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Addressing of Global Environmental Problems and the Solutions: A Bibliometric Analysis

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ABSTRACT

Environmental problems and their solutions demand a holistic approach to address key challenges effectively. Previous studies have included reviews but lacked bibliometric analysis. This study bridges the gap by conducting a bibliometric analysis of research on "environmental problems and their solutions" using data from the Scopus database. Applying the PRISMA method, 39 articles were selected from an initial 353 documents. Analytical tools like Scopus, VOSviewer, and RStudio were utilized to visualize bibliometric relationships, temporal trends, collaboration patterns, and key themes. Research distribution from 1990 to 2023 fluctuated, with notable peaks in certain years. The United States leads global contributions, followed by Russia, Germany, and Turkey. Strategic themes such as "environmental problems" and "water treatment" were prominent, while "energy resources" remained a developing theme. This study offers a strategic map for understanding environmental research landscapes, fostering global collaboration, and shaping future multidisciplinary research strategies focusing on energy transitions and sustainable innovations.

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INTRODUCTION

The world is facing an unprecedented set of environmental challenges, ranging from deforestation, water scarcity, pollution, and climate change (Shivanna, 2022; Wang & Azam, 2024). These problems are largely caused by humans, whose activities threaten ecosystems, biodiversity, and the health and well-being of people around the world. As the world's population continues to grow and industrial activity expands, pressures on natural resources and the environment are becoming increasingly urgent (Malhi et al., 2020; Tong et al., 2022; Weiskopf et al., 2020). This situation requires urgent action and effective interventions or appropriate solutions. These challenges are explicitly recognized in global sustainability frameworks such as the 2030 Agenda and the Sustainable Development Goals (SDGs), particularly SDGs 6 (clean water and sanitation), 7 (affordable and clean energy), 11 (sustainable cities and communities), 12 (responsible consumption and production), 13 (climate action), 14 (life below water), and 15 (life on land), which together articulate an internationally accepted vision of the environmental conditions that societies should strive to achieve.

Over the past few decades, environmental science, policy, and technology have advanced significantly. Scholars have focused their studies on environmental issues and offered solutions (new methods and tools) to address these issues (Afifa et al., 2024; Awewomom et al., 2024; Dwivedi et al., 2022; Shabir et al., 2023). They are oriented towards efforts to reduce environmental damage and promote sustainability efforts (Baidya & Saha, 2024; Cheng et al., 2023; Durrani et al., 2024; Gu, 2024; Li et al., 2022). Given the large number of studies conducted, it is important to understand the patterns, trends, and strategic directions of these academic efforts. In this context, ethnobiology and social–ecological systems research have played an important role by showing how traditional ecological knowledge, local belief systems, and community-based practices can be integrated with contemporary environmental management strategies to enhance resilience, adaptive capacity, and justice for indigenous and local communities (e.g., Berkes, 2012; Reyes-García et al., 2014; Folke, 2006). Such perspectives underscore that effective environmental solutions must be grounded not only in biophysical science and technology but also in culturally embedded knowledge, values, and institutions.

Bibliometric analysis offers a systematic approach to evaluating the development of research in a field, including identifying publication trends, key actors, global collaborations, and emerging topics. Using bibliometric analysis tools, researchers can describe the intellectual structure of the scientific literature and identify gaps that require further exploration. Therefore, bibliometric analysis becomes increasingly important to provide data-based insights into future research directions. This is particularly relevant for understanding how different knowledge traditions—such as ethnobiology and social–ecological systems thinking—are represented in the global literature, and how they intersect with broader sustainability agendas such as the SDGs and other international frameworks (e.g., the Paris Agreement, the Convention on Biological Diversity, and the Sendai Framework for Disaster Risk Reduction).

Several previous studies have used reviews to examine environmental and innovation issues. Based on a search in the Scopus database, 18 articles were found over the past six decades, namely since 1961 (Adami & Schiavon, 2021; Anastas et al., 1999; Chen, 1991; Conesa & Schulin, 2010; Greksa et al., 2024; Gurney, 1961; Haunschild, 2004; Hiney & Smith, 1998; Ladnorg & Brendl, 2002; Manulak, 2015; Oerther et al., 2024; Pavlovich Anisimov et al., 2015; Resnik et al., 2005; Sexton, 2000; Starzyk et al., 2023; Vasil'eva & Shabanova, 2017; Weis & De Falco, 2022; Williams & Rangel-Buitrago, 2019). However, there is no single article of bibliometric analysis or systematic literature review type. Although there have been several reviews, there are several major gaps that have not been fully answered. There has been no study that thoroughly explores the thematic content of the existing literature. Adequate analysis of global collaboration patterns and potential synergies between various stakeholders including funding is still lacking.

Moreover, they rarely examine how the literature connects environmental problems and their solutions with ethnobiological knowledge, social–ecological systems perspectives, and the global sustainability agenda embodied in the SDGs. Importantly, many studies also pay limited attention to the science–policy nexus—that is, the ways in which scientific evidence is translated (or fails to be translated) into policy design and implementation. Bridging this gap between science and policy is widely recognized as a critical condition for effectively addressing environmental issues, yet the extent to which this topic is reflected in the global research landscape on environmental problems and solutions remains poorly understood.

In light of these considerations, the research gap of this study can be stated explicitly as follows: to date, there has been no bibliometric study that systematically maps the global research landscape explicitly framed around "environmental problems and their solutions", while simultaneously situating this landscape within the broader contexts of ethnobiology and social–ecological systems, global sustainability frameworks such as the SDGs, and the science–policy nexus. Existing reviews tend to focus on specific sectors, technologies, or case studies, with limited exploration of global collaboration patterns, the roles of institutions and funders, and the strategic thematic structures that organize the field. This lack of an integrated, data-driven overview makes it difficult for researchers, educators, and policymakers to identify where research efforts are concentrated, which topics remain underexplored, and how different strands of work (e.g., technological, policy-oriented, ethnobiological, educational) might be more effectively connected.

This article aims to address that gap by conducting a comprehensive bibliometric analysis of research on the theme of "Environmental Problems and Solutions" using data from the Scopus database. Specifically, the study seeks to: (1) describe the temporal distribution and growth of publications; (2) analyze authorship, institutional affiliation, funding sponsors, country contributions, subject areas, and core journals; and (3) identify strategic themes, emerging topics, and dominant keywords that characterize this field. To make the analysis more coherent and integrated, the research questions are organized into several interrelated thematic clusters: (a) publication dynamics and collaboration networks; (b) subject areas, institutional and country contributions, and funding patterns; and (c) thematic structures and keyword trends. This thematic grouping is intended to facilitate a more holistic discussion of the findings and to clarify how the results relate to broader debates on ethnobiology and social–ecological systems, global sustainability frameworks such as the SDGs, and the science–policy interface in environmental governance. By doing so, this study is expected to provide data-based insights that can support more focused and impactful future research strategies.

The world is facing an unprecedented set of environmental challenges, ranging from deforestation, water scarcity, pollution, and climate change (Shivanna, 2022; Wang & Azam, 2024). These problems are largely caused by humans, whose activities threaten ecosystems, biodiversity, and the health and well-being of people around the world. As the world's population continues to grow and industrial activity expands, pressures on natural resources and the environment are becoming increasingly urgent (Malhi et al., 2020; Tong et al., 2022; Weiskopf et al., 2020). This situation requires urgent action and effective interventions or appropriate solutions.

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This article aims to conduct a comprehensive bibliometric analysis of research on the theme of "Environmental Problems and Solutions." This article makes important contributions in several ways, namely (1) by providing a comprehensive map of the research landscape in the field of environmental challenges and innovation, this article helps academics and policymakers understand the strategic direction needed; (2) in-depth analysis of global collaboration patterns and research themes can encourage more effective synergies between stakeholders; and (3) this article offers data-based insights that can be used to design more focused and relevant future research strategies.

RESEARCH METHODS

Research Questions (RQs)

To achieve the goal of identifying trends in research on environmental issues and solutions, we propose eight research questions (RQs) as follows: RQ 1: What is the distribution and growth rate of publications related to environmental issues and solutions? RQ 2: Who are the dominant authors in publications related to environmental issues and solutions? RQ 3: What is the picture of institutional affiliation in publications related to environmental issues and solutions? RQ 4: Which institutions lead or actively fund research and publications on environmental issues and solutions? RQ 5: Which countries are dominant in publications and what is the map of collaboration between countries on environmental issues and solutions? RQ 6: Which subject areas are dominant as starting points for researchers studying environmental issues? RQ 7: Which journals are the most relevant sources of publications on environmental issues and solutions? RQ 8: What are the most cited documents globally on environmental issues and solutions? RQ 9: What is the pattern of thematic maps in research on environmental issues and solutions? RQ 10: What are the trends of the most used keywords in research on environmental problems and their solutions?

To enhance the coherence of the analysis, these research questions are not treated as ten isolated items but are grouped into three interrelated thematic clusters: (1) publication dynamics and collaboration networks (RQ1 and RQ5); (2) authorship, institutional, country, funding, and subject-area patterns (RQ2–RQ4, RQ6, and RQ7); and (3) intellectual structure, thematic development, and keyword trends (RQ8–RQ10). This thematic clustering also guides the organization of the Results and Discussion section, allowing the findings to be presented and interpreted in a more integrated and holistic manner, and making it easier to relate the empirical patterns to broader debates on environmental governance and sustainability.

Article search and inclusion criteria

The search focused on the phrase "environmental+problems+solutions" in the search in "all fields", where the articles found were 353. This search was too broad, resulting in a relatively small number of articles. many articles. Therefore, the search was changed to a search in "title, abstract, and keywords" so that the number of articles found was much smaller, namely only 201 (article status 1991-2024). The search was carried out using an official subscription account belonging to the Universitas Muhammadiyah Malang. Data simulation used "Analyze search results" available in the Scopus system (RQ 1-RQ 6). To enrich the data and analysis, the data was exported to *CSV format (to visualize the data process with VOSviewer [RQ 10] and RStudio [RQ 7-RQ 9]) and *RIS (to be synchronized with Reference Manager [Mendeley]).

The search resulted in 353 articles, so these articles needed to be filtered to focus the analysis. We used the PRISMA Method in this inclusion and exclusion process (Page et al., 2021; Sohrabi

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et al., 2021). The order of inclusion and exclusion is shown in Figure 1. Final Results The result of this process was 39 articles that met the analysis criteria.

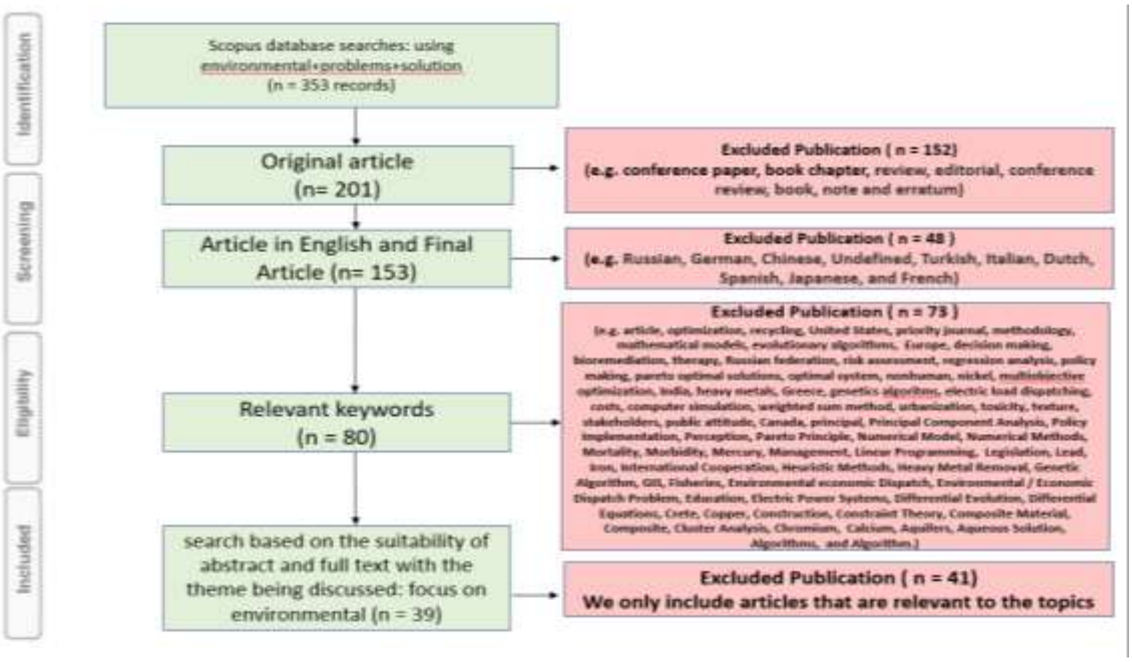

Figure 1. PRISMA flow diagram

Data Analysis Techniques

The data for this study were obtained from the Scopus database, which provides access to the latest scientific literature in various disciplines. The analysis process was carried out using a combination of tools including the Scopus built-in system, VOSviewer, and RStudio. The Scopus system was used to conduct initial data searches and extract relevant metadata. VOSviewer was used to visualize bibliometric relationships. RStudio was used for more in-depth data analysis, such as thematic clustering. This integrative approach ensures comprehensive, accurate, and reliable analysis results. The overall bibliometric workflow—covering performance analysis, science mapping, and visualization—follows widely used guidelines for bibliometric research and science mapping (Donthu et al., 2021; Aria & Cuccurullo, 2017), ensuring that the procedures adopted in this study are methodologically robust and comparable with other bibliometric studies.

RESEARCH RESULT

Temporal distribution (RQ 1)

Figure 2 shows the number of articles in the Scopus database, each year since 1990 (after exclusion and inclusion processes) until 2023. The data fluctuates over the years, with significant peaks in the number of documents occurring around 1993, 1996, 2011, 2014, and 2020. There are also years with no documents recorded, such as 1994, 1997, and 2012. This pattern does not imply irregular production or recording of documents over time, but it could be that the database does not receive articles that match the search.

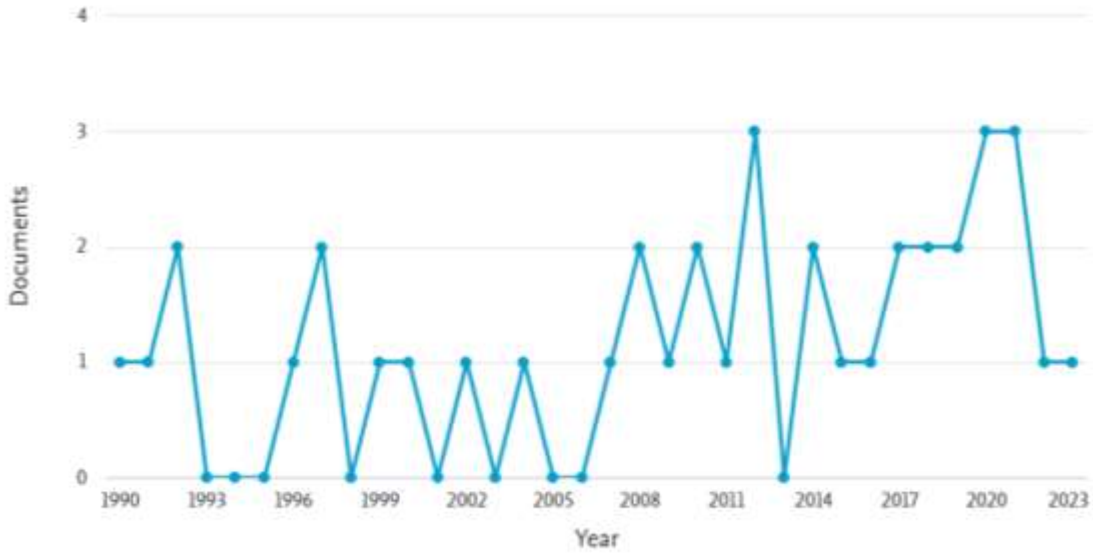

Figure 2. Documents by year

Figure 2, detailing the number of documents recorded each year from 1990 to 2023, offers a comprehensive view of documentation trends and fluctuations over three decades. Upon closer inspection, it is clear that the data reveal significant variability, with several distinct peaks and troughs marking the timeline. This variability suggests a complex relationship between the various external and internal factors that influence research and article publication.

The most notable peaks in document counts occurred in 1993, 1996, 2011, 2014, and 2020. Each of these years could represent periods of increased activity or initiatives that required extensive documentation efforts. For example, the spikes in 1993 and 1996 could have been caused by organizational changes, new projects, or external events that prompted increased research and publication needs as outputs. These years may have seen spikes in research, reporting, or regulatory requirements that forced researchers to create and archive more documents than usual.

Author contribution (RQ 2)

Figure 3 shows the number of documents written by 15 different people. Each bar represents an author, and the length of the bars indicates that all authors contributed roughly the same number of documents, one article each. The consistent length of the bars indicates little variation in contributions, indicating that they each participated in an equal capacity.

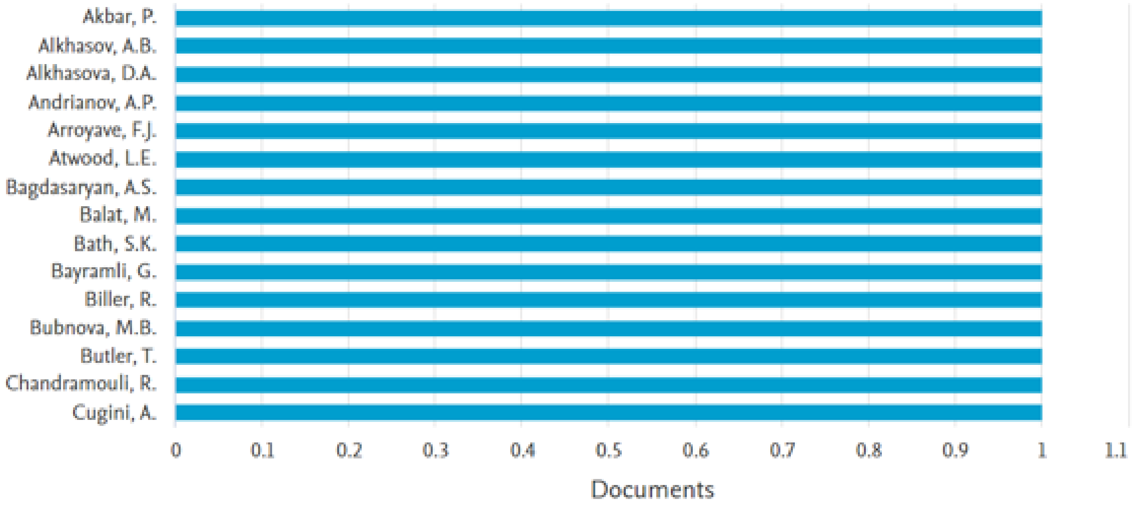

Figure 3. Author contributions

Institutional affiliation (RQ 3)

Figure 4 shows the number of documents contributed by different institutions. Pennsylvania State University and the Russian Academy of Science lead the way with the highest number of contributions of two articles. Other institutions, such as the International Technology Corporation, the Far East Forestry Research Institute, and the Pacific National University each contributed one document. This chart highlights the differences in research output, with some institutions contributing more than others.

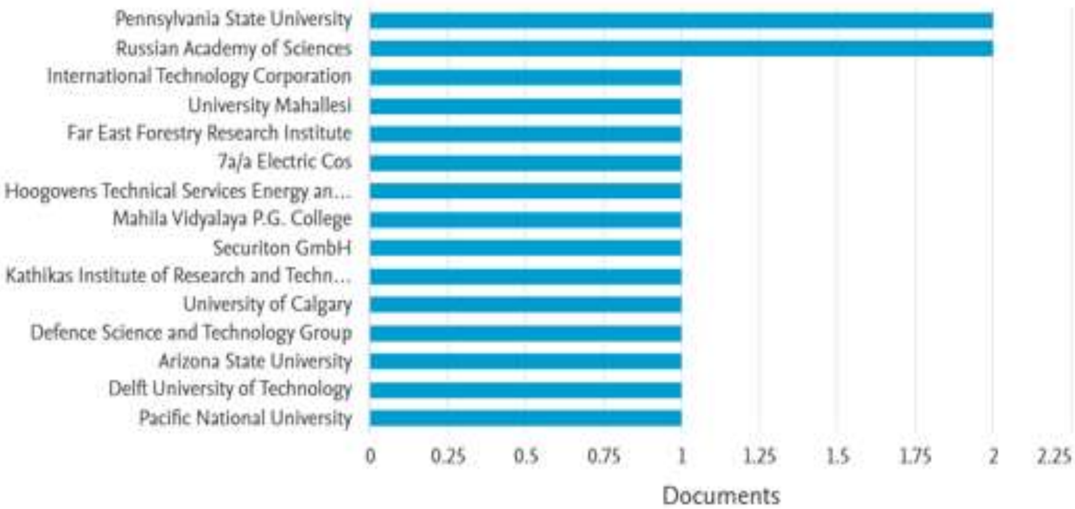

Figure 4. Institutional affiliation

Funding Sponsor (RQ 4)

Figure 5 shows the number of documents whose research to publication was supported by different funding sponsors. Institutions such as Brown University, College of Communication Pennsylvenia, Latvijas Zinates Padome, National Science Foundation, Pennsylvania Department of Environmental Protection, Russian Science Foundation, Seventh Framework Programme, Technische Universitat Chemnitz, and Univerte de Geneve contributed almost the same, no institution produced more than one document. This shows that there are only nine institutions that contribute funding to the theme of environmental problems and solutions.

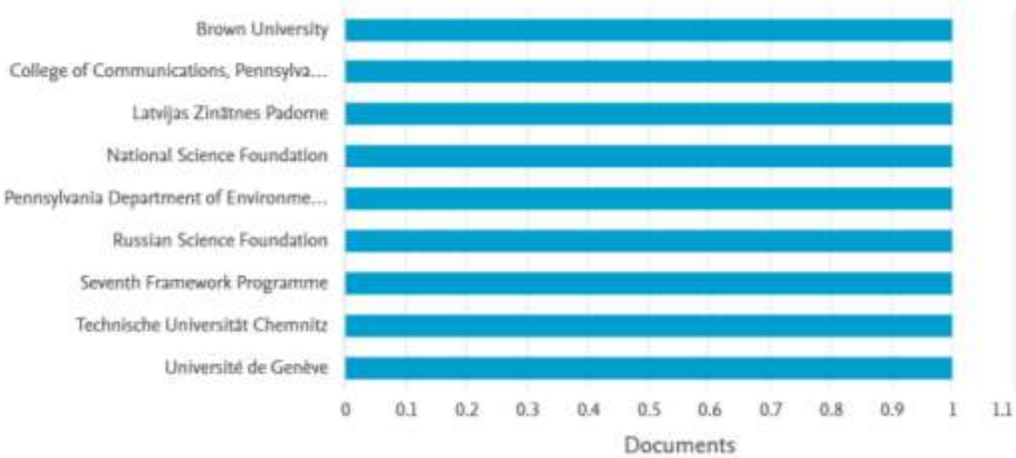

Figure 5. Funding Sponsor

Country of authorship and collaboration (RQ 5)

Country of origin of authors writing on environmental issues and solutions is presented in Figure 6, while an overview of collaborations focused on this theme is presented in Figure 7.

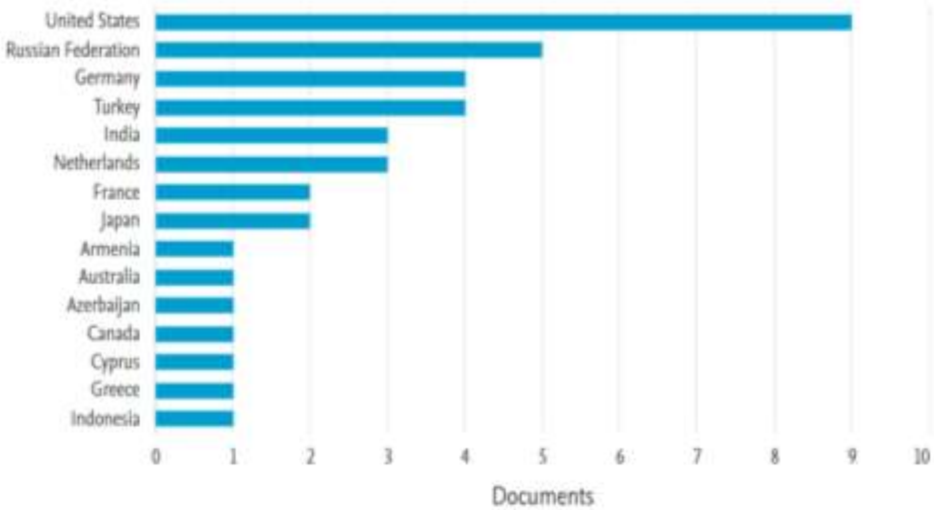

Figure 6. Country or region of author

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Figure 7. Country collaboration map

Figures 7 and Figure 8 provide an analysis of documents by country or region and collaboration patterns between countries. Both diagrams illustrate the geographical distribution of research contributions and collaborative efforts on a global scale. Figure 7 shows the number of documents produced by authors from different countries. The United States leads significantly, with a higher number of publications than any other country, with nine articles. This indicates a strong research output or contribution from the US, perhaps due to its extensive academic and research infrastructure. Following the United States are Russia (five articles), Germany and Turkey (four articles each), and India and the Netherlands (three articles each). Interestingly, following Japan and India, Indonesia contributes one article.

Subject area (RQ 6)

Figure 8 shows the percentage of subject areas of documents published in Scopus. The largest area is “Social Sciences” at 20.0%, followed by “Engineering” at 12.9%, and “Others” at 17.1%. Areas such as “Energy” (8.6%), “Environmental Sciences” and “Chemical Engineering” (both 7.1%) also have significant contributions to representation. Other areas, including “Business, Management,” “Arts and Humanities,” “Chemistry,” and “Earth and Planetary Sciences,” each have 5.7%. Finally, “Computer Science” has 4.3%. This chart highlights the diversity of research across these disciplines.

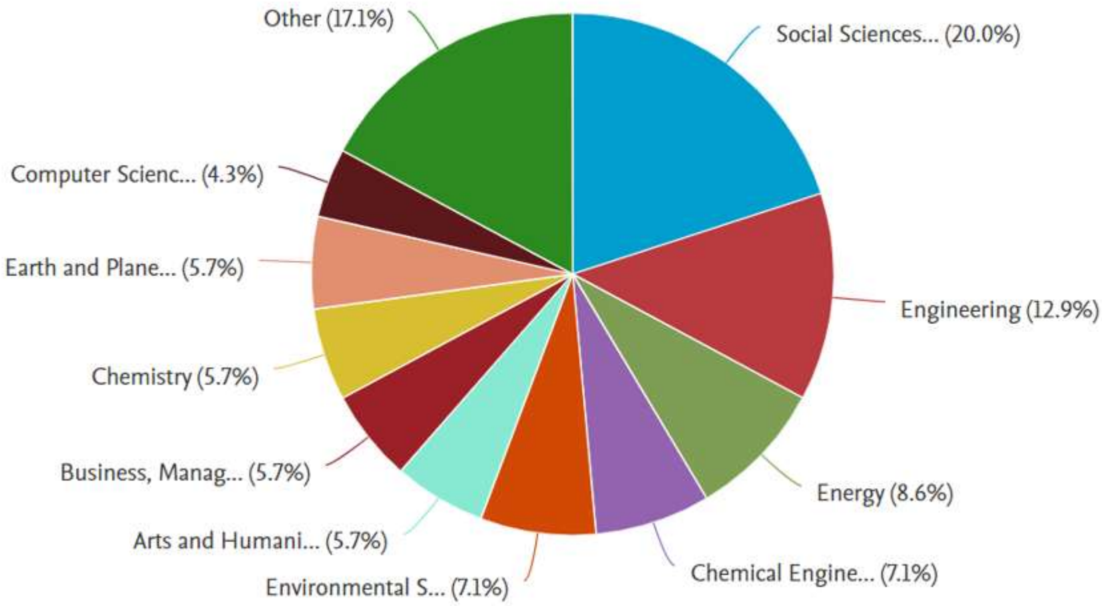

Figure 8. Subject area

Most Relevant Sources (RQ 7)

Figure 9 shows the most relevant sources based on the number of published documents. Two sources, the American Biology Teacher and the Journal of Biological Education, lead with two documents each. This shows the significant contribution of biology education in helping to solve environmental problems. Other sources, including the American Journal of Botany, Crop Protection, and Economic Botany, each contributed one document, highlighting a variety of disciplines such as plant science, education, and environmental studies. This diversity shows that research in this area is interdisciplinary, drawing on various fields to build comprehensive knowledge about environmental problems and their solutions.

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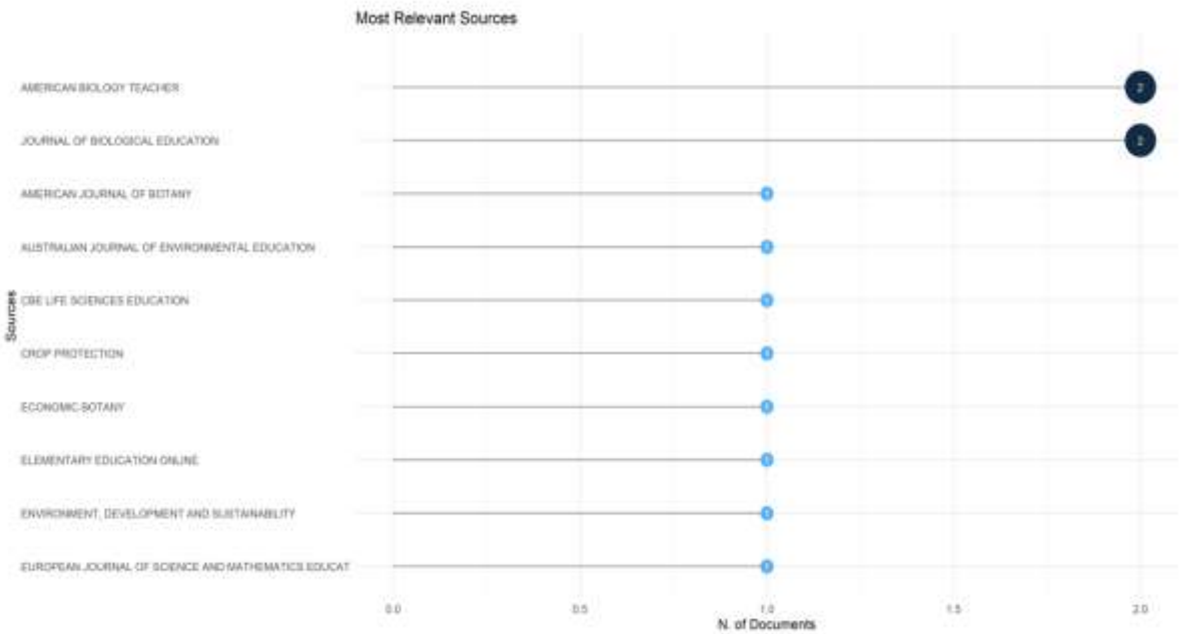

Figure 9. Most Relevant Sources

Most Cited Documents (RQ 8)

Figure 10 presents the data of the most cited documents globally. Based on Figure 11, it shows that the two most cited articles are "Zangori L, 2017" with 83 citations, followed by "Uno GE, 2009" with 75 citations. This highlights the international impact of these two studies. These two articles stand out because they discuss environmental issues with an innovative science-based educational approach, making them important references in the study of environmental education and solutions to ecological problems.

Viewed together, the patterns in Figures 3–10 suggest that a relatively small group of authors and institutions, located primarily in high-income countries, act as hubs in the global knowledge network on environmental problems and solutions, supported by a limited number of major funding agencies. This concentration of scholarly production in the Global North, combined with the predominance of subject areas such as environmental science, engineering, and education, points to a research landscape in which technological and pedagogical approaches are strongly represented, whereas contributions from institutions in highly vulnerable regions and from disciplines such as ethnobiology, social sciences, or indigenous studies remain comparatively marginal. Conceptually, this imbalance raises important questions about whose environmental

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problems and whose solutions are most visible in the literature and highlights the need for more inclusive and geographically diverse research collaborations.

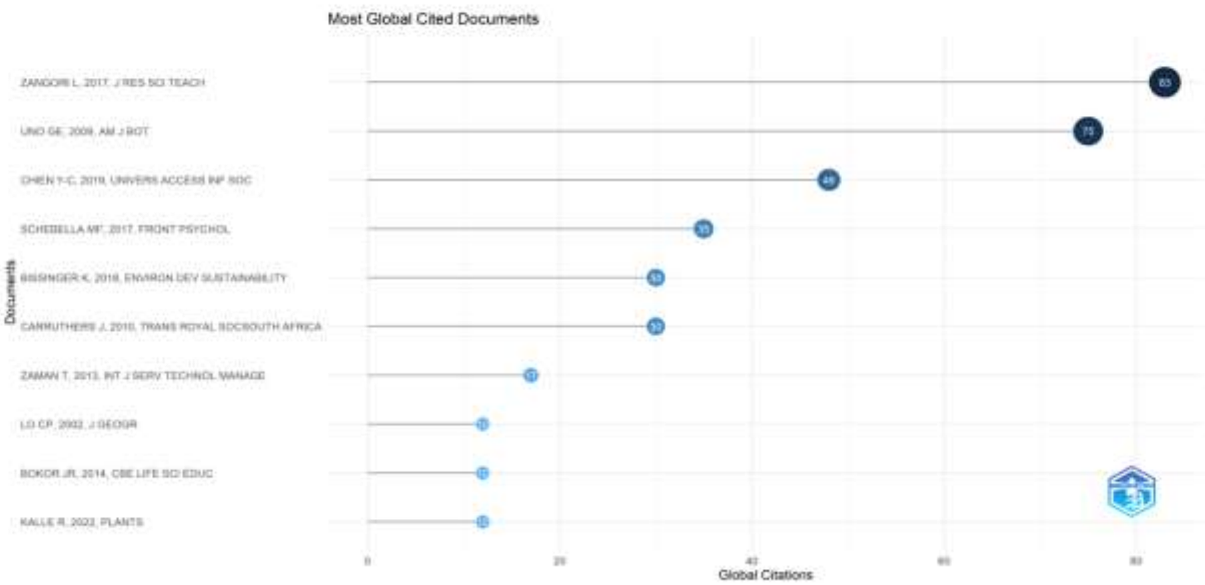

Figure 10. Most cited documents globally

Thematic maps (RQ 9)

Figure 11 shows the results of the R Studio simulation related to thematic maps. This map helps to visualize how a particular topic is developing, showing which areas are important and mature compared to others. The upper vertical axis (Relevance degree) places "environmental problems" and "water treatment" as topics that are at the point of combining Niche Themes and Motor Themes at once. In contrast, "energy resources" on the lower axis (Relevance degree) is placed as part of emerging or basic themes and declining themes at once.

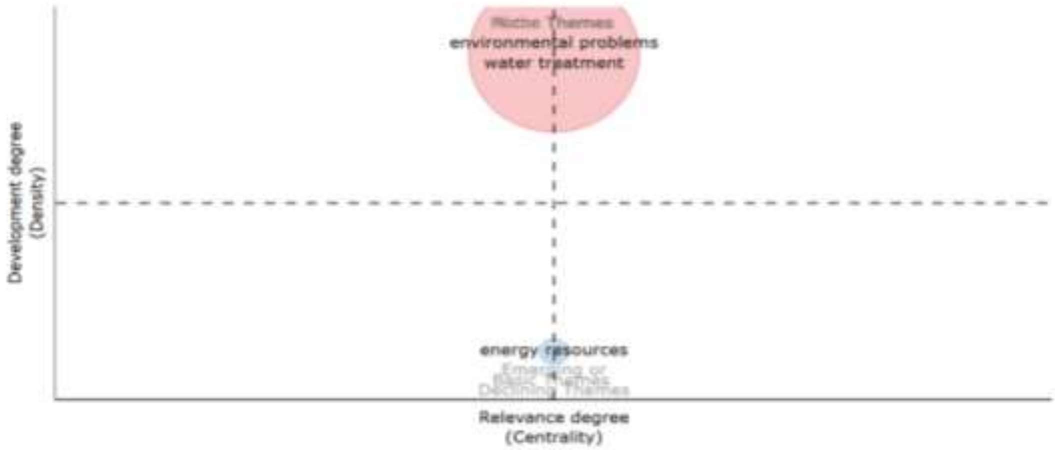

Figure 11. Thematic map

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Dominant keywords (RQ 10)

The dominant keywords in the study of environmental problems and solutions in the Scopus database are presented in the form of keyword co-occurrence simulation results from VOSviewer (Figure 12). There is a center on "energy resources" with a dense cluster of red nodes related to fossil fuels and traditional energy topics such as coal, natural gas, air pollution, and environmental benefits. The interconnected terms highlight the complexity and environmental challenges of conventional energy production. On the right, the green node labeled "agroforestry" is connected to "energy resources", indicating a relationship with sustainable practices, which is in contrast to the cluster that uses a lot of fossil fuels. This simulation likely emphasizes the balance between traditional energy sources and the transition to more environmentally friendly energy sources as a sustainable solution (Akpan & Kumba, 2024; Balat, 2005; Waldron et al., 2017).

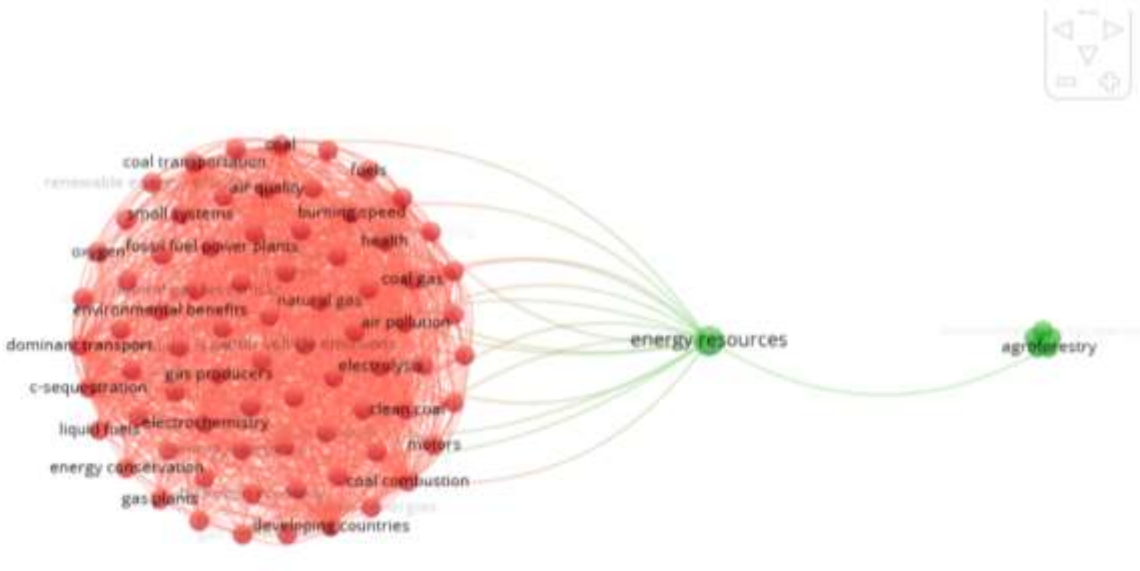

Figure 12. Keywords related to environmental problems and their solutions

On the left side of the figure, there is a large, dense cluster of red nodes representing terms such as "coal transportation," "air quality," "fossil fuel power generation," "natural gas," "air pollution," "environmental benefits," and "liquid fuel electrochemistry." This dense network of interconnections suggests that these topics are closely related to one another, perhaps indicating their interdependence or shared relevance in discussions about fossil fuels and nonrenewable energy sources. Terms such as "coal," "natural gas," "gas producers," "clean coal," and "energy conservation" hint at the broader debates surrounding traditional energy sources, their environmental impacts, and technological processes, such as electrolysis and gas feedstocks.

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Conceptually, the juxtaposition of these themes and keyword clusters shows that research on environmental problems and solutions is organized around two partially overlapping logics: a more "technological–infrastructural" logic that emphasizes engineered interventions in energy and water systems, and a more "ecological–landscape" logic that foregrounds land use, agroforestry, and ecosystem-based approaches. The relative prominence of the technological–infrastructural themes in the strategic quadrants of the thematic map suggests that techno-centric solutions currently dominate the field, whereas socially embedded, community-based, or ethnobiological approaches appear as emerging or peripheral. This pattern resonates with long-standing debates in environmental governance about the tension between top-down technological fixes and bottom-up, place-based solutions, and helps to explain why some types of solutions are more visible in the global literature than others.

From a conceptual perspective, these multi-level patterns—spanning temporal trends, actor constellations, funding structures, and thematic clusters—portray a field that is simultaneously expanding and uneven, with clear opportunities to better align scientific production with the environmental priorities and equity concerns articulated in global sustainability frameworks such as the SDGs.

DISCUSSION

Conversely, the peaks in 2011 and 2014 may reflect a resurgence of interest or activity in a particular sector, perhaps due to technological advances, policy changes, or the initiation of significant programs that required extensive documentation. In 2020 stands out as another peak year, likely influenced by global events such as the COVID-19 pandemic. This unprecedented situation forced many organizations to adapt quickly, necessitating increased research and publication on the health, safety, and environmental issues it created; often without adequate peer review. During the pandemic, many journals were free to publish articles on COVID-19 topics, across almost all subject areas. The dramatic circumstances of COVID-19 likely led to an increase in document production across sectors (Feigin et al., 2023; Filip et al., 2022; Hiscott et al., 2020; Kumar et al., 2021).

Conversely, the chart also shows specific years where no documents were recorded, most notably in 1994, 1997, and 2012. The absence of documents recorded in these years raises questions about the underlying reasons for this phenomenon. It may indicate periods of reduced activity, perhaps due to budget cuts, and changes in the focus of research policies. Another possibility is that there are gaps in data collection or reporting methodology, leading to inadvertent omissions in recorded data. These dormant years can have significant implications, highlighting potential vulnerabilities in system document management and the need for consistent record-keeping practices.

Overall, the patterns observed in the diagram underscore irregular production and perhaps indexing of articles over time. These inconsistencies may reflect complex dynamics at play within organizations and sectors that drive the need for documentation. Factors such as changes in leadership, changes in the regulatory landscape, technological advances, and external pressures—such as economic downturns or public health crises—can all contribute to fluctuations in document counts. Taken together, these temporal patterns suggest that research on environmental problems and their solutions does not grow in a simple linear fashion but tends to intensify around periods of heightened global attention—for example, major environmental disasters, high-profile international agreements, or shifts in global sustainability agendas. Conceptually, this indicates that knowledge production in this field is closely coupled with socio-political dynamics and crisis-driven funding cycles, which may help to explain why certain themes (such as water treatment or climate mitigation) receive surges of attention at specific times while other important issues remain comparatively underexplored.

In this particular chart, as in Figure 1, all authors listed, from "Akbar, P.," to "Cugini, A.," have authored or co-authored approximately the same number of documents, one article. This suggests a highly selective or specific dataset where each author's contribution is relatively equal, with no one being dominant. The consistent length of the bars also suggests there is little variation in the number of publications among these authors for the time period or dataset under consideration. Based on Figure 3, one might see the collaborative nature of the work, suggesting that each author has a comparable role in the research output, perhaps indicating a shared or evenly distributed contribution to knowledge production. Nevertheless, these 15 authors can be a reference recommendation in the study of environmental problems and their solutions.

This chart is important to understand the research output associated with this institution in a given dataset or time period, thus helping stakeholders or researchers quickly identify which institutions are the most productive in terms of research output. The variation in the length of the bars highlights the differences in the contribution of documents. The fact that Pennsylvania State University and the Russian Academy of Science produced slightly more articles suggests that they had a greater role in generating or leading the research effort for this particular study or project, while other institutions contributed less in comparison.

Figure 5 reflects the importance of funding from various sources, both from universities, governments, private institutions, and international foundations in the study of environmental problems and their solutions. Given that the countries of origin of the donor agencies are the US and Europe, it is important to encourage the involvement and attention of donor agencies from countries in South and North America, Asia, Australia-Oceania, and even Africa. The reason is clear because the study of environmental problems and their solutions is a global domain (Ayers, 2009; Cambaza et al., 2020; Onokwai & Matthews, 2022).

These countries have strong educational systems and research institutions that support scientific and academic output. In addition, the presence of countries such as the Netherlands, France, Japan and Australia highlights the diversity in research contributions, representing regions across continents. Countries listed with fewer documents, such as Armenia, Azerbaijan, Canada, Cyprus, Greece and Indonesia indicate lower levels of research output compared to developed countries. This could be due to a variety of factors, including the scale of research funding, the number of researchers, or areas of research focus that may not overlap with the research themes of this particular dataset. However, the representation of these countries underscores the global nature of research, with smaller or developing countries also contributing knowledge.

Turning to Figure 8, the country collaboration map offers insight into international collaboration by mapping connections between countries involved in collaborative research efforts. Lines connecting countries represent active partnerships, with the thickness or color of the lines potentially indicating the strength or frequency of collaboration. Based on Figure 8, the map shows significant collaborative relationships between the United States and other countries, reflecting the central role of the United States in the global network of research on environmental problems and solutions. This may stem from its leading research institutions and collaborations supported by large international grants and funding agencies (Matthews et al., 2020; Newman, 2024; Yao, 2021).

In addition to US-centered collaborations, other important relationships exist between countries in Europe, as well as between Europe and Asia. Such collaborations are common in fields where multinational research projects are encouraged, such as environmental studies, health research, and environmental technological innovation (Horta, 2022; Low, 2009). Cross-continental collaborations, particularly between Western countries and Asian countries and regions, are evidence of the increasing globalization of research, whereby the exchange of knowledge on environmental problems and solutions has transcended national and continental borders (Barrell & Hsu, 2019; Newman, 2024; Stephenson & Moller, 2009; Yao, 2021).

The combination of data from Figures 7 and 8 highlights not only the contributions of countries but also the interconnectedness of the global research community. The distribution of contributions by country reflects the research capacity, resources, and focus of each country in the region, while the collaboration map shows the networks of intellectual exchange and cooperation that are essential to addressing complex global problems (Matthews et al., 2020; Yao, 2021). For countries with fewer publications due to limited resources and funding, collaboration schemes provide a pathway to meaningful contributions through partnerships with institutions in research-intensive countries (Cerdeira et al., 2023; Costello & Zumla, 2000; Varshney et al., 2016). This collaborative approach allows for the transfer of expertise, resources, and innovation, driving scientific progress across disciplines, and even cultures, in addressing environmental issues.

Figure 8 offers a comprehensive view of how academic and research focus is distributed across fields, with a clear dominance in social sciences, engineering, and other fields. Environmental issues are complex issues that span multiple dimensions, and their approach requires multidisciplinary collaboration (Newman, 2024; Qiu et al., 2024). Studies in the social sciences can be used to understand human behavior, public policies, and social dynamics that influence environmental degradation or preservation (Gatersleben et al., 2014; Kormos et al., 2021). On the other hand, engineering provides technological solutions, such as the development of renewable energy, waste treatment, and environmentally friendly technologies (Elhadidy & Shaahid, 2009; Rathore & Panwar, 2023; Ryu, 2010). In addition, other fields such as economics play a role in creating incentive mechanisms for sustainability, while law focuses on strengthening environmental regulations (Ivanova, 2020; Rathore & Panwar, 2023). By integrating perspectives from these different fields, holistic and sustainable solutions can be designed to address environmental issues effectively.

The fact that the majority of journals (eight journals) listed have only one document in the chart may suggest that, while these sources are relevant, they are not the most dominant contributors to the literature in the specific research scope of this dataset. However, the inclusion of several journals from different fields suggests a cross-disciplinary approach to the research.

These journals cover a range of themes, such as botany, environmental education, agriculture, and mathematics and science education.

The presence of these sources suggests that researchers are drawing on a range of literature across a range of fields, rather than relying solely on one or two dominant journals. This is particularly relevant in areas related to environmental education and studies, where research benefits from insights drawn from a range of disciplines (Basile & White, 2000; Klaassen, 2018; Tan & So, 2019). This spread suggests that while certain sources are key contributors, a wide range of academic journals is essential to producing a comprehensive and comprehensive body of knowledge.

The first article (Zangori et al., 2017), has the highest citation rate on the theme of environmental problems and solutions in Scopus because this article combines an interdisciplinary approach to environmental education, focusing on the development of model-based reasoning in understanding the carbon cycle and climate change. This topic is very relevant to the global challenges of climate change, especially in educational contexts involving socio-scientific issues. This article also makes a significant contribution by providing a learning framework that allows students to integrate scientific understanding with social value-based decision making. Its main strengths are its direct relevance to environmental education teaching, application in the curriculum, and implications for building students' scientific literacy.

Meanwhile, the second article (Uno, 2009) was the second most cited due to the importance of botanical literacy in building environmental awareness. This article highlights the need to address plant blindness, which is the indifference to the important role of plants in the ecosystem, through learning that focuses on the function of plants in mitigating climate change and the carbon cycle. By focusing on how students should learn botany, this article emphasizes an innovative pedagogical approach to improving environmental literacy broadly. Its strength lies in its influence on the design of a more inclusive and ecologically based curriculum, as well as its role in building awareness of the importance of plant conservation.

The topics of environmental problems and water treatment are at the intersection of Niche Themes and Motor Themes, indicating that although these topics are specific and concentrated (niche), they are also the main drivers of environmental research. This means that research in this area not only has a significant impact on the development of science but is also relevant to pressing global problems. Environmental problems cover broad and strategic issues, such as pollution, deforestation, and climate change, while water treatment is more specific but still plays an important role in solving global problems, such as clean water treatment amidst the water resource crisis (Arnell et al., 2015; Evans-Agnew & Aguilera, 2023; Khaine & Woo, 2015; Sivakumar, 2011).

The topic of energy resources is at the bottom axis of the intersection of Emerging or Basic Themes and Declining Themes, indicating that although this topic is fundamental, the relevance of research in this area may be declining for several reasons. One of them is the shift in research focus from traditional energy sources to more specific topics, such as renewable energy or energy efficiency (Altın, 2024; Dong et al., 2024; Meliani et al., 2021; Ukoba et al., 2024).

However, because it remains in the Emerging or Basic Themes area, energy resources also reflect an important basis for the development of new themes, especially in energy technology innovation. The thematic map as presented in Figure 13 shows the dynamics of research in environmental issues, with environmental problems and water treatment as strategic areas that drive scientific discourse and solutions. Meanwhile, energy resources reflect a shift in focus from basic themes to more focused or specific research areas (Alshami et al., 2024).

The green node labeled "agroforestry" is positioned further out from the dense red network, connected by a thinner line to the "energy resources" node. Agroforestry, a sustainable land management practice that combines agriculture and forestry, emerges as an alternative or contrasting concept to the highly industrialized and fossil fuel-dependent topics in the red cluster. Its placement demonstrates the potential relationship between energy resources and sustainable land use, highlighting the broader perspective of environmental conservation considerations in the energy sector (Barrios et al., 2018; Octavia et al., 2023; Zeratsion et al., 2024).

The simulation illustrates the complexity of energy resource management, balancing conventional reliance on fossil fuels with cleaner, more sustainable practices. The red cluster shows the various factors related to traditional energy production, ranging from environmental concerns (such as air pollution and health impacts) to technical aspects (such as electrochemical and Meanwhile, the green cluster with "agroforestry" shows the shift towards renewable energy or nature-based solutions.

The visual representation of VOSviewer illustrates the complexity of the research network related to energy production, consumption and sustainability, which is still dominated by old energy paradigms, such as fossil fuels. This dominance reflects the global dependence on non-renewable resources, both in terms of infrastructure and political-economic dynamics, such as countries' dependence on oil and coal (Bookbinder, 2024; Odell, 2000). The close relationship between fossil fuels and environmental issues, such as climate change and pollution, shows that this paradigm has a broad impact on the global ecosystem. In this network, fossil fuels appear at the center of many problems, illustrating how difficult the transition to a more environmentally friendly energy system is due to the multidimensional interconnectedness of technology, policy and social behavior (Azubuike et al., 2024; Knuth et al., 2022; Miller et al., 2013; Piggot et al., 2020).

However, this map also shows the emergence of new practices, such as agroforestry, which are starting to become part of the global conversation on energy sustainability. Agroforestry offers nature-based solutions by utilizing plants and trees as part of a production system that can sequester carbon, provide bioenergy feedstock, and increase land productivity ecologically (Barbosa-Evaristo et al., 2018; Gebrewahid & Meressa, 2020; Monckton & Mendham, 2022; Zeratsion et al., 2024). Although still in its early stages of adoption, the practice represents a paradigm shift toward more sustainable solutions. This representation helps map how the transition from the old paradigm to the new paradigm requires a systemic approach, significant investment, and multidisciplinary collaboration to integrate innovative practices such as agroforestry into the global energy system.

To synthesize these findings more clearly, the discussion can be organized around three interrelated thematic clusters: (1) publication dynamics and collaboration networks; (2) authorship, institutional, country, funding, subject-area and journal patterns; and (3) thematic structures and keyword trends. Organizing the discussion in this way allows the results to be interpreted in a more integrated and holistic manner, and clarifies how they respond to the research questions formulated in this study.

First, from the perspective of publication dynamics and collaboration networks, the fluctuating yet overall increasing trend of publications suggests that research on environmental problems and their solutions tends to intensify during periods of heightened global concern. Peaks in publication output often coincide with major environmental crises, international agreements, or shifts in global sustainability agendas, indicating that knowledge production in this field is closely coupled with socio-political dynamics and crisis-driven funding cycles. At the same time, the existence of years with very few or no documents that fit the search criteria implies that certain issues may temporarily fall out of focus, raising questions about the continuity and long-term consolidation of knowledge in this domain.

Second, the patterns of authorship, institutional affiliation, country contributions, funding sponsors, subject areas, and core journals collectively point to a research landscape that is both expanding and uneven. A relatively small group of authors and institutions—concentrated primarily in high-income countries—acts as hubs in the global knowledge network on environmental problems and solutions, supported by a limited number of major funding agencies. Environmental science, engineering, and education dominate the subject-area profile, reflecting a strong emphasis on technological and pedagogical approaches. However, the relatively modest contribution from institutions in highly vulnerable regions, and from disciplines such as ethnobiology, social sciences, and indigenous or local knowledge studies, suggests that the voices and priorities of communities most affected by environmental degradation are still under-represented. Conceptually, this imbalance raises the question of "whose environmental problems" and "whose solutions" are most visible in the literature and underscores the importance of fostering more inclusive and geographically diverse collaborations.

Third, the thematic maps and keyword analyses reveal how research on environmental problems and solutions is organized around several key themes. One cluster reflects a more technological–infrastructural logic, focusing on energy systems, water treatment, and engineered interventions, while another cluster reflects a more ecological–landscape logic, emphasizing land use, agroforestry, and ecosystem-based or nature-based solutions. The prominence of technological themes in the strategic quadrants of the thematic map suggests that techno-centric solutions currently dominate the field, whereas socially embedded, community-based, and ethnobiological approaches tend to appear as emerging or peripheral. This configuration resonates with long-standing debates in environmental governance concerning the tension between top-down technological fixes and bottom-up, place-based solutions, and highlights the need to better integrate local and indigenous knowledge systems into mainstream research agendas.

These thematic patterns are also closely related to the broader sustainability agenda embodied in the 2030 Agenda and the Sustainable Development Goals (SDGs). Clusters related to water treatment, energy transitions, and ecosystem management align strongly with SDGs 6, 7, 13, 14, and 15, indicating that much of the global research effort is oriented toward clean water and sanitation, affordable and clean energy, climate action, and the protection of terrestrial and marine ecosystems. However, the relatively limited visibility of themes related to governance, participation, equity, and traditional knowledge suggests that important dimensions of SDGs 10 (reduced inequalities), 11 (sustainable cities and communities), and 16 (peace, justice, and strong institutions) are not yet fully integrated into the bibliometric core of this field. Strengthening these linkages would help align scientific production more closely with the holistic and interdependent nature of the SDGs.

Furthermore, the findings shed light on the science–policy nexus in environmental governance. The dominance of articles that focus on technical solutions for energy and water, combined with the relatively small number of publications that explicitly address policy design, institutional arrangements, or multi-level governance, suggests that the translation of scientific evidence into policy remains a critical challenge. While some highly cited documents provide important conceptual and empirical foundations for linking environmental science with policy, the overall pattern indicates that more systematic work is needed to bridge the gap between researchers and policymakers. Expanding research that explicitly examines policy processes, co-production of knowledge, and boundary organizations could help ensure that scientific insights into environmental problems and their solutions are more effectively incorporated into decision-making.

Taken together, organizing the discussion around these key themes—(1) publication dynamics and collaboration networks, (2) authorship, institutional, country, funding, subject-area and journal patterns, and (3) thematic structures and keyword trends—provides a clearer and more coherent narrative of the field. This thematic structure also helps to highlight the connections between different findings and how they contribute to the overall research questions, while linking the bibliometric patterns to broader debates on ethnobiology and social–ecological systems, global sustainability frameworks such as the SDGs, and the science–policy interface. In doing so, the discussion offers a holistic view of the implications of the study and identifies concrete directions for future research, including the need to amplify contributions from the Global South, to better integrate traditional and local knowledge, and to strengthen institutional linkages between science and policy in addressing environmental problems and their solutions.

CONCLUSION

This bibliometric analysis provides important insights into research on environmental issues and their solutions based on Scopus data. The temporal distribution shows fluctuations in the number of publications from 1990 to 2023, with significant peaks in certain years, but also interspersed with years without documents. This distribution may reflect the dynamics of listing or research focus at a certain time. From the author contributions, it is clear that each author in the dataset has a relatively even contribution, reflecting the selective nature of this dataset, with 15 authors who can be important references in this study. Institutional affiliations and research funding indicate a significant role of institutions such as Pennsylvania State University and the Russian Academy of Science, although most funding comes from institutions with small and diverse contributions, highlighting the need for increased financial support for research in this area.

In terms of themes and global collaborations, the United States leads the research contributions with nine articles, followed by Russia, Germany, and Turkey, indicating the well-established academic infrastructure in these countries. The study is multidisciplinary, with "Social Sciences" as the dominant field (20%), followed by "Engineering" (12.9%) and other fields. The most relevant sources, such as the American Biology Teacher and the Journal of Biological Education, highlight the importance of education in understanding and addressing environmental issues. The most cited documents, by Zangori (2017) and Uno (2009), reinforce the relevance of a science-based educational approach. The thematic map highlights "environmental problems" and "water treatment" as strategic themes, while "energy resources" is in the emerging and fundamental themes category. Keyword analysis shows the relationship between traditional energy sources such as fossil fuels and sustainable practices such as agroforestry, reflecting the dynamics of the energy transition. Overall, this study shows the need for cross-disciplinary collaboration, financial investment, and innovative approaches to address environmental challenges holistically.

Future research is recommended to explore strategic themes such as environmental problems and water treatment in more depth, given their relevance and significant contribution to the thematic map. Studies on the integration of new technologies for sustainable water treatment or policies to mitigate environmental impacts could be a top priority. In addition, it is necessary to explore sustainable practices such as agroforestry, which are emerging as potential solutions to address the energy and environmental crises. Case-based research, especially in tropical regions such as Indonesia, can provide new insights into the implementation of agroforestry at scale. Given the importance of a multidisciplinary approach, collaboration between social sciences, engineering, energy, and the environment should be enhanced to produce more holistic solutions. Long-term research on the energy transition from fossil fuels to renewable energy is also important, including analysis of the accompanying geopolitical, economic, and social challenges. To support research development, bibliometric analysis methods can continue to be utilized to monitor the development of the theme, identify knowledge gaps, and expand international collaboration networks.

These findings have important implications in various aspects. In policy, this research can support policymakers to prioritize investments in themes such as clean water treatment and energy transition. In addition, the study results highlight the importance of greater investment in research infrastructure, especially in developing countries, to encourage a more balanced contribution globally. In terms of energy transition, a focus on sustainable practices such as agroforestry can accelerate the development of policies and technologies that support carbon emission reduction. Public literacy is also an important area that needs to be strengthened, given the relevance of environmental-based education in building public awareness of this issue. Ultimately, research findings can be an important contribution in supporting global agendas, such as the Sustainable Development Goals (SDGs), particularly in the provision of clean water, affordable energy, and action on climate change.

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