

BIBLIOMETRIC ANALYSIS OF OPERATING ROOM SUSTAINABILITY USING VISUAL MAPPING METHOD (2005-2025)

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Abstract. This study aims to comprehensively reveal the academic contributions, trends, and gaps of nurses and operating theatre nurses in the field of sustainability through a 20-year bibliometric analysis. In this bibliometric analysis, scientific articles published between 2005 and 2025 were scanned in the Web of Science database using the keyword “operating room sustainability”. Publication trends, citation networks, author collaborations, and global distributions were analysed bibliometrically using VOSviewer and Bibliometrix (R package). The findings obtained from this analysis were visualised and interpreted through graphs and tables. The analysis yielded 572 publications. A striking increase in publications at the intersection of nursing and sustainability has been observed over the past two decades. Research has particularly focused on energy efficiency, waste management, environmental awareness education, and the development of sustainable health policies. The greatest contributions were found to come from the USA, Canada, the UK, and Australia, with rising momentum observed in Turkey and some European countries. Collaboration networks indicate a rapid increase in multidisciplinary and systems-focused studies. Nurses are no longer merely caregivers but also advocates for planetary health. To strengthen this leadership role, practice-based research, policy innovation, and the integration of sustainability topics into nursing education are required. The findings from this bibliometric review provide a roadmap for building greener hospitals, resilient health systems, and a healthy planet.

Keywords: *operating room nurse, surgical sustainability, public and environmental health, carbon footprint, bibliometric analysis*

Introduction

Climate change, environmental pollution, and the depletion of natural resources necessitate the restructuring of health systems from a sustainability perspective, particularly requiring comprehensive changes in nursing practices and policies. In 2017, the World Health Organization defined environmentally sustainable health systems as those that improve health outcomes while minimizing negative environmental impacts and considering future generations (WHO, 2017). The nursing profession, being directly involved in patient care and forming the operational backbone of healthcare systems, emerges as a critical actor in achieving environmental sustainability goals (Luque-Alcaraz et al., 2022). A 20-year bibliometric analysis by Luque-Alcaraz and colleagues examined the relationship between nursing and sustainable healthcare systems, highlighting a significant academic momentum between 2017 and 2021, with the United States, the United Kingdom, and Sweden identified as leading countries in the field (Luque-Alcaraz et al., 2022). Nurses’ perceptions of sustainability are also evolving; multiple studies indicate that while nurses consider sustainability an ethical responsibility, they encounter challenges in translating it into practice due to clinical pressures (Zoromba et al., 2025; Luque-Alcaraz et al., 2024). This suggests that although nurses demonstrate a high level of awareness, systemic barriers impede its integration into daily practice.

Furthermore, leadership and organizational culture play a pivotal role in promoting sustainability, with prosocial leadership behaviors shown to enhance nurses' sustainability awareness through organizational culture (Atalla et al., 2024), demonstrating that effective leadership can drive attitudinal and behavioral transformation. Integrating sustainability into nursing education is a key strategy, and studies indicate a strong theoretical and behavioral link between nursing students' sustainability awareness and green purchasing intentions (Abdelrahman et al., 2025; Richardson et al., 2017). Operating theatre nurses, in particular, occupy a strategic position in reducing the environmental footprint of healthcare services due to their direct responsibility for surgical materials, energy consumption, and waste management (Flynn et al., 2025). Factors such as sterilization processes, control of single-use materials, waste segregation, and energy efficiency render operating theatres among the units with the highest environmental impact within healthcare institutions (Sherman et al., 2019). Evidence further suggests that educational interventions employing sustainability-focused scenarios significantly improve nurses' and midwives' knowledge and attitudes toward sustainability (Álvarez-Nieto et al., 2024). Consequently, nurses, particularly operating theatre nurses, are not only practitioners of sustainable healthcare systems but also effective advocates, leaders, and educators. However, to fully realize this potential, bibliometric trends, attitudes and perceptions, leadership approaches, educational interventions, and systemic barriers must be analyzed in detail. This study aims to comprehensively reveal the academic contributions, trends, and gaps of nurses and operating theatre nurses in the field of sustainability through a 20-year bibliometric analysis. The questions addressed in this study are as follows: (1) What is the distribution and trends of academic publications in the field of operating theatre nursing and sustainability over the last 20 years? (2) Which countries, institutions, and authors have published the most in the field of operating theatre nursing? (3) Which keyword clusters do the sub-themes of sustainability in operating room nursing (e.g., operating room practices, environmental impact reduction strategies, educational interventions) concentrate on? (4) Which studies and journals receive the most citations in operating room nursing?

Materials and Methods

This study is based on bibliometric analysis methods and performs systematic science mapping analyses using bibliometrix, one of the open-source R packages (Aria and Cuccurullo, 2017). The approach used is structured around defining research questions, data collection, defining analysis processes, and visualisation steps. For search strategy and study selection, the bibliometric properties of articles on sustainability in the operating room in the Web of Science (WOS) database were examined. This database is a critical resource for comprehensive studies in both nursing and sustainability. In eligibility criteria, a comprehensive review of the extant literature was conducted on 29 August 2025 using the keyword "operating room sustainability" in the Web of Science, resulting in the identification of 572 original English-language publications. The search was conducted without any time restrictions and covered all scientific categories. A comprehensive review of the extant literature was conducted, with studies identified from 2005 to 2025. Following a thorough scanning process, the studies were categorised as research and review articles.

In data synthesis and statistical analysis, Bibliometrix (R Studio package) was used to analyse bibliometric data to determine publication trends, citation analyses, and geographical distribution (Aria and Cuccurullo, 2017). VOSviewer (version 1.6.19) was used in the mapping processes of author, country, and keyword networks. Visualisation of similarities (VOS) can present large bibliometric maps in a user-friendly manner; it provides detailed analysis capabilities with scaling, zooming, panning, and search functions (Van Eck and Waltman, 2010). Data structures obtained with Bibliometrix (e.g., co-citation and co-authorship networks) were visualised using VOSviewer. The software created distance-based maps using its technique. Validity was strengthened by having two independent researchers review the data collection and analysis stages (Cobo et al., 2011; Van Eck and Waltman, 2007). As the present study was conducted using bibliometric analysis, ethical committee approval is not required.

Results and Discussion

The findings obtained from the study are presented below. *Figure 1* shows that the authors with the highest number of citations in the field of operating theatre nursing and sustainability between 2005 and 2025 have shaped the research agenda in this field. Each dot in the graph represents an author. The size of the dots is indicative of the number of citations received by the author, whilst the colour of the circles signifies the authorship of work on similar topics. The lines between the circles indicate the co-citation relationship between the authors. The high citation density of authors at the center of the network indicates that these names are decisive in methodological frameworks and conceptual discussions. Accordingly; it is noteworthy that authors Bilec, melissa m. (n=297) and van der Eijk, Anne c (n=41) form the core of the network by establishing numerous connections with other researchers. In the analysis conducted with keywords in the VOSviewer programme, author keywords were used. Each dot in the graph represents a keyword. The size of the dots is indicative of the frequency with which the keyword is repeated in the article, whilst the colours of the circles represent clusters (thematic groups) created based on the keywords' associations. The lines between the circles indicate when two keywords appear together in the same studies. When the threshold value in the co-occurrence network of keywords was set to 2 (at least two connections), 177 keywords were linked to each other, resulting in the image shown in *Figure 2*. Examining *Figure 2*, it can be seen that the most frequently used keywords are 'sustainability' with 98 connections, 'operating room' with 54 connections, and 'environmental sustainability' with 53 connections. These terms have strong connections with other sub-themes, e.g. 'climate change' with 49 connections and 'carbon footprint' with 42 connections. As a result, an analysis of 177 keywords that appeared at least twice and were related to each other identified a total of 19 clusters, 769 connections, and 1.110 connection strengths. This shows that studies focusing on sustainability relationships are becoming increasingly diverse but are concentrated on certain key themes.

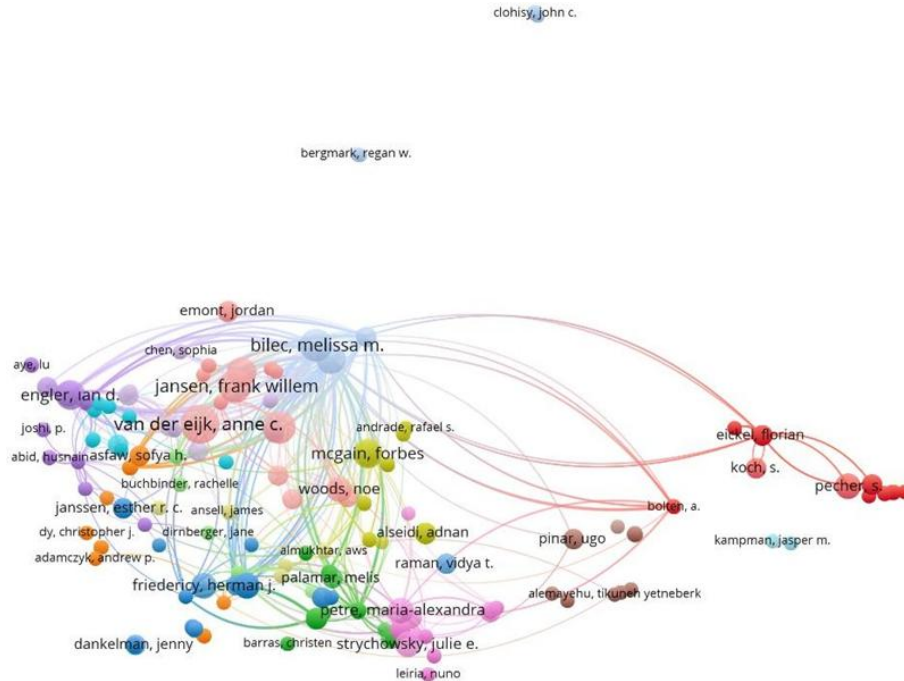


Figure 1. Author citation network (Visualisation via VOSviewer).

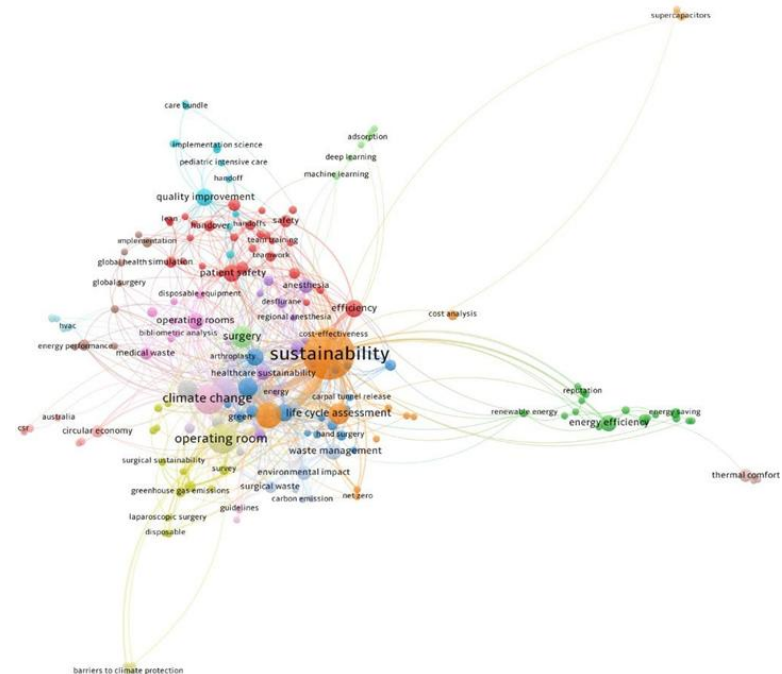


Figure 2. Keyword co-occurrence network (Displayed using VOSviewer).

The most frequently used words in the publications were analyzed using the Bibliometrix package of the RStudio programme. Each dot denotes the frequency with which a keyword is used. Larger dots represent words that are more frequently used in the literature, that is, words that are centrally located. The colour of the dot (light blue, dark blue, or navy blue) serves to highlight relative density; darker colours generally indicate more frequently used keywords. *Figure 3* shows that the top 10 most frequently used words in the dataset had a total usage of 586, representing 75% of the main themes

in the studies. The term "sustainability" is prominent in the field, with 150 publications, positioning it as the most significant source in this area. As indicated by the data, the next term is "impact" with 68 publications, followed by the term "carbon footprint" with 64 publications and "surgery" with 58 publications. Each dot denotes a country. The size of the dot is proportional to the number of publications or citations received by the respective country. The placement of a given nation on the map is determined by the degree of collaboration it exhibits with other countries. Nations that demonstrate a high level of collaboration are positioned in close proximity on the map. The utilisation of analogous hues in the representation of countries signifies the intensity of collaborative endeavours or the congruence of research interests among nations. The lines between the circles indicate instances of collaboration or co-authorship between the countries in question. The thickness of the line is proportional to the strength of the collaboration, as indicated by the number of joint publications. *Figure 4* shows that the United States, the United Kingdom and Sweden are leading in this field, with publication and citation intensity centered in these countries. It was determined that the international collaboration network is particularly concentrated in European-centered clusters, but Asian and South American countries are represented more limitedly in the network. This finding indicates that research activities in this field are unevenly distributed regionally. It can be hypothesised that the observed variations in research output and funding are attributable to a number of factors, including research funding, academic infrastructure, international collaborations, and the representation of academic journals in global scholarly communications.

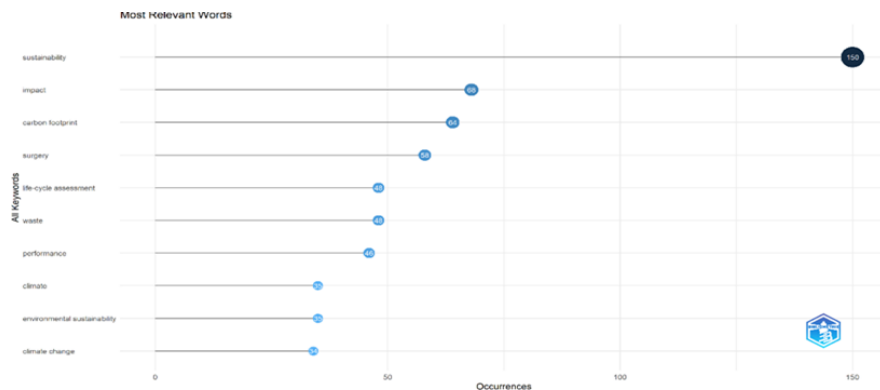


Figure 3. Most frequently used words (Displayed with Bibliometrix).

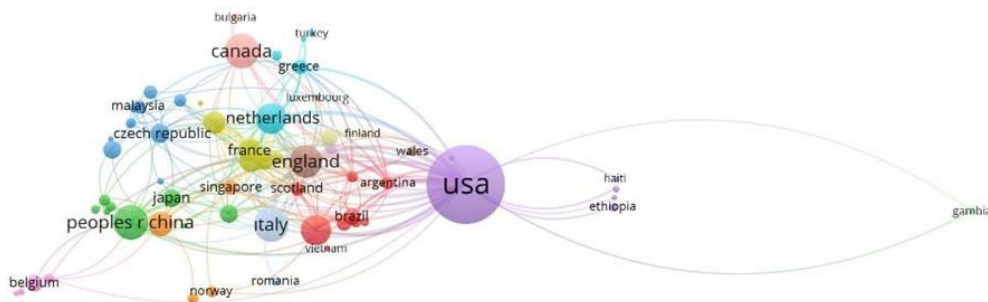


Figure 4. Country citation network (Displayed with VOSviewer).

Upon examining *Figure 5*, it is observed that the top five institutions produced a total of 135 publications. Each dot represents an institution (university, research centre, etc.). The size of the dot is indicative of the weight of that institution in the collaboration

network (usually the number of publications or the strength of its connections). Institutions of the same colour represent subgroups characterised by relatively more intensive collaboration. Lines indicate instances of co-authorship or collaboration between two institutions. The thickness of the line is indicative of the strength of the relationship (for example, the greater the number of articles shared between two institutions, the thicker the line). Leiden University, with $n=30$, was identified as the institution with the most relevant connections, located at the center of the network and connected to three different clusters. It was observed that Pittsburgh University, with $n=29$, and Toronto University, with $n=28$, followed. It was found that the 12 peripheral institutions were represented by only one publication and did not collaborate with other institutions. This finding highlights the need for stronger institutional partnerships in the field. *Figure 6* shows that while the average number of publications per year was 2 between 2005 and 2010, the minimum number of publications rose to 11 after 2012. The number of articles peaked in 2024 with 105 publications. This increase indicates growing academic interest in the field and greater visibility in the literature.



Figure 5. Institutional collaboration network (Displayed using VOSviewer).

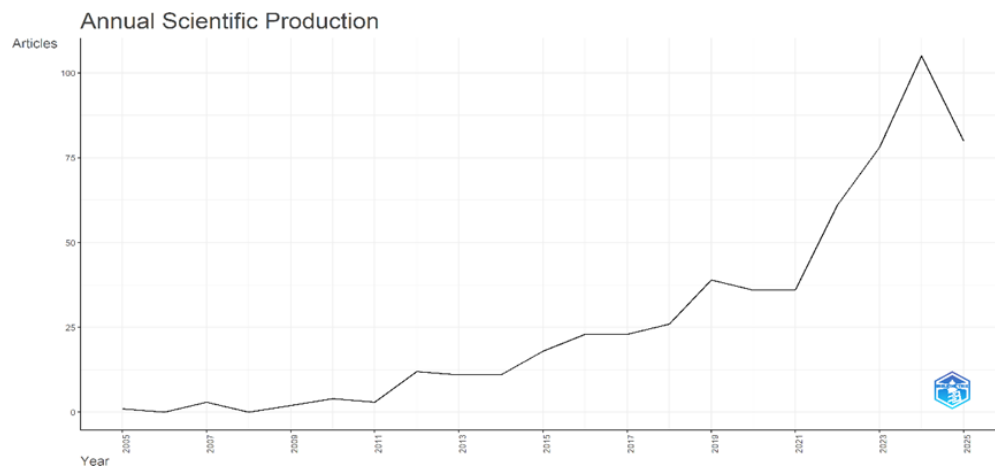


Figure 6. Annual article growth trend (Displayed with Bibliomterix).

Figure 7 shows the annual average citation increase trend for studies (articles) related to the topic of 'operating room sustainability'. The highest average number of citations per publication was 12.4 in 2014. It is evident that studies in the field of sustainability were given significant importance in 2014. The most cited sources on operating room sustainability were analysed using the R Studio programme and are presented in *Figure 8*. Each dot in the graph represents a journal. The size of the dot is proportional to the number of citations received by the journal (indicating that a journal with a higher number of citations will have a larger bubble). The colour of the dot (light blue, dark blue, or navy blue) serves to highlight the relative density; darker colours generally indicate more cited sources. Examining *Figure 8*, it can be seen that the top three most cited sources are Anesthesia & Analgesia ($n=433$), Journal of Cleaner Production ($n=353$) and Energy and Buildings ($n=265$). The top three journals account for 3.81% of total citations (1.051/27.594). The prominence of these journals,

particularly in the fields of clinical practice and environmental sustainability, highlights the interdisciplinary nature of the operating theatre nursing and sustainability literature.

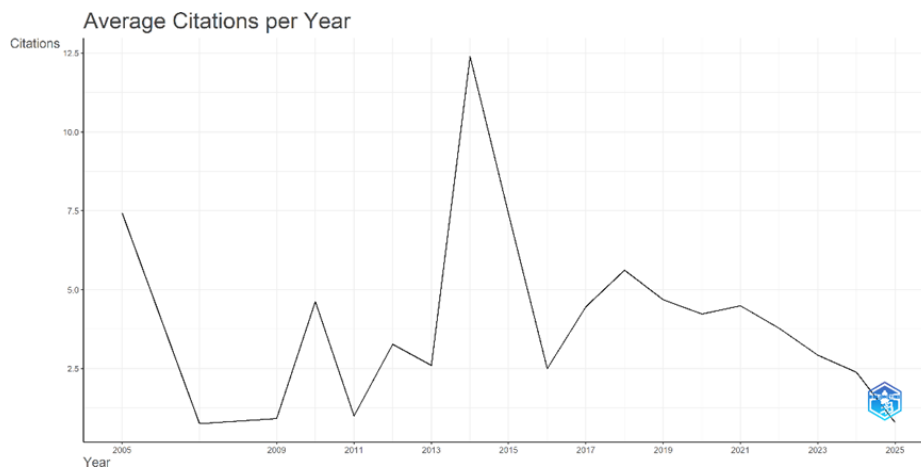


Figure 7. Annual average citation growth trend (Bibliometrics Display).

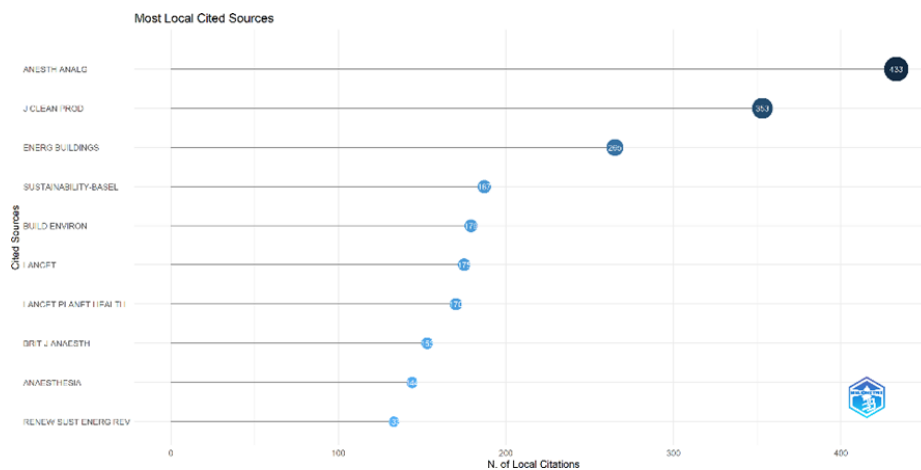


Figure 8. Most cited sources (Displayed with Bibliomterix).

González-Pizarro et al. (2023) showed that survey results among global healthcare professionals indicated low awareness of the carbon impact of inhalation gases. Nurses are key actors in environmentally responsible practices (Akbulut and Özsoy, 2025; Asfaw et al., 2021). However, our findings suggest that although sustainable nursing practices are represented in the academic field, they are still concentrated around certain researchers and opportunities for interdisciplinary interaction are limited. Between 2005 and 2025, the literature on operating theatre nursing and sustainability has undergone a significant evolution in identifying strategies to reduce environmental impacts. The increase in the number of publications after 2012 and the high citation intensity in 2014 (12.4 citations/article) indicate an increase in academic visibility on sustainability issues. These findings are consistent with the increased interest in sustainable operating theatre practices in research conducted after 2020 (Akbulut and Özsoy, 2025). Network analyses reveal that authors such as Melissa M. Bilec and Anne C. van der Eijk have high citation densities and shape the research agenda in the field. The work of Bilec et al. (2018) details strategies for reducing the carbon footprint of anesthetic gases and materials used in laparoscopic surgical procedures. This research pioneered the concrete identification of environmental sustainability strategies in operating theatre practices

and provided a methodological framework for other researchers (Bilec et al., 2018). The Healthcare Sustainability Mode and Effect Analysis (HSMEA) method developed by De Ridder et al. (2022) aims to systematically increase sustainability in operating theatres. This approach complements the work of Bilec and colleagues by focusing on optimizing waste management and resource use in surgical processes.

The HSMEA method provides a concrete tool for reducing the environmental impact of operating theatre practices and encourages interdisciplinary collaboration (De Ridder et al., 2022). According to recent publications, there is methodological diversity and a lack of implementation in environmental sustainability studies in operating theatres. Similarly, the study by Klarenbeek et al. (2025) evaluated waste production and carbon footprint by applying the HSMEA method in orthopedic surgical procedures. This study is important in demonstrating the adaptability of sustainability methods to different surgical fields. In particular, it reveals that the strategies implemented by operating theatre nurses and other healthcare professionals to reduce environmental impacts can be expanded and optimized (Klarenbeek et al., 2025). Akbulut and Özsoy (2025) evaluated 98 studies between 2009 and 2024 in their bibliometric analysis and emphasized that the issue of carbon footprint in operating theatres is gaining momentum. González-Pizarro et al. (2023) showed that survey results among global anesthesia clinicians indicated low awareness of the carbon impact of inhalation gases. Asfaw et al. (2021s) propose feasible strategies for energy efficiency and waste management in operating theatres. Another important dimension supporting these methodological developments is the perception and practices of operating theatre nurses regarding sustainability. In a study conducted in Norway, both nurse anesthetists and operating theatre nurses perceived sustainability as an individual and organizational responsibility, emphasizing the need for recycling and education (Flynn et al., 2025). These findings offer a complementary perspective, demonstrating that internal practices must be supported not only by technical but also by behavioral and education-based strategies (Almukhtar et al., 2024). Furthermore, a qualitative study conducted in Finland revealed that perioperative nurses have a weak understanding of sustainability principles; while economic and ecological perspectives are considered in decision-making, social and cultural dimensions are not sufficiently integrated (Leppänen et al., 2022). According to the data obtained from the country network analysis, the prominence of countries such as the United States, the United Kingdom, and Sweden indicates that the field is concentrated in Western-centric literature. However, the environmental impacts of operating theatres are critically important in developing countries (González-Pizarro et al., 2023). Therefore, research from Asia, Africa, and Latin America should be encouraged. This is because sustainability and operating theatre nursing are interdisciplinary fields; this is evidenced by the frequent publication of articles in this field in engineering-focused journals such as the *Journal of Cleaner Production* and *Energy and Buildings*, as well as clinical journals such as *Anesthesia & Analgesia* (Asfaw et al., 2021).

Due to language limitations, only including English publications is a limitation of the study and there is a risk of some regional studies being overlooked. Another limitation of the study is that since Web of Science was chosen as the database, studies indexed outside of this site are excluded from the scope. The key strengths of this study are that it is the first sustainability analysis study conducted in the field of operating room nursing. Another key strength is the use of a cutting-edge data analysis technique (bibliometric) that is fully up-to-date. By analysing a large dataset spanning decades,

this study effectively identifies historical trends and key contributions. This approach can ensure that nurses consider environmental sustainability in their daily practice. In this regard, the findings of the bibliometric review provide a concrete roadmap for the future of a healthy planet. The comprehensive approach adopted will also pave the way for a healthier and more environmentally sustainable global environment. This integration will enable nurses to combine their professional knowledge and skills with strategies aimed at solving global environmental problems.

Conclusion

This study examined publications focusing on sustainability in operating theatres and included in the Web of Science database through a bibliometric analysis. The findings obtained from this analysis were visualized and interpreted through graphs and tables. The results of the research show that nurses have now moved beyond their traditional roles to become advocates not only for patients but also for the health of the planet. This transformative leadership role is critically important for the sustainability of healthcare services. To effectively fulfil this new mission, steps such as practice-based research, policy innovation, and the integration of sustainability issues into nursing education are required. This approach can ensure that nurses consider environmental sustainability in their daily practice. In this regard, the findings of the bibliometric review provide a concrete roadmap for the future of a healthy planet. This integration will enable nurses to combine their professional knowledge and skills with strategies aimed at solving global environmental problems.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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