult to uncover

the development trajectory and knowledge structure of restorative environment studies. To address this issue, the current study employs a bibliometric approach, utilizing VOSviewer and CiteSpace software to conduct an in-depth analysis of the restorative environment literature from the Web of Science database. The study examines several dimensions, including annual publication volume, institutional affiliations, and keyword co-occurrence clustering, with the aim of revealing the overall characteristics, research progress, key themes, and future research directions in the field of restorative environment research.

This paper is structured as follows: The first section introduces the research background and objectives. The second section outlines the data sources and research methods, including the selection of the Web of Science database and the application of bibliometric tools. The third section presents the results of the analysis, covering trends in annual publications, international collaboration, research institutions, source journals, keyword clustering, and emergent word analysis. The fourth section discusses the implications of the findings, focusing on the advantages of bibliometric analysis, contributions to existing research, gaps in the field, future research directions, and limitations of the study. Finally, the fifth section summarizes the key findings, offers recommendations for future research, and highlights the contributions of this study to sustainable development.

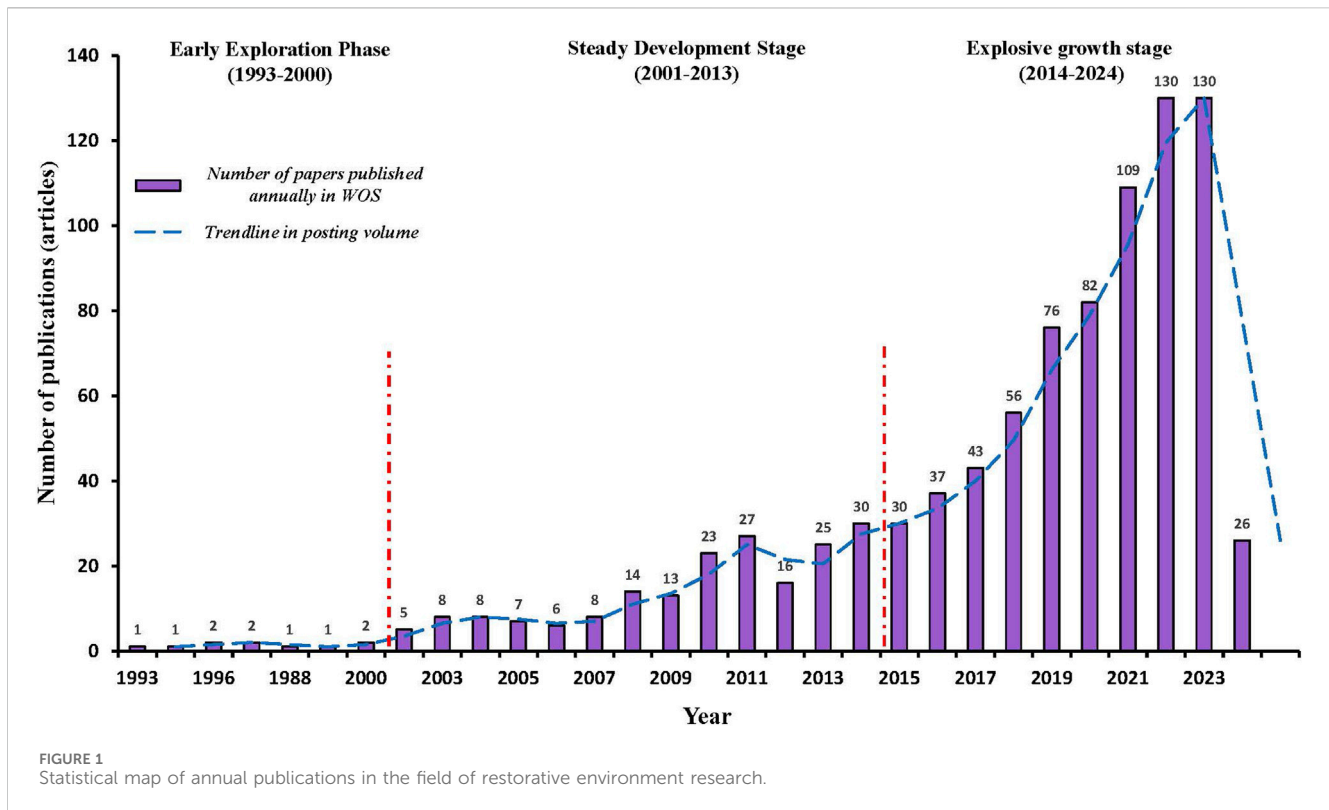
## 2 Data sources and research methods

### 2.1 Data sources

For this study, the literature was extracted from the Web of Science (WoS) database, an esteemed resource widely recognized for its comprehensive academic content across diverse fields, including the natural and social sciences, as well as engineering. The WoS is acknowledged for providing accurate and reliable data essential for scholarly research (Chen, 2006). To guarantee the reliability and thoroughness of the data, the analysis focused specifically on the WoS core collection, which includes both the Science Citation Index Expanded (SCIE) and the Social Sciences Citation Index (SSCI). The literature selection was driven by a series of strategically chosen search terms, such as "TS = 'restorative environment'", "attention recovery", "restorative perception", and "psychological recovery", among others. To enhance the precision of the search, these terms were refined by analyzing citation frequencies and article usage patterns. The study adopted the following inclusion criteria: 1) Relevance to the topic: All selected publications must explore restorative environments and their effects on mental health, environmental quality, urban planning, or similar domains; 2) Type of publication: Only peer-reviewed journal articles (Article) were considered, while conference papers and book chapters were excluded. Following the application of these criteria, a final set of 919 articles was retained, with the data retrieval date set at 20 March 2024.

### 2.2 Research methods

In order to ensure the precision of data analysis and optimize the effectiveness of visualization, this study adopted bibliometric



methods, incorporating the advanced information visualization tools VOSviewer and CiteSpace. These tools enable a comprehensive extraction of key elements, such as keywords, research institutions, authors, and source journals, from the selected literature. By conducting co-occurrence analysis, they allow for the construction of a detailed knowledge structure, thereby providing deeper insights into the research landscape (Chaturvedi et al., 2023).

VOSviewer and CiteSpace are widely recognized tools in the field of bibliometric analysis. VOSviewer excels in creating keyword co-occurrence maps and collaboration network visualizations, effectively showcasing the prevailing research hotspots and trends. In contrast, CiteSpace specializes in revealing the citation networks and research trajectories through co-citation and emergent word analysis (Tan et al., 2021). The selection of these tools is driven not only by their ability to manage large-scale datasets with efficiency but also by their capacity to offer multi-dimensional visualizations, empowering researchers to explore literature and academic networks from diverse viewpoints.

While VOSviewer and CiteSpace are extensively used in bibliometric studies, other tools like BibExcel and Gephi also offer valuable alternatives (Chen, 2006). However, VOSviewer and CiteSpace stand out for their superior graphical interfaces and advanced analytical capabilities, particularly in performing complex co-occurrence and co-citation analyses. These tools are not only intuitive and accessible but also exceptionally efficient in handling large datasets (Vaneck and Waltman, 2010; OuYang and Du, 2019). Thus, the decision to utilize these two tools for this research is both highly justified and practical.

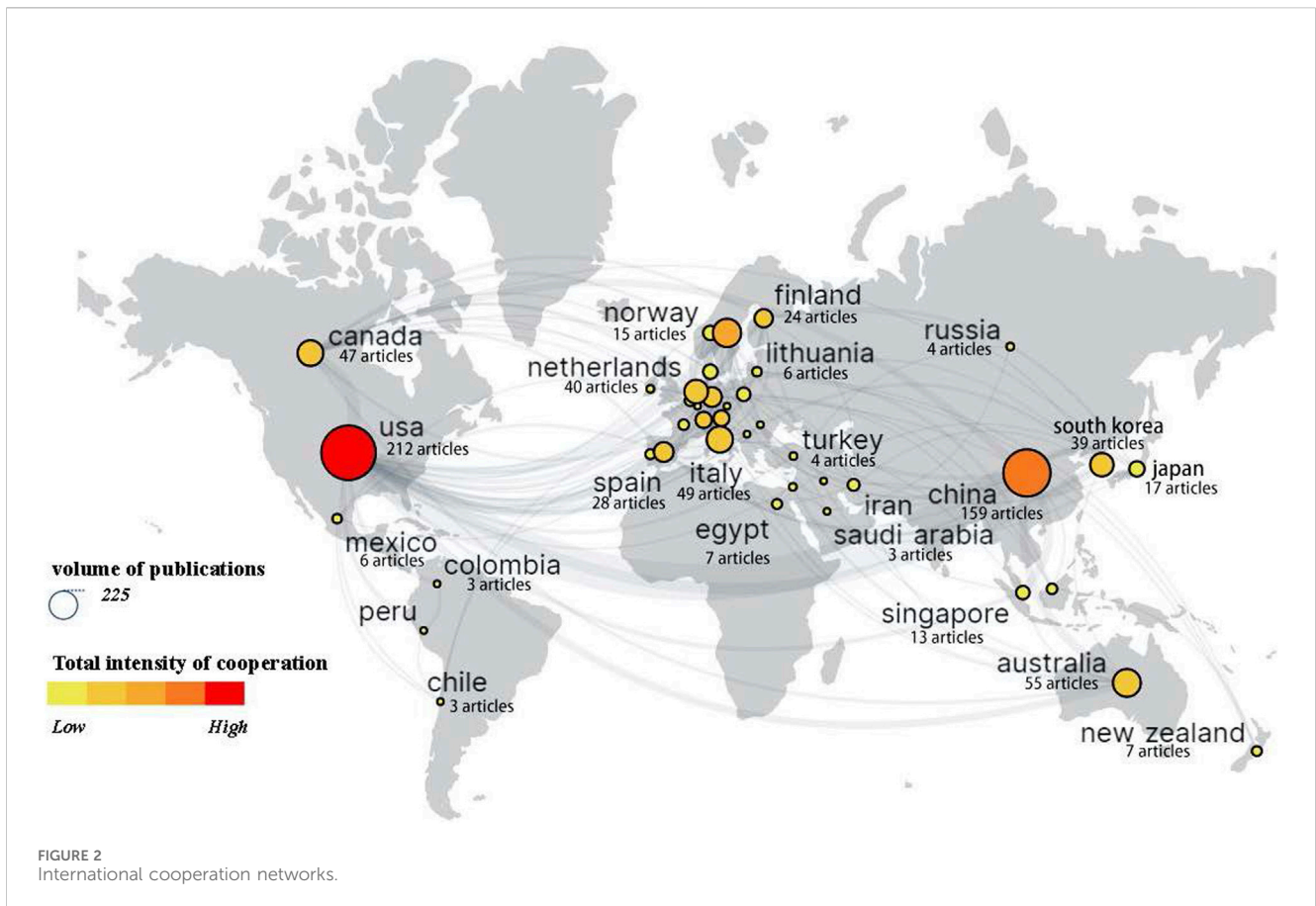
## 3 Research results

### 3.1 Annual publication volume analysis

The volume of scholarly publications is a critical indicator of scientific progress, serving as a reflection of knowledge accumulation and the ongoing contributions of researchers within a given field (Shao et al., 2021). To assess this trend, the study extracted, cleaned, and deduplicated data from the Web of Science (WoS) database, generating a chart that illustrates the annual publication trends (see Figure 1). This visualization demonstrates a consistent upward trend in the number of publications within the domain of restorative environment research.

Figure 1 illustrates the annual publication trends in restorative environment research from 1984 to 2024. The data indicate that the development of research in this area can be divided into three clear phases:

- (1) Preliminary Exploration (1993–2000): In this phase, the publication volume remained modest, with only 10 papers published in total. This period marked the early stages of restorative environment research, where scholars began to investigate the concept and its emerging relevance.
- (2) Steady Development (2001–2013): From 2001 to 2013, the number of publications steadily increased, reaching a total of 160 papers. This period witnessed a growing acknowledgment of the significance of restorative environments, as research became more sophisticated, expanded, and attracted broader academic interest.



(3) Rapid Expansion (2014–2024): Since 2014, there has been a notable increase in publication volume, with the number of papers expected to total 749 by 2024, accounting for 81% of all publications. This surge is largely attributed to the growing focus on the connection between environment and mental health, especially during the COVID-19 pandemic. The crisis acted as a catalyst for a wave of research investigating how environmental factors affect human wellbeing, leading to a substantial acceleration in the field’s development.

In conclusion, the publication trend in restorative environment research demonstrates an increasing depth and scope of scholarly engagement over time. From its initial exploration, through gradual development, to its recent rapid growth, this trajectory underscores the ongoing evolution of academic inquiry and the expanding focus on this critical field of study.

### 3.2 International collaboration analysis

To gain a comprehensive understanding of global cooperation in restorative environment research, this study employs an international collaboration network (29 nodes, 139 links) and examines the top ten countries based on publication volume. Figure 2 offers a clear depiction of the academic collaboration dynamics within this field, while the top ten countries by publication volume are listed in Table 1. By analyzing node size

(which reflects the number of publications), link thickness (indicating the intensity of collaboration), and color density (representing collaboration frequency), it becomes apparent that the United States, China, the United Kingdom, Sweden, and Australia form the central network of academic collaboration in this domain. Simultaneously, the figure illustrates a gradual expansion of collaborations towards emerging nations. However, countries in the global South, including those in South America, Africa, and Southeast Asia, are still underrepresented in these international partnerships. In Figure 2, these nations are represented by smaller nodes and fewer connections, signifying their limited engagement in the global research network. This collaborative structure not only shapes the key research themes but also promotes the worldwide dissemination of restorative environment theories.

As of 20 March 2024, data reveals that the United States, China, the United Kingdom, and Sweden occupy central positions in the international collaboration network within the Web of Science Core Collection. Figure 2 illustrates that the United States, with a total collaboration intensity of 116, holds a dominant position in global academic networks, forming extensive partnerships with China, the UK, Sweden, South Korea, and Australia. In terms of citation impact, the United States leads with 13,488 total citations, followed by the United Kingdom (5,531 citations) and Sweden (5,393 citations). These findings underscore the United States’ preminent role in restorative environment research while highlighting the growing influence of China and European

TABLE 1 Top 10 national publications.

Rank	Country	Publications	Total citations	Total intensity of cooperation
1	America	212	13,488	116
2	China	159	2,511	72
3	England	90	5,531	71
4	Sweden	67	5,393	67
5	Australia	55	4,029	25
6	Italy	49	2,227	30
7	Canada	47	1,258	36
8	Netherlands	40	3,381	30
9	South korea	39	776	24
10	Germany	28	564	29

countries. The prominent node size and numerous connections of China in Figure 2 further emphasize its expanding role and increasing participation in international collaborative efforts.

Key insights from Figure 2 are summarized as follows:

- (1) United States (USA): The United States, with 212 publications, stands as the global leader in academic collaboration within the field of restorative environments. It boasts the widest collaboration network and the highest intensity of partnerships, particularly with China, the United Kingdom, Sweden, South Korea, and Australia. The USA is represented in Figure 2 by the largest node and the darkest color, underscoring its dominant academic influence.
- (2) China: Ranking second with 159 publications, China has established an extensive network of collaborations, notably with the United States, reflecting the highest degree of bilateral cooperation. The numerous links in Figure 2 further highlight China's significant and active role within the global research network.
- (3) United Kingdom (UK): With 90 publications, the UK ranks third in both research output and academic influence. Its collaborative efforts are primarily focused on partnerships with European nations (such as Sweden and the Netherlands) as well as with the United States.
- (4) Sweden: Holding the fourth position with 67 publications, Sweden exerts substantial research influence. Its collaborative ties are predominantly with the USA and other European countries, further reinforcing its standing in the global research landscape.
- (5) Australia: Ranking fifth with 55 publications, Australia's research contributions primarily center on urban greening and public health. The nation plays a crucial role in academic collaboration within the Asia-Pacific region, with its strongest partnerships being with the United States and China.

In conclusion, the findings underscore the pivotal roles of the United States, China, the United Kingdom, Sweden, and Australia in advancing restorative environment research. These countries are distinguished by their robust international collaborations and

influential contributions to the field. The dominance of the United States, China, and the United Kingdom is primarily driven by strong research funding, supportive policies, the influence of academic institutions, and active participation in global research networks. The United States maintains a central position in restorative environment research, bolstered by sustained support from organizations such as the National Science Foundation (NSF). This funding has been essential in developing key theoretical frameworks like Attention Restoration Theory (ART) and Stress Reduction Theory (SRT) (Kaiser et al., 2022). In recent years, China has made rapid strides in this area, largely driven by its "Ecological Civilization" policy and the National Natural Science Foundation of China's (NSFC) active promotion of restorative environment research and urban green infrastructure (Wu et al., 2024). The United Kingdom has focused heavily on the role of green spaces in improving social wellbeing, as reflected in its "Environmental Improvement Plan." This emphasis has solidified its leadership in environmental psychology and urban planning research (Edeigba et al., 2024). Although Sweden and Australia have fewer publications, their impact on the field remains substantial. Swedish academic institutions have been instrumental in the theoretical development of restorative environments and continue to play a vital role within the European research network. Australia's research, which integrates urban greening with public health, and its close collaborations with the United States and China, further enhance its global research influence. Together, the contributions of these nations provide valuable insights and drive international collaboration, enriching the global understanding of restorative environment research and advancing the field as a whole.

### 3.3 Analysis of research institutions

Analyzing the publication output of leading research institutions offers valuable insights into the distribution and influence of key contributors to restorative environment research. This study ranks institutions based on their publication volume, with the ten most influential ones listed in Table 2. The data indicate that the foremost institutions are

TABLE 2 Top 10 statistics of research organisations in terms of the number of articles published.

Rank	Unit and country	Number of publications
1	Uppsala University - Sweden	35
2	Swedish University - Sweden	32
3	University of Exeter - United Kingdom	24
4	National Taiwan University - China	19
5	University of Michigan - United States	18
6	University of Copenhagen - Denmark	17
7	University of Illinois - United States	17
8	Tongji University - China	15
9	Tampere University - Finland	15
10	University of Melbourne - Australia	14

TABLE 3 Top 10 international journals and publications.

Rank	Name of the journal	Number of publications
1	Journal of Environmental Psychology	92
2	International Journal of Environmental Research and Public Health	69
3	Frontiers in Psychology	64
4	Urban Forestry and Urban Greening	64
5	Landscape and Urban Planning	46
6	Environment and Behavior	39
7	Sustainability	36
8	Forests	16
9	Health and Place	14
10	Landscape Research	12

primarily situated within higher education establishments. The top-ranking institutions globally include: Uppsala University (35 papers), Swedish University of Agricultural Sciences (32 papers), University of Exeter (24 papers), National Taiwan University (19 papers), University of Michigan (18 papers), University of Copenhagen (17 papers), University of Illinois (17 papers), Tongji University (15 papers), Tampere University (15 papers), and University of Melbourne (14 papers).

These findings emphasize the crucial role of universities in advancing restorative environment research, underscoring their leadership in shaping global academic discourse in this field.

### 3.4 Analysis of literature sources

By ranking sources and publication volumes, as shown in Table 3, this study identified the top ten high-impact journals in restorative environment research. These include: Journal of Environmental Psychology (92 papers), International Journal of Environmental Research and Public Health (69 papers), Frontiers in Psychology (64 papers), Urban Forestry & Urban Greening

(64 papers), Landscape and Urban Planning (46 papers), Environment and Behavior (39 papers), Sustainability (36 papers), Forests (16 papers), Health and Place (14 papers), and Landscape Research (12 papers).

The data indicate that the majority of publications in this field are concentrated in journals related to psychology, public health, landscape architecture, and urban planning. This concentration underscores the interdisciplinary nature of restorative environment research and highlights the critical role these disciplines play in advancing both theoretical understanding and practical applications.

### 3.5 Keyword cluster analysis

The co-occurrence frequency of keywords was set to a minimum of 3 in VOSviewer. After consolidating synonymous terms, a network of 326 distinct keywords was generated (see Figure 3). The analysis reveals that restorative environment research can be categorized into five main clusters of hotspots.

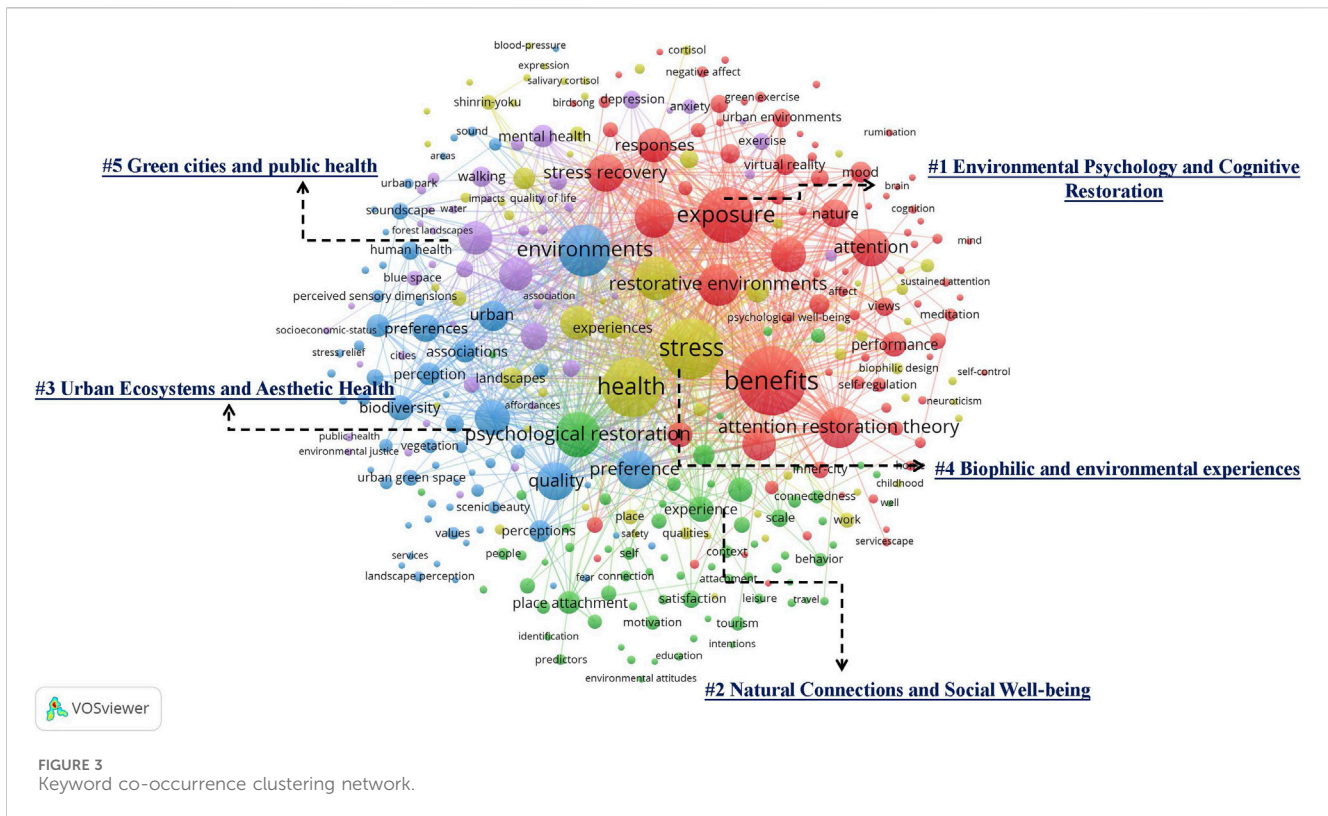


FIGURE 3  
Keyword co-occurrence clustering network.

- Cluster #1: Environmental Psychology and Cognitive Restoration
- Cluster #2: Nature Connection and Social Wellbeing
- Cluster #3: Urban Ecosystems and Aesthetic Health
- Cluster #4: Biophilia and Environmental Experience
- Cluster #5: Green Cities and Public Health

These clusters highlight the central themes in restorative environment research, reflecting the diversity and interconnections of topics explored by scholars. The analysis emphasizes the multi-dimensional nature of the field, providing valuable insights into how environmental factors impact both mental and physical wellbeing.

### 3.5.1 Cluster #1: environmental psychology and cognitive restoration

This cluster includes 85 items, focusing on key topics such as environmental psychology, cognitive function, attention restoration, the impact of natural environments, restorative environment design, mental health promotion, and urban green space planning. The integration of environmental psychology and cognitive restoration offers a novel perspective on human-environment interactions, enriching environmental design research and enhancing its scientific and practical value. Environmental psychology explores how environmental factors influence cognitive processes and psychological states, emphasizing the positive effects of natural environments on attention, emotion regulation, and memory. This has led to the emergence of restorative environment design (White et al., 2010), which aims to create spaces that promote psychological recovery and reduce stress, helping individuals cope with daily life pressures and improve overall wellbeing (White and

Gatersleben, 2011). Core principles of restorative design include optimizing the relationship between nature and cognition, integrating restorative environments with mental health initiatives, and enhancing urban quality of life through green space development. These considerations highlight the importance of natural environments in cognitive restoration, support the innovative application of restorative design, and enrich the cultural and emotional value of environmental design (Corraliza et al., 2012). The intersection of environmental psychology and cognitive restoration not only underpins the scientific basis of design but also drives innovation by bridging theory with practice.

### 3.5.2 Cluster #2: nature connection and social wellbeing

This cluster encompasses 70 items, with a central focus on keywords like nature connection, social wellbeing, environmental perception, community participation, urban greening, public health, emotional wellbeing, environmental justice, quality of life, and urban design. A key theme emerging from this cluster is the interplay between nature connection and social wellbeing, which provides a fresh viewpoint on how natural environments influence collective and individual wellbeing. This exploration enhances urban planning and social policy research, while also enriching the humanistic dimension of urban environmental design. Nature connection theory explores the impact of human-nature interactions on social cohesion, community involvement, and public health. It emphasizes how these interactions foster emotional health, strengthen community ties, and improve quality of life. This intersection of nature and social wellbeing

has given rise to an emerging paradigm—nature-based enhancement of social wellbeing (Hartmann et al., 2013). This framework advocates for community involvement in the preservation and utilization of green spaces, thus promoting environmental stewardship and enhancing collective happiness (Gao et al., 2019). The foundational principles of this paradigm advocate for integrating natural environments into urban spaces to foster social wellbeing. They emphasize urban greening, community engagement, and the promotion of both public and emotional health. From a design perspective, the emphasis is on creating environments that not only support ecological sustainability but also promote social equity and improve quality of life through community participation in environmental planning. The integration of nature connection with social wellbeing offers essential ecological insights, furthering the interdisciplinary approach necessary for urban planning that supports both sustainable communities and environmental justice (Jahani and Saffariha, 2020; Bilius et al., 2021).

### 3.5.3 Cluster #3: urban ecosystems and aesthetic health

This cluster comprises 64 items and focuses on themes such as urban ecosystems, aesthetic health, urban greening, parks, urban forests, soundscapes, environmental aesthetics, urban design, renewal, ecological services, biodiversity, and the health of urban residents. At the intersection of urban ecosystems and aesthetic health lies a novel approach to understanding how the aesthetics of urban environments contribute to residents' wellbeing. This perspective enriches research in both urban ecology and environmental psychology, while also enhancing the aesthetic and health-oriented value of urban environmental design. By exploring the role of urban ecosystem aesthetics in mental and physical health, environmental aesthetics theory emphasizes the positive influence of green spaces, parks, and urban forests in reducing stress and improving overall quality of life. This integration has led to the development of a new design philosophy—ecological aesthetic health design. This approach promotes interaction between residents and nature by designing urban spaces that offer both ecological and aesthetic benefits, thereby improving environmental perceptions and boosting resident satisfaction (Zhang et al., 2022). The design principles of this approach focus on the aesthetic features of urban ecosystems and their direct impact on residents' health. This includes the thoughtful planning of green spaces, parks, and urban soundscapes to optimize environmental perception. Furthermore, these principles stress the importance of urban design in improving mental health and contributing to biodiversity and ecological services through responsible urban planning (Ma et al., 2023). Ultimately, the integration of urban ecosystems and aesthetic health provides vital ecological aesthetic principles that not only enhance urban beauty but also improve residents' wellbeing through sustainable, innovative design practices (Zhang et al., 2024).

### 3.5.4 Cluster #4: biophilia and environmental experience

This cluster includes 62 items, with keywords such as biophilia, environmental experience, natural contact, physical and mental health, restorative environments, natural environment perception,

forest bathing, healing landscapes, urban green spaces, health promotion, ecological design, psychological restoration, and emotional regulation. The intersection of biophilia and environmental experience offers a fresh perspective on the deep, inherent connection between humans and nature, emphasizing its significant impact on health. This perspective enriches research within health psychology and environmental design, emphasizing the crucial role of design in promoting human wellbeing (Sahoo et al., 2021). By examining the influence of biophilia theory on human interactions with natural settings, research on environmental experience illustrates how natural contact can improve physical and mental health, promote psychological restoration, and enhance emotional regulation. This combination has given rise to a novel design strategy—biophilic design (Malyan et al., 2022). Biophilic design seeks to foster stronger human-nature connections by creating environments that promote health, leading to improved quality of life and overall wellbeing (Lindal and Hartig, 2015). Key design principles focus on integrating biophilic elements into environmental design, encouraging natural interaction for health benefits, and enhancing emotional regulation and psychological restoration. Design considerations stress the importance of natural environments in supporting human health, underline the role of design in facilitating psychological healing and emotional balance, and highlight how thoughtful environmental design can elevate quality of life and happiness (Huang Z. et al., 2024). The integration of biophilia and environmental experience provides both scientific and humanistic insights into environmental design, promoting innovative, human-centered approaches that advance its application in fostering better health outcomes.

### 3.5.5 Cluster #5: green cities and public health

This cluster encompasses 45 items, with key terms such as urban greening, public mental health, urban design, urban green spaces, parks, forests, urban soundscapes, environmental justice, socioeconomic status, residents' quality of life, mental health promotion, emotional regulation, stress reduction, community participation, physical activity, and blue-green spaces. The intersection of green urbanism and public mental health offers a new perspective on the crucial role urban green spaces play in enhancing public mental health. This perspective contributes to research in urban planning and public health, highlighting the social value of urban environmental design (Staats et al., 2016). By investigating the impact of urban green spaces on mental health and overall wellbeing, green urbanism theory illustrates how urban parks, forests, and green spaces can reduce stress, improve emotional wellbeing, foster social interaction, and strengthen community cohesion (Zhao et al., 2019). This integration has led to the emergence of a novel urban planning approach—green urban mental health promotion (Nicosi et al., 2020). This strategy focuses on optimizing the design and distribution of urban green spaces to provide more opportunities for residents to connect with nature, thereby improving mental health and enhancing quality of life (Luo et al., 2022). Key design principles explore the relationship between green spaces and public mental health, examine the role of urban design in mental health promotion, and assess how community participation and socioeconomic status influence mental health outcomes. Design considerations emphasize the importance of urban green spaces in enhancing public mental health, the role of



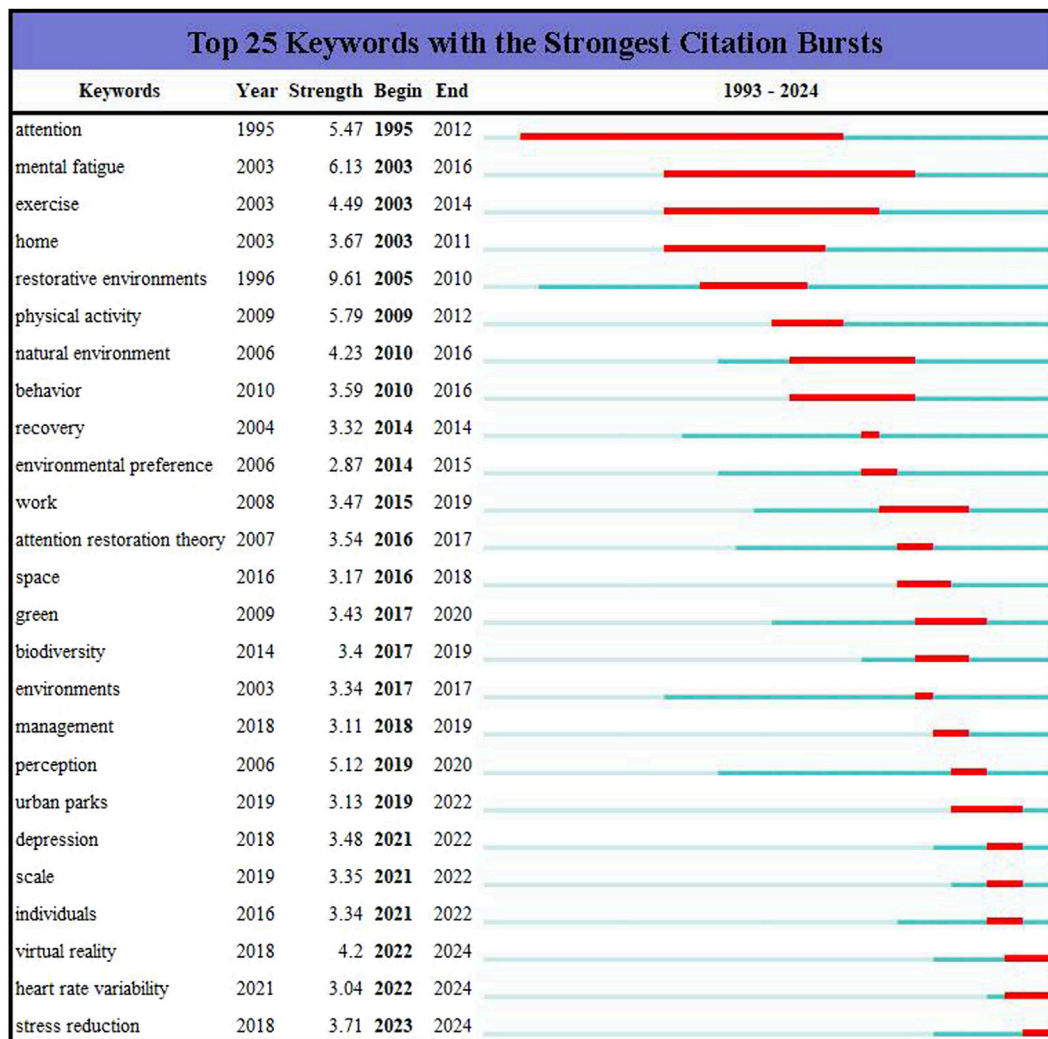


FIGURE 4 Keywords with the strongest citation bursts.

urban design in improving quality of life, and the significance of community participation in fostering social cohesion and mental health (Chaturvedi et al., 2025a). The fusion of green urbanism and public mental health offers both ecological and social benefits for urban planning, advancing urban greening initiatives and promoting mental health through interdisciplinary, human-centered approaches.

### 3.6 Burst term analysis

Figure 4 highlights the top 25 emerging keywords in restorative environment research, shedding light on the evolving trends and shifting focal points in the field.

Early Exploration Stage (1993–2005): In this initial phase, the keyword “attention” started to gain momentum around 1995, continuing to rise steadily until 2012. This upward trajectory reflects the growing academic interest in the mechanisms of attention restoration.

Mid-term Development Stage (2006–2016): During this period, the keyword “mental fatigue” emerged as a significant topic around 2003, reaching its peak citation intensity of 6.13 by 2016. Similarly, “exercise” began to attract attention around 2003, with its citation intensity rising to 4.49 by 2014. These trends indicate an increasing focus on how environments can reduce mental fatigue and promote physical activity.

Recent Deepening Stage (2017–2024): From 2017 onward, keywords such as “virtual reality” and “stress reduction” have shown substantial increases in research intensity, with values reaching 4.2 and 3.71, respectively. These trends are expected to continue growing through 2024. Additionally, the keyword “perception” saw a surge in 2019 and 2020, peaking at 5.12, highlighting the rising importance of environmental perception in restorative environment research.

In summary, the trends illustrated in Figure 4 emphasize the growing integration of advanced technologies like virtual reality into restorative environment studies, alongside an intensified focus on strategies for stress reduction and psychological recovery.

## 4 Discussion

### 4.1 Advantages of bibliometric analysis

The integration of bibliometric analysis with visual knowledge mapping offers a powerful methodology for conducting literature reviews, allowing scholars and researchers to obtain a thorough and systematic understanding of research trends within a given field (Bhardwaj et al., 2023; Yan et al., 2022). By utilizing advanced tools such as CiteSpace and VOSviewer, researchers can process large datasets efficiently, swiftly identifying key trends and emerging topics, thereby overcoming the limitations of traditional review methods (Chen et al., 2023; Wang and Ge, 2024).

This approach also enables the identification of interdisciplinary connections and facilitates the quantitative analysis of knowledge transfer across various domains. By leveraging extensive literature data from databases like the Web of Science, it becomes possible to construct clear academic collaboration networks and research topic maps, providing essential support for ongoing scholarly discussions (Chaturvedi et al., 2025b; Dubey et al., 2023).

Moreover, bibliometric analysis allows for the examination of large volumes of literature from sources such as the Web of Science, generating scientific visualizations that include keywords, countries, institutions, and authors, thus offering intuitive insights into research. This method supports a comprehensive investigation of the current state, developmental phases, and potential future directions of research. It is applicable across a variety of academic databases, including Google Scholar, Scopus, and non-English databases like CNKI (Nugroho et al., 2022; Ramadhan et al., 2024). Consequently, this approach equips researchers with powerful tools to explore global research frontiers and identify emerging trends.

### 4.2 Contributions to existing research

This study presents a comprehensive and systematic examination of the research landscape in restorative environment studies through bibliometric analysis, making several important contributions. First, it extends the scope of prior research by covering a broader time frame and providing a more thorough analysis compared to earlier studies (Fang et al., 2018; Weber and Trojan, 2018; Ratcliffe, 2021). The integration of VOSviewer and CiteSpace allows for a detailed visual representation of key research directions and emerging hotspots in the field of restorative environment research. Second, the study identifies five core clusters within the discipline: Environmental Psychology and Cognitive Restoration, Nature Connection and Social Wellbeing, Urban Ecosystems and Aesthetic Health, Biophilia and Environmental Experience, and Green Urbanism and Public Mental Health. These clusters not only capture distinct focal areas but also reflect the evolving trends and development stages within restorative environment research. Third, the analysis of the international collaboration network highlights the significant influence of countries such as the United States, China, the United Kingdom, Sweden, and Australia. This underscores the importance of global cooperation in advancing

restorative environment research and knowledge dissemination. Furthermore, by assessing the publication output of leading research institutions, the study provides valuable insights into the academic contributions of influential universities in the field. Finally, the study's examination of high-output journals reveals that restorative environment research is predominantly published in journals related to psychology, public health, landscape architecture, and urban planning. This insight can guide researchers in identifying appropriate academic outlets for their work.

### 4.3 Research gaps

Despite significant progress in restorative environment research, several critical gaps remain that warrant further exploration:

First, there exists a notable gap between theoretical advancements in restorative environment research and its practical application in policy-making. While numerous studies have established the positive impact of restorative environments on mental health and wellbeing, the integration of these findings into management practices and policy decisions is still limited (Siah et al., 2022; Xie et al., 2022). Many existing studies focus primarily on theoretical aspects, with insufficient attention given to translating these theoretical results into actionable public policies and management strategies. This study uses bibliometric analysis to systematically review research hotspots in the field and identify the knowledge gap between academia and policymakers. Through an analysis of international collaboration networks and high-output journals, the study highlights the leading countries and institutions in implementing restorative environment policies, as well as summarizing practical experiences from various nations. This provides valuable guidance for future policy integration. Furthermore, the keyword clustering analysis uncovers cross-disciplinary trends in urban planning, health management, and social welfare, offering data-driven support for policymakers and facilitating the translation of theory into practice.

Second, while much of the current research focuses on the quantifiable benefits of restorative environments, their intangible values remain underexplored. Much of the existing literature concentrates on how restorative environments affect physiological indicators of mental health, such as heart rate and cortisol levels, but there is a lack of systematic evaluation regarding their cultural ecosystem services and broader social values (Nakamura et al., 2023; Nukarinen et al., 2022). This study, using keyword co-occurrence and burst word analysis, uncovers research connections between restorative environments and themes like cultural ecosystem services, social cohesion, and community welfare. It proposes a more comprehensive research framework to explore the potential non-direct health benefits of restorative environments. Notably, the study identifies a significant rise in keywords such as “environmental justice,” “social equity,” and “social value of urban greening” in recent years, reflecting a growing academic interest in the social dimensions of restorative environments. Additionally, by examining the work of high-impact research institutions and authors, this study identifies research groups focused on evaluating the social value of restorative environments, providing insights for future empirical studies.

Finally, there is a marked geographic imbalance in restorative environment research, with limited contributions from the Global South. Currently, most research originates from North America and Europe, which may limit the global applicability of the findings (Bolognesi et al., 2023; Shine and Elphick, 2023). Through an analysis of international collaboration, this study reveals a stark contrast in research output, with countries in the Global South contributing less significantly. Regions such as Sub-Saharan Africa, South Asia, and Latin America, due to varying economic development levels, urban planning systems, and environmental governance policies, are less equipped to conduct restorative environment research. However, the geographical distribution analysis also reveals a rising trend in research output from countries like China and Brazil, although their global influence remains limited. Moreover, burst word analysis indicates that academic attention to topics like “the application of urban greening in developing countries” has been growing, suggesting that restorative environment research is gradually expanding to the Global South. These findings advocate for broader applicability of restorative environment theory across various developmental stages and cultural contexts, offering valuable guidance for urban planning and environmental design in the Global South.

#### 4.4 Policy implications

This study’s bibliometric analysis unveils the global trajectory of restorative environment research and identifies key research gaps across different regions. Based on these insights, several targeted policy recommendations are proposed to optimize urban policies, public health initiatives, and environmental design:

1. **Urban Policies:** Urban planning must incorporate clear, measurable indicators for restorative environments. Governments should focus on expanding green space availability, optimizing their distribution, and ensuring these spaces are accessible to low-income communities. Drawing inspiration from countries like the Netherlands, which have established robust standards for evaluating restorative environments, policymakers should embed these standards within urban renewal and infrastructure policies. This would facilitate the systematic integration of restorative environments into urban planning frameworks. Specifically, in densely populated urban centers, attention should be given to small-scale restorative spaces such as rooftop gardens, community green spaces, and pocket parks. These compact, yet vital, areas will help alleviate the deficit in green spaces and provide urban residents with crucial psychological restoration.
2. **Public Health Strategies:** There is a need to deepen the integration of restorative environments within public health initiatives. Governments and healthcare organizations should promote “green prescription” programs, wherein exposure to nature serves as a therapeutic tool for mental health. For instance, individuals experiencing depression or high stress could be encouraged to spend more time in restorative environments as a means of alleviating anxiety and mental strain. Moreover, health centers and elder care facilities could incorporate horticultural therapy zones, walking greenways,

and meditation gardens to foster long-term wellbeing. Policymakers should also ensure that these restorative spaces are accessible to vulnerable populations, including the elderly, disabled, and low-income individuals. This can be achieved by adding features like accessible pathways, seating, and shade structures, ensuring equitable access to the health benefits offered by restorative environments.

3. **Environmental Design:** Urban planners and landscape architects must prioritize the functional benefits of restorative environments, alongside their aesthetic appeal. The design of public green spaces should draw directly from the theoretical insights of restorative environment research, focusing on enhancing natural landscapes, reducing noise pollution, and creating spaces conducive to walking and resting. In areas with limited land availability, solutions like vertical greening, rooftop gardens, and community gardens should be prioritized. These small but effective spaces provide urban dwellers with accessible and meaningful opportunities for psychological recovery. Moreover, the integration of smart technologies such as air quality sensors, adaptive lighting for nighttime safety, and virtual reality applications can further enrich the restorative potential of these spaces. By diversifying the environmental experience, these technological innovations will help create more personalized, immersive, and effective restorative environments. Through the adoption of these policy measures, governments, public health agencies, and urban planners can effectively leverage the insights derived from restorative environment research. Such initiatives will enhance urban livability, promote residents’ mental and physical health, and contribute to the sustainable development of urban spaces.

#### 4.5 Limitations of the study

While this study employs bibliometric techniques and visualization tools to comprehensively analyze research on restorative environments, several limitations must be considered:

1. The study relies exclusively on the Web of Science (WoS) database, which, while offering extensive coverage, predominantly indexes high-impact journals. This may introduce citation bias, potentially distorting the trends identified within the field. Additionally, WoS primarily features English-language publications, which means that valuable studies published in other languages might be excluded, possibly limiting the breadth of the analysis. Moreover, since the data was collected on 20 March 2024, the most recent research findings might not have been incorporated, creating a temporal gap in the dataset.
2. The bibliometric approach employed here is based on co-occurrence relationships, making it highly sensitive to the quality and completeness of the data. As the study depends on literature indexed by WoS, some relevant studies might be underrepresented due to delays in database updates, inconsistent indexing practices, or fluctuations in journal impact factors. Furthermore, bibliometric analysis typically relies on publication year and citation relationships for

statistical interpretation. However, academic influence often develops gradually, meaning that highly impactful studies published recently might not yet exhibit stable citation patterns. This delay could lead to emerging research trends being underrepresented or overlooked.

3. This study is limited to published academic literature, but much academic knowledge is generated through other means, such as unpublished reports, policy documents, conference proceedings, corporate research, and studies by non-governmental organizations. These forms of gray literature play a significant role in shaping research ideas and academic discourse, yet they were excluded from this study. Additionally, the structure of academic publishing, research funding priorities, and the biases inherent in high-impact journals may influence the visibility of certain research topics, potentially affecting the representation of specific research trends in the bibliometric analysis.
4. The study adopts the disciplinary classification system provided by the WoS database, which can introduce biases when defining interdisciplinary research. Restorative environment research spans various fields, including psychology, urban planning, public health, and environmental science. However, the way these disciplines are categorized in WoS may result in some studies being classified under unrelated or niche areas, potentially skewing the overall trends in the field. Additionally, the rigid structure of the disciplinary classification system may hinder the accurate identification of emerging interdisciplinary studies, potentially leading to insufficient recognition of cross-disciplinary research areas.

## 5 Conclusion

This study, utilizing the Web of Science database along with VOSviewer and CiteSpace software, offers a comprehensive analysis of the academic literature on restorative environment research. It explores the current state of research, highlights emerging themes, and anticipates future trends, making valuable contributions both to academic knowledge and practical applications. The key findings are summarized as follows:

Research on restorative environments is predominantly concentrated in leading higher education institutions, including Uppsala University, the Swedish University of Agricultural Sciences, and the University of Exeter. These institutions have shown significant success in both publication output and academic influence. Internationally, the United States plays a pivotal role in fostering collaborations, particularly with countries such as China, the United Kingdom, and Sweden, highlighting the importance of global cooperation in advancing the field.

Prominent journals in restorative environment research, including the *Journal of Environmental Psychology* and the *International Journal of Environmental Research and Public Health*, are central to academic discourse. These journals not only occupy leading positions in fields like psychology, public health, landscape architecture, and urban planning, but also promote interdisciplinary integration, illustrating the diverse and wide-reaching impact of restorative environments in contemporary society.

The body of research can be categorized into five major clusters: environmental psychology and cognitive restoration, nature connection and social wellbeing, urban ecosystems and aesthetic health, biophilic environmental experiences, and green urbanism in relation to public mental health. These clusters reflect the broad and evolving scope of research, highlighting the interdisciplinary connections that bridge environmental design, public health, and social welfare.

The focus of research has evolved over time, transitioning from foundational studies on restorative environments and Attention Restoration Theory (ART) to more recent investigations on natural environments and mental fatigue. In the latest phase, virtual reality technology and stress management have become key areas of interest. This progression suggests that restorative environment research is increasingly incorporating modern technologies like virtual reality, expanding the field's scope and its potential applications.

Future research should diversify its data sources by incorporating additional databases such as Scopus, Google Scholar, and CNKI. This would allow for a more comprehensive analysis and reduce the citation bias associated with relying on a single database. Moreover, integrating multilingual text mining techniques, natural language processing (NLP), and machine translation would significantly extend the coverage of non-English language research, thereby enhancing the completeness of the dataset. In terms of the intangible values of restorative environments, future studies could incorporate remote sensing data to track the distribution of urban green spaces, natural resources, vegetation cover, and biodiversity. This data could be combined with psychological health survey results to explore how specific environmental features impact psychological restoration and emotional regulation. Additionally, community-based participatory surveys that gather feedback on environmental perceptions and social wellbeing would provide valuable insights, helping to quantify the intangible benefits of natural environments. To address the time lag effect inherent in bibliometric methods, it is essential to implement dynamic data updates and rolling window analyses. These approaches would enable real-time monitoring of newly published research, and artificial intelligence-driven trend prediction models could be employed to identify emerging research hotspots more accurately. Regarding knowledge diversity, the inclusion of gray literature should be a priority. Mining policy documents, conference papers, and industry reports would help fill the gaps left by formally published research. Furthermore, future studies could combine qualitative content analysis with bibliometric methods through multimodal analysis techniques, creating a more holistic research framework that offers deeper insights into the evolution of academic thought. For interdisciplinary research, co-word analysis coupled with machine learning classification algorithms could be employed to establish a more flexible disciplinary classification system. This would improve the identification of cross-disciplinary research areas. Additionally, network science methods could be used to investigate knowledge flows between disciplines, providing a clearer understanding of the true interdisciplinary nature of restorative environment research. With these methodological advancements, future studies will be better equipped to depict the dynamic trajectory of knowledge development in the field. This will provide more accurate academic support for both policymaking and practical applications.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## Author contributions

ZY: Conceptualization, Data curation, Formal Analysis, Writing—original draft, Writing—review and editing. ZT: Investigation, Methodology, Project administration, Resources, Writing—original draft, Writing—review and editing. ZH: Software, Supervision, Validation, Visualization, Writing—original draft, Writing—review and editing.

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## References

- Backman, S., Huang, Y., Chen, C., Lee, H., and Cheng, J. (2022). Engaging with restorative environments in wellness tourism. *Curr. Issues Tour.* 26, 789–806. doi:10.1080/13683500.2022.2039100
- Bhardwaj, D. R., Salve, A., Kumar, J., Kumar, A., Sharma, P., and Kumar, D. (2023). Biomass production and carbon storage potential of agroforestry land use systems in high hills of north-western Himalaya: an approach towards natural based climatic solution. *Biomass Convers. Biorefinery* 14, 18079–18092. doi:10.1007/s13399-023-03952-0
- Bilius, L.-B., Vatavu, R.-D., and Marquardt, N. (2021). “Smart vehicle proxemics: a conceptual framework operationalizing proxemics in the context of outside-the-vehicle interactions,” in *Human-Computer Interaction – INTERACT 2021*. Editor C. Ardito, 12933, 150–171. doi:10.1007/978-3-030-85616-8\_11
- Bolognesi, M., Toffalini, E., and Pazzaglia, F. (2023). Perceived psychological restorativeness in relation to individual and environmental variables: a study conducted at potto beach in sardinia, Italy. *Sustainability* 15 (3), 2794. doi:10.3390/su15032794
- Chaturvedi, S., Kumar, A., Min, L., and Kumar, R. (2025a). A perspective on green solutions and future research paths for microplastic and nanoplastic contamination in drinking water. *Clean. - Soil, Air, Water* 53 (1). doi:10.1002/clen.202400104
- Chaturvedi, S., Kumar, A., Min, L., Mohan, K., Singh, N., and Kumar, R. (2025b). Insights into earthworms and fungi: pioneering roles in mitigating global food scarcity and combatting land degradation. *Land Degrad. and Dev.* doi:10.1002/ldr.5446
- Chaturvedi, S., Kumar, A., Singh, V., Chakraborty, B., Kumar, R., and Min, L. (2023). Recent advancement in organic aerosol understanding: a review of their sources, formation, and health impacts. *Water, Air, Soil Pollut.* 234 (12), 750. doi:10.1007/s11270-023-06772-0
- Chen, C. (2006). CiteSpace II: detecting and visualizing emerging trends and transient patterns in scientific literature. *J. Am. Soc. Inf. Sci. Technol.* 57 (3), 359–377. doi:10.1002/asi.20317
- Chen, M., Zhang, Y., Dong, L., and Guo, X. (2023). Bibliometric analysis of stroke and quality of life. *Front. Neurology* 14, 1143713. doi:10.3389/fneur.2023.1143713
- Corraliza, J. A., Collado, S., and Bethelmy, L. (2012). Children’s perceived restoration: adaptation of the PRCS for children to a Spanish sample. *Psychology* 3 (2), 195–204. doi:10.1174/217119712800337729
- Deemer, D., Peavey, E., Teti, S., Hercules, W., Wong, J., and Anderson, D. (2023). How should organizations be held accountable for promoting environments that foster social connection? *AMA J. ethics* 2511, E825–E832. doi:10.1001/amajethics.2023.825
- Du, Y., Zou, Z., He, Y., Zhou, Y., and Luo, S. (2022). Beyond blue and green spaces: identifying and characterizing restorative environments on sichuan technology and business university campus. *Int. J. Environ. Res. Public Health* 19, 13500. doi:10.3390/ijerph192013500
- Dubey, P., Dubey, P., Agrawal, P., Chourasia, H., Nayak, M., and Gehani, H. (2023). “Bibliometric analysis of data science research: a decade of insights from Web of

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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science,” in 2023 Fourth International Conference on Smart Technologies in Computing, Electrical and Electronics (ICSTCEE), 1–6. doi:10.1109/ICSTCEE60504.2023.10585030

Edeigba, B. A., Ashinze, U. K., Umoh, A. A., Biu, P. W., and Daraojimba, A. I. (2024). Urban green spaces and their impact on environmental health: a Global Review. *World J. Adv. Res. Rev.* 21 (2), 917–927. doi:10.30574/wjarr.2024.21.2.0518

Fang, Y., Yin, J., and Wu, B. (2018). Climate change and tourism: a scientometric analysis using CiteSpace. *J. Sustain. Tour.* 26 (1), 108–126. doi:10.1080/09669582.2017.1329310

Gao, T., Zhang, T., Zhu, L., Gao, Y., and Qiu, L. (2019). Exploring psychophysiological restoration and individual preference in the different environments based on virtual reality. *Int. J. Environ. Res. Public Health* 16 (16), 3102. doi:10.3390/ijerph16173102

Guo, W., Wen, H., and Liu, X. (2023). Research on the psychologically restorative effects of campus common spaces from the perspective of health. *Front. Public Health* 11, 1131180. doi:10.3389/fpubh.2023.1131180

Hartmann, P., Apaolaza, V., and Alija, P. (2013). Nature imagery in advertising: attention restoration and memory effects. *Int. J. Advert.* 32 (2), 183–210. doi:10.2501/IJA-32-2-183-210

Huang, B., Zhao, Y., Yang, J., Wang, W., Guo, T., Luo, X., et al. (2024a). Thermal comfort and restorative benefits of waterfront green spaces for college students in hot and humid regions. *Sustainability* 16 (20), 8924. doi:10.3390/su16208924

Huang, J., Song, Y., Sheng, Y., Zhang, Y., and Hu, D. (2024b). Restorative potential assessment of public open space in old urban communities in the context of aging—a case study of dabeizhuang community in maanshan, China. *Buildings* 14 (9), 2671. doi:10.3390/buildings14092671

Huang, Z., Wang, B., Luo, S., Wang, M., Miao, J., and Jia, Q. (2024c). Integrating streetscape images, machine learning, and space syntax to enhance walkability: a case study of seongbuk district, seoul. *Land* 13 (10), 1591. doi:10.3390/land13101591

Jahani, A., and Saffariha, M. (2020). Aesthetic preference and mental restoration prediction in urban parks: an application of environmental modeling approach. *Urban For. and Urban Green.* 54, 126775. doi:10.1016/j.ufug.2020.126775

Kaiser, K. E., Braswell, A. E., and Fork, M. L. (2022). NSF supported socio-environmental research: how do crosscutting programs affect research funding, publication, and citation patterns? *Ecol. Soc.* 27, art25. doi:10.5751/es-13281-270325

Lindal, P. J., and Hartig, T. (2015). Effects of urban street vegetation on judgments of restoration likelihood. *Urban For. and Urban Green.* 14, 200–209. doi:10.1016/j.ufug.2015.02.001

Luo, S., Shi, J., Lu, T., and Furuya, K. (2022). Sit down and rest: use of virtual reality to evaluate preferences and mental restoration in urban park pavilions. *Landsc. Urban Plan.* 220, 104336. doi:10.1016/j.landurbplan.2021.104336

Ma, H., Xu, Q., and Zhang, Y. (2023). High or low? Exploring the restorative effects of visual levels on campus spaces using machine learning and street view imagery. *Urban For. and Urban Green.* 88, 128087. doi:10.1016/j.ufug.2023.128087

- Malyan, S. K., Singh, O., Kumar, A., Anand, G., Singh, R., Singh, S., et al. (2022). Greenhouse gases trade-off from ponds: an overview of emission process and their driving factors. *Water* 14 (6), 970. doi:10.3390/w14060970
- Masullo, M., Toma, R. A., Navarro Ruiz, J. M., Hernandez Bellot, J., and Maffei, L. (2023). The effects of different sound environments on physiological stress recovery and perceived restorativeness. *INTER-NOISE-NOISE-CON Congr. Proc.* 265 (2), 5553–5561. doi:10.3397/in\_2022\_0819
- Moura, R., Camilo, C., Lima, M. L., Luis, S., Elliott, L. R., and White, M. P. (2024). Anxiety meets nature: the role of nature in the relationship between socioeconomic status, anxiety and well-being/Ansiedad y naturaleza: el papel de la naturaleza en la relación entre estatus socioeconómico, ansiedad y bienestar. *PsyEcology* 15 (2), 143–162. doi:10.1177/21711976241264147
- Nakamura, G., Soares, B. E., Pillar, V. D., Diniz-Filho, J. A. F., and Duarte, L. (2023). Three pathways to better recognize the expertise of Global South researchers. *npj Biodivers.* 2 (1), 17. doi:10.1038/s44185-023-00021-7
- Nicosi, V., Wilson, J., Yoshino, A., and Viren, P. (2020). The restorative potential of coastal walks and implications of sound. *J. Leis. Res.* 62 (2), 149–168. doi:10.1080/00222216.2020.1741329
- Nugroho, A. S. E., Tjhin, V. U., Kosasih, W., and Prabowo, H. (2022). Bibliometric analysis of research trend on agile it governance. *Int. J. Econ. Bus. Account. Res. (IJEBAR)* 6 (1), 65–79. doi:10.29040/ijebare.v6i1.2976
- Nukarinen, T., Rantala, J., Korpela, K., Browning, M. H., Istance, H. O., Surakka, V., et al. (2022). Measures and modalities in restorative virtual natural environments: an integrative narrative review. *Comput. Hum. Behav.* 126, 107008. doi:10.1016/j.chb.2021.107008
- OuYang, F., and Du, X. (2019). Application of spatial data analysis in architectural planning. *IOP Conf. Ser. Earth Environ. Sci.* 234 (1), 012035. doi:10.1088/1755-1315/234/1/012035
- Park, N. S., Jang, Y., Yoon, J. W., Chung, S., and Chiriboga, D. A. (2022). Relationship of social isolation with mental distress among older Korean Americans: the moderating role of social cohesion. *Health and Soc. Care Community* 30 (6), e4909–e4919. doi:10.1111/hsc.13903
- Rachel, K., and Stephen, K. (1989). *The experience of nature: a psychological perspective*. Cambridge University Press.
- Ramadhan, S., Raharjo, S. B., Taufik, O. A., Kozin, W., Habibullah, A., Dudin, A., et al. (2024). Global research trend in digital learning: analysis using bibliometrix on the Scopus database. *Educ. Adm. Theory Pract.* 30 (4), 1537–1547. doi:10.53555/kuely.v30i4.814
- Ratcliffe, E. (2021). Sound and soundscape in restorative natural environments: a narrative literature review. *Front. Psychol.* 12, 570563. doi:10.3389/fpsyg.2021.570563
- Sahoo, U. K., Tripathi, O. P., Nath, A. J., Deb, S., Das, D. J., Gupta, A., et al. (2021). Quantifying tree diversity, carbon stocks, and sequestration potential for diverse land uses in Northeast India. *Front. Environ. Sci.* 9, 724950. doi:10.3389/fenvs.2021.724950
- Shao, H., Kim, G., Li, Q., and Newman, G. (2021). Web of science-based green infrastructure: a bibliometric analysis in CiteSpace. *Land* 10 (7), 711. doi:10.3390/land10070711
- Shine, R., and Elphick, M. (2023). When, where, and why has research been conducted on snakes? *J. Herpetology* 57, 197–203. doi:10.1670/22-054
- Siah, C., Kua, E., and Goh, Y. (2022). The impact of restorative green environment on mental health of big cities and the role of mental health professionals. *Curr. Opin. Psychiatry* 35, 186–191. doi:10.1097/YCO.0000000000000778
- Staats, H., Jahncke, H., Herzog, T. R., and Hartig, T. (2016). Urban options for psychological restoration: common strategies in everyday situations. *PLoS ONE* 11 (1), e0146213. doi:10.1371/journal.pone.0146213
- Tan, H., Sun, J., Wenjia, W., and Zhu, C. (2021). User Experience&Usability of driving: a bibliometric analysis of 2000-2019. *Int. J. Human-Computer Interact.* 37 (4), 297–307. doi:10.1080/10447318.2020.1860516
- Tundisi, J. (2024). The use of Urban Forest Parks to improve human-nature relations and cognitive ability performance in older adults. *Braz. J. Biol. = Revista brasileira de Biol.* 84, e283001. doi:10.1590/1519-6984.283001
- Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., and Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *J. Environ. Psychol.* 11 (3), 201–230. doi:10.1016/s0272-4944(05)80184-7
- Vaneck, N. J., and Waltman, L. (2010). Software survey:VOSviewer,a computer program for bibliometric mapping. *Scientometrics* 84 (2), 523–538. doi:10.1007/s11192-009-0146-3
- Wang, H., and Ge, Y. (2024). “Exploring worldwide research trends on fake news through a bibliometric and visual analysis,” in *2024 international conference on asian language processing (IALP)*, 13–18. doi:10.1109/IALP63756.2024.10661184
- Weber, A. M., and Trojan, J. (2018). The restorative value of the urban environment: a systematic review of the existing literature. *Environ. Health Insights* 12, 1178630218812805. doi:10.1177/1178630218812805
- White, E. V., and Gatersleben, B. (2011). Greenery on residential buildings: does it affect preferences and perceptions of beauty? *J. Environ. Psychol.* 31 (1), 89–98. doi:10.1016/j.jenvp.2010.11.002
- White, M., Smith, A., Humphries, K., Pahl, S., Snelling, D., and Depledge, M. (2010). Blue space: the importance of water for preference, affect, and restorativeness ratings of natural and built scenes. *J. Environ. Psychol.* 30 (3), 482–493. doi:10.1016/j.jenvp.2010.04.004
- Wu, K., Bryant, M., Toland, A., He, Y., and Chen, B. (2024). Regenerating tradition: empowering rural revitalization through Li culture and green infrastructure in a design case study of Yulong village, Hainan, China. *J. Chin. Archit. Urbanism* 6 (2), 1304. doi:10.36922/jcau.1304
- Xie, M., Mao, Y., and Yang, R. (2022). Flow experience and city identity in the restorative environment: a conceptual model and nature-based intervention. *Front. Public Health* 10, 1011890. doi:10.3389/fpubh.2022.1011890
- Yan, C., Li, H., Pu, R., Deeprasert, J., and Jotikasthira, N. (2022). Knowledge mapping of research data in China: a bibliometric study using visual analysis. *Libr. Hi Tech.* 42, 331–349. doi:10.1108/lht-11-2020-0285
- Yan, T., Leng, H., and Yuan, Z. (2024). Construction of the “Full Path” of restorative effects on older adults’ mental health in parks under seasonal differences: taking Changchun as an example. *Front. public health* 12, 1269249. doi:10.3389/fpubh.2024.1269249
- Zhang, X., Lin, E. S., Tan, P. Y., Qi, J., Ho, R., Sia, A., et al. (2024). Beyond just green: explaining and predicting restorative potential of urban landscapes using panorama-based metrics. *Landsc. Urban Plan.* 247, 105044. doi:10.1016/j.landurbplan.2024.105044
- Zhang, Y., Xiao, B., Al-Hussein, M., and Li, X. (2022). Prediction of human restorative experience for human-centered residential architecture design: a non-immersive VR-DOE-based machine learning method. *Automation Constr.* 136, 104189. doi:10.1016/j.autcon.2022.104189
- Zhao, J., Wu, J., and Wang, H. (2019). Characteristics of urban streets in relation to perceived restorativeness. *J. Expo. Sci. and Environ. Epidemiol.* 29 (11), 309–319. doi:10.1038/s41370-019-0188-4
- Zhu, C., Li, J., Luo, J., Li, X., Li, T., Wang, W., et al. (2024). An investigation of the restorative benefits of different spaces in an urban riverside greenway for college students—a simple autumn outdoor experiment. *Sustainability* 16 (18), 7968. doi:10.3390/su16187968