Bibliometric Analysis of Green Skills Development: Trends, International Collaboration, and Implications for Sustainable Development Goals

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Abstract: The development of green skills has gained significant attention in recent years, driven by the increasing global focus on achieving the Agenda 2030 goals and the United Nations Sustainable Development Goals (SDGs). Green skills are recognized as essential for fostering sustainable practices across industries, supporting the transition to a low-carbon economy, and addressing pressing environmental challenges. A notable surge in scholarly interest is observed, with 79% of publications related to "green skills development" in the Web of Science database being published after 2015. This indicates the growing recognition of green skills as a key element in advancing sustainability agendas. In this study, a bibliometric analysis was conducted using data from 962 articles extracted from the Web of Science database. The evolution of scientific output, thematic trends, and international collaboration patterns were examined. The analysis reveals a steady increase in publications, particularly post-2015, with an expanding range of research topics, including renewable energy, energy efficiency, green entrepreneurship, and climate adaptation. The distribution of authorship across countries highlights significant international cooperation, with countries from both the Global North and South actively contributing to the discourse. The findings underscore the interdisciplinary nature of green skills research, which spans diverse fields such as environmental science, education, policy studies, and technology. Moreover, the growing body of research reflects a clear shift towards integrating green skills within education and training systems as a means of achieving SDG targets, particularly those related to sustainable economic growth, decent work, and climate action. This study provides valuable insights into the emerging trends and collaborative networks in green skills development, offering a foundation for future research aimed at enhancing the effectiveness of green skill programs and policies. It is evident that continued focus on this area is critical for driving global sustainability efforts and achieving long-term environmental goals.

Keywords: Green skills; Development; Bibliometric analysis; Sustainable Development Goals (SDGs); Energy

1 Introduction

The transition to a green economy has led to increased attention to the development of green skills [1] that are needed to drive sustainable practices [2] in various industries. These skills, which include knowledge in areas such as renewable energy, waste management, sustainable agriculture and environmental protection [3], are essential to addressing the environmental challenges facing the world today.

In the last period, we can observe at the global level a greater effort to achieve environmental and economic objectives, respectively by analogy, the ability to integrate sustainability in educational systems [4]. The importance of green skills goes beyond environmental impact. As industries become greener, there will be an increasing demand for skilled workers capable of managing sustainable and innovative solutions [5]. This growing demand has already been recognized by decision-makers and educational institutions, which are increasingly prioritizing the integration of environmental competences into curricula and vocational training programs [6]. According to the International Labor Organization [6, 7], the transition to a green economy could create millions of new jobs, emphasizing the urgency of training the workforce and the need for specialized training in important areas, such as renewable energy or circular economy [8, 9].

Despite this recognition, a significant gap [9, 10] is identified between the demand for green skills and their availability on the labor market. While the development of sectors such as renewable energy has seen rapid growth, the supply of workers with the necessary skills remains limited [11, 12]. As a result, we can state that there is an urgent need for both education and industry to work more closely together to ensure that workers are well prepared with the necessary skills [4, 12]. The role of education systems [13–15] and policy frameworks in addressing these challenges is essential. Numerous comparative studies focus on the development of green skills in different regions or countries [16–18], reinforcing the role of local contexts [17], respectively economic, cultural and political ones, in shaping green skills demands and workforce strategies. As industries such as renewable energy, sustainable agriculture and green manufacturing grow, so does the demand for workers with green skills. Research often points to a gap between the supply of trained professionals and the growing demand for these skills.

Despite the high demand for green skills, many countries do not have enough training programs that integrate sustainability into educational programs. This obviously creates a barrier for workers to enter green labor markets [7, 19]. Numerous studies highlight the positive impact of green skills development on economic growth, especially in green technologies and industries. Green jobs can be an engine for sustainable economic development and social inclusion [20–22]. Effective policies that align education, industry and government efforts are important to promote the development of green skills [23, 24]. Studies show that countries with strong green policies [25], such as the European Union or parts of Asia, often have more advanced green skills ecosystems.

With this regard, the purpose of this paper is to explore the academic community's interest in green skills development, through bibliometric analysis, using the Web of Sciences database.

The analyzed period spans from 1991 to 2024, covering 962 research documents published across 700 diverse sources. The structure of this paper is divided into five sections. The first section provides an introduction and a literature review. The second section outlines the methodology employed, specifically the bibliometric analysis. The third section presents the results of the analysis of 962 research documents through bibliometric techniques. The discussion section interprets the findings in the context of previous studies and offers a broader perspective on the research outcomes. The final section, Conclusions, summarizes the key findings of the study, suggests potential directions for future research, and highlights the limitations encountered during the analysis.

2 Methodology

Bibliometric analysis is conducted to provide objective, quantitative insights into the evolution of knowledge on specific topics [26], identify potential areas for future research, and explore other relevant aspects.

Using bibliometric analysis software such as RStudio or VOS Viewer has become a modern approach to literature review. This method enables the analysis of large volumes of data and uncovers insights that traditional methods may overlook.

To explore the scientific development of "Green Skills Development," we selected the Web of Science database due to its extensive collection, encompassing 185 million documents from over 33,000 journals, as well as books, conference proceedings, and more than 70 million patents sourced from over 50 patent authorities. This diversity allows for the analysis of various types of documents, such as articles, proceeding papers, review articles, early access, book chapters, and so on. Furthermore, the database covers a wide range of fields, including major disciplines such as life sciences, physical sciences, engineering, social sciences, arts, and humanities, with particularly strong representation in natural sciences, engineering, computer science, and materials science.

The search criteria were set to "Topic," which includes title, abstract, Keywords Plus, and author keywords. Exported content included both "full record and cited references". The analysis was carried out in December 2024, covering all years of publication from 1991 to 2025. It is important to mention that the publication process for 2024 is not yet finished; thus, the number of publications for this year could increase by the end. Additionally, for one paper that has already been accepted, the final publication year appears to be 2025.

Regarding the types of published documents, all document types were included, with the majority being articles (72.66%). Moreover, the research field of this analysis was not restricted to specific areas; thus, we considered all fields of research. The most prominent fields were: Education and Educational Research (15.512%), Green and Sustainable Science and Technology (14.685%), Environmental Sciences (13.754%), and Environmental Studies (12.616%).

Generally speaking, in the Web of Science database, most authors publish in English, although other languages are also available for authors to choose from. Analyzing the languages used in this study from a statistical point of view, 14 languages were identified. Of these, 96.484% of documents were published in English, while 2.276% were published in Russian, Spanish, Chinese, or French.

The bibliometric analysis for this study was performed using the "biblioshiny for bibliometrix" application, a tool integrated into the R 4.0.3 software. This platform, originally developed in the 1960s by John Chambers and colleagues [27], facilitates comprehensive bibliometric evaluations.

The software helped us process our exported database while taking into account our criteria. R Studio software

provides a large range of results related to citations, authors, documents, affiliations, and countries. For this analysis, we focused on examining the evolution of scientific production, collaborations between authors and their countries, the most cited countries and documents, the affiliations of the most prominent authors in this field, and, finally, the evolution of keywords used by authors on this topic.

3 Results and Discussion

The bibliometric analysis highlights the extensive research activity surrounding "Green Skills Development" over a substantial time frame (1991–2025). The 962 documents, published across 700 diverse sources, demonstrate robust academic interest in the field. The involvement of 3061 authors, with most works being collaborative (an average of 3.4 co-authors per document), underscores the interdisciplinary and cooperative nature of research in this area. Additionally, the 23.28% rate of international co-authorship reflects the global importance of green skills and the need for cross-border collaboration to address sustainability challenges effectively.

The analysis also reveals some key patterns in the field's evolution. The literature is relevant and impactful, with an average citation count of 13.2 per document and 45137 references overall. The average document age of 5.81 years suggests a strong focus on recent developments, while the diverse range of 3346 keywords indicates that the field encompasses a broad spectrum of themes and methodologies.

3.1 Scientific Production

Figure 1 demonstrates a gradual rise in publications from 1991 to the early 2000s, followed by an exponential growth phase starting around 2010. During the early years, the number of articles remained minimal, reflecting limited academic engagement with the topic. This could be attributed to the nascent stage of global awareness regarding sustainability and green skill development. However, from 2005 onward, there is steady growth, potentially spurred by increased recognition of environmental issues and the integration of sustainability principles into education and workforce development.

The rapid increase in publication output after 2015 aligns with global initiatives like the SDGs, which have amplified the focus on green skills as essential for achieving sustainable transitions. The peak around 2024 highlights heightened research activity, possibly driven by greater funding and international collaboration. Overall, the graph illustrates the field's growing importance and the global academic community's efforts to address challenges related to green skills development.

Table 1 highlights the steady growth in scientific interest in "green skills development" over time, with an increase in the number of documents indexed in the Web of Science database across all periods. Early periods (1991–2010) saw rapid percentage growth, peaking at 200% in 2001–2005, as the topic gained initial traction. From 2011 onward, the growth rate slowed, reflecting the field's maturation, although the absolute number of publications continued to rise significantly, reaching 419 documents in 2021–2025. The lower growth rate of 37% in the current period is likely due to 2024 being incomplete, with more publications expected by the period's end. This trend underscores the sustained and expanding scholarly interest in this area over the past three decades.
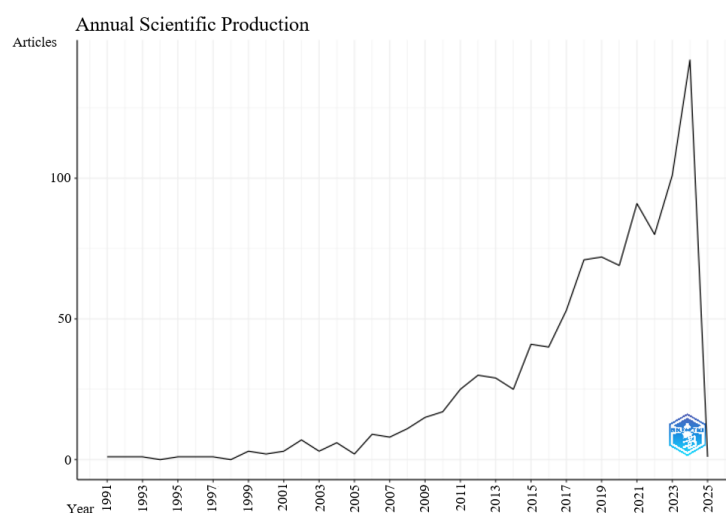
Figure 1. The evolution of annual scientific production

Authors' conceptualization based on the information extracted from WoS database

Table 1. Key parameters of our model

| Timeframe	Number of Existing Scientific Documents in the WoS Database	The Percentage Increase of Scientific Interest from One Period to the Next for Studying the Subject of "Green Skills Development"
2021-2025	419	37%
2016-2020	305	103%
2011-2015	150	150%
2006-2010	60	186%
2001-2005	21	200%
1996-2000	7	75%
1991-1995	4	-

Note: Authors' conceptualization based on the information extracted from WoS database

3.2 Collaboration

Figure 2 illustrates the distribution of corresponding authors' countries in publications on "Green Skills Development," distinguishing between Single Country Publications (SCP) and Multiple Country Publications (MCP). The leading contributors are from the USA, followed by China and the United Kingdom, indicating that these countries dominate research in this field. The significant proportion of SCP in these countries suggests that much of the research is conducted domestically, reflecting strong local expertise and capacity in the topic.

However, there is also considerable MCP representation in countries like the United Kingdom, Italy, and Australia, indicating active international collaboration. Countries such as India, Malaysia, and South Africa have a noticeable contribution, reflecting growing research interest in developing and emerging economies. Romania, Germany, and Russia also appear on the list, albeit with relatively fewer publications, suggesting that "Green Skills Development" is a globally relevant topic, with contributions spanning both developed and developing nations. The balance between SCP and MCP underscores the importance of both national focus and international collaboration in advancing research in this area.

The collaboration map (Figure 3) highlights the global nature of research on "Green Skills Development," with the United States, Europe, and China serving as key hubs of international partnerships. The dense connections between Western European countries, such as the United Kingdom, Germany, France, and Italy, indicate strong intra-regional collaboration, supported by well-established research infrastructures and funding mechanisms. The United States plays a pivotal role in fostering collaborations across continents, while China is emerging as a significant global research partner, with active linkages to both Western nations and neighboring countries in Asia.
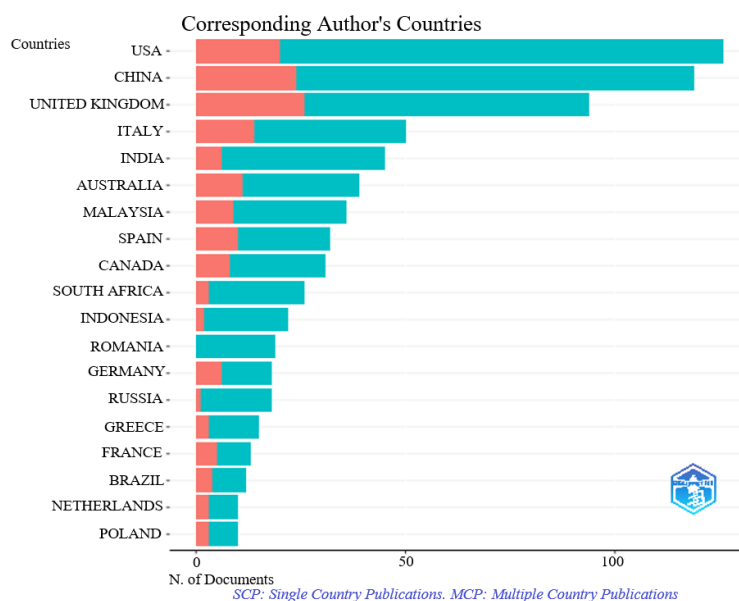
Figure 2. Corresponding author's countries

Authors' conceptualization based on the information extracted from WoS database

*Single Country Publications (SCP) and Multiple Country Publications (MCP)
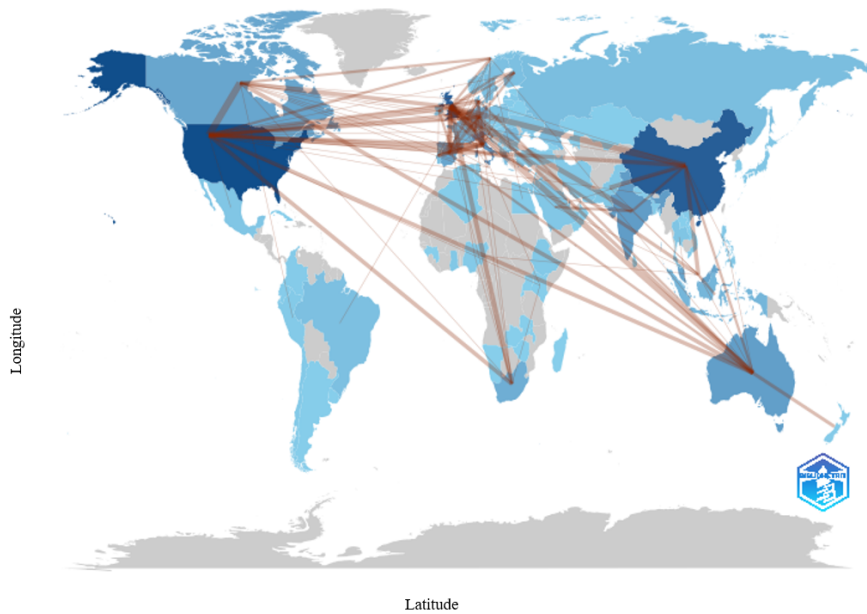
Figure 3. Collaboration world map

Authors' conceptualization based on the information extracted from WoS database

Beyond the major hubs, countries like Australia, India, and South Africa demonstrate active involvement in global research networks, reflecting the increasing participation of emerging economies in addressing green skills challenges. The collaboration between developed and developing nations emphasizes the shared effort to tackle global sustainability issues by leveraging expertise and resources across regions. Overall, the map underscores the importance of international cooperation in advancing research and practical solutions for green workforce transformation.
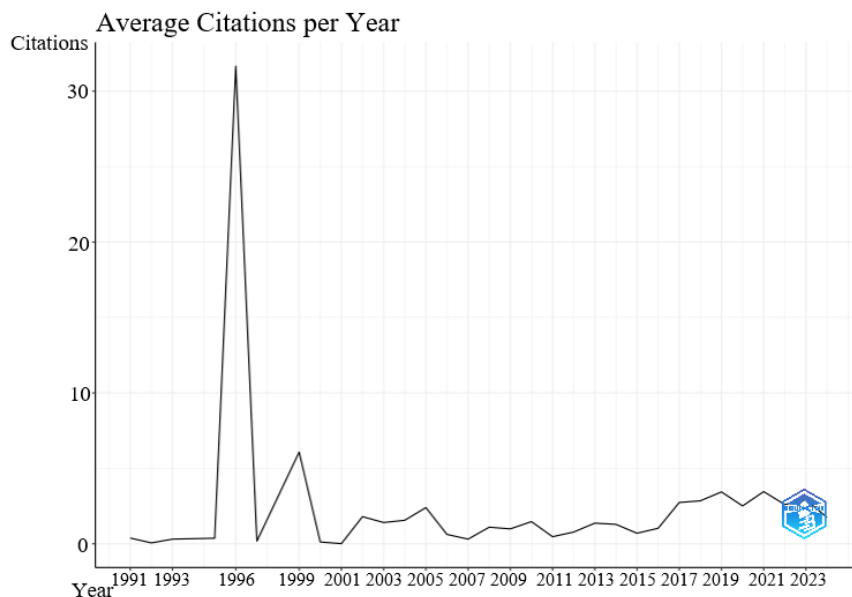
3.3 Citation

Regarding the evolution of average citations per year for publications on "Green Skills Development" (Figure 4), a significant spike is evident in the late 1990s, where the average citations per year exceeded 30. This anomaly suggests that one or a few highly influential publications were cited extensively during this period. After this peak, the average citations declined sharply, stabilizing at a much lower level through the early 2000s and beyond.

**Figure 4.** The evolution of average citations per year

Authors' conceptualization based on the information extracted from WoS database

From the mid-2000s onward, the average citation trend remains relatively flat, with only modest fluctuations. This stability indicates that while the field has grown in terms of research output, no single publication has achieved an extraordinary level of influence in recent years. However, a slight upward trend can be observed in the 2020s, potentially reflecting renewed interest in the topic as global attention to sustainability and green skills has increased.

The average citations per year decreased partly due to the increase in the number of publications. As the volume of research grows, the pool of citations is distributed across a larger number of documents, reducing the average citations per document. This phenomenon reflects a broadening of the research field, where newer publications may take time to accumulate citations, and the influence becomes more distributed across multiple works.

Analyzing the most cited countries (Figure 5), we can see that the USA dominates in terms of total citations, with 3009, indicating its significant influence and contribution to high-impact publications. This aligns with the spike in average citations per year observed in the late 1990s, suggesting that key influential works during that period may have originated from the USA.

Countries like China, the United Kingdom, and Australia also show substantial citation numbers, indicating their active involvement in impactful research. However, their total citation counts are significantly lower than the USA, reflecting a more consistent, steady contribution rather than a concentration of high-impact publications. This distribution suggests that while global participation in this research area has grown, the USA has historically produced seminal works that continue to influence the field, driving the citation peaks observed in earlier years. The steady average citations post-2000 align with the broader involvement of these other countries, representing a more distributed contribution to academic discourse.
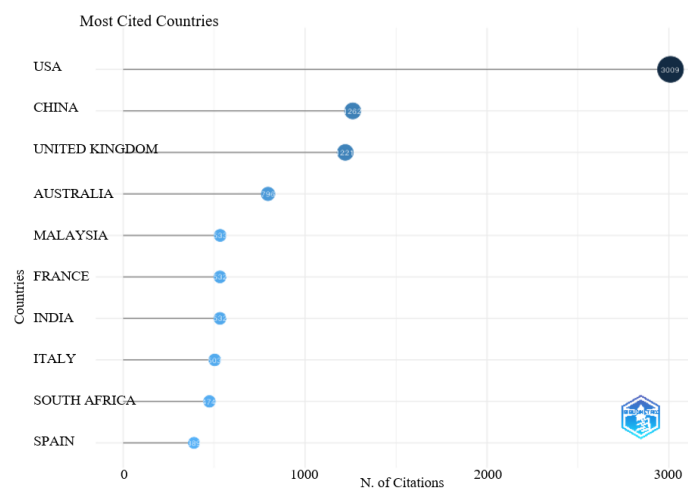
Figure 5. Most cited countries

Authors' conceptualization based on the information extracted from WoS database
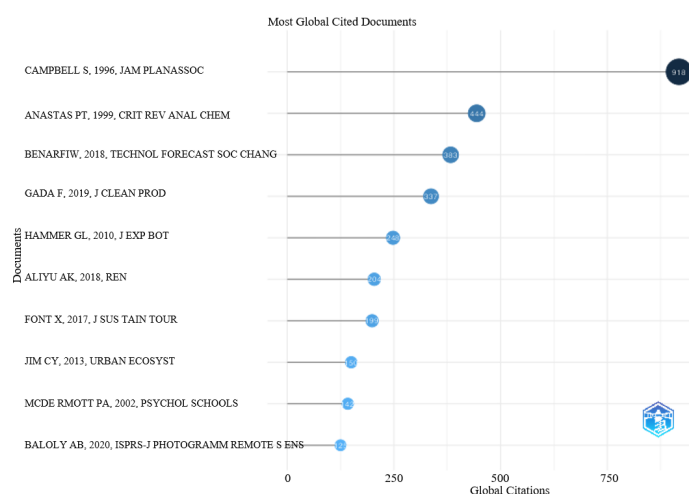
Figure 6. Most global cited documents

Authors' conceptualization based on the information extracted from WoS database

The presence of highly cited works aligns with the dominance of the USA, China, and the United Kingdom in the total citation count. Many of these impactful publications are likely authored or co-authored by researchers from these leading countries, further solidifying their influence on the global academic landscape.

Regarding the Figure 6, the most cited document, authored by Campbell S. in 1996, stands out with 918 citations. This level of influence indicates a foundational or groundbreaking work that shaped subsequent research. Similarly, the prevouous works with 444 citations and 383 citations indicate significant contributions to the field, reflecting their global impact. These documents likely address critical theoretical frameworks, methodologies, or case studies that resonate widely within the academic community. The prominence of these documents highlights the concentration of academic influence within certain high-impact publications, mirroring the trends seen in the most cited countries. These works play a critical role in driving the evolution of the field and shaping future research directions.
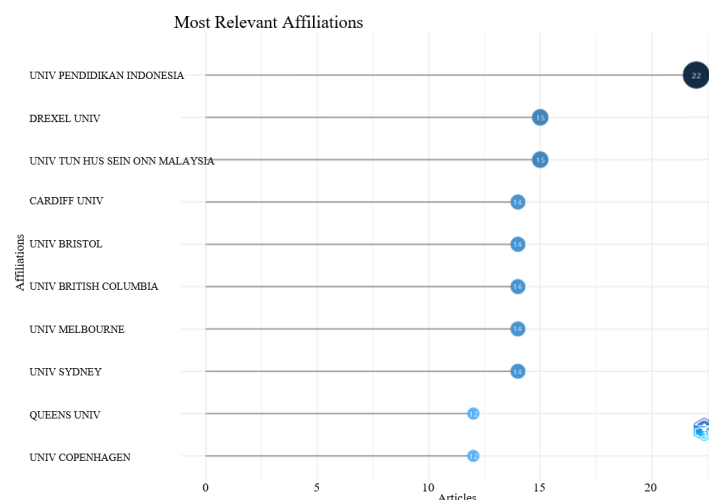
4 Affiliation

This distribution of affiliations (Figure 7) underscores the growing recognition of "Green Skills Development" as a multidisciplinary and international research area. It also reflects the active involvement of universities from both developed and emerging economies, bridging global and regional perspectives on sustainability and workforce transformation. The diversity in affiliations suggests collaboration opportunities and knowledge sharing among institutions worldwide.

The University of Pendidikan Indonesia leads with 22 publications, reflecting its strong focus and leadership in this research area. This dominance may highlight the university's commitment to addressing sustainability and green skills challenges, particularly within the context of a developing economy like Indonesia.

Other institutions, such as Drexel University (15 publications) and University Tun Hussein Onn Malaysia (15 publications), indicate significant contributions from both Western and Southeast Asian universities. Institutions like Cardiff University, University of Bristol, and University of British Columbia (each with 14 publications) demonstrate the participation of universities from developed countries, suggesting a diverse global interest in this topic. The inclusion of prominent universities from Australia (University of Melbourne and University of Sydney) and Europe (University of Copenhagen and Queen's University) further reinforces the global nature of the research.

Figure 8 showcases notable trends in the production of research on "Green Skills Development" by leading affiliations, with the most significant growth occurring between 2015 and 2020. This period coincides with the global adoption of the SDGs in 2015, which emphasized education and sustainability as critical priorities. Institutions such as the University of Pendidikan Indonesia, Drexel University, and University Tun Hussein Onn Malaysia experienced particularly rapid growth during this time, reflecting their increased focus on addressing green skills challenges and aligning their research agendas with global sustainability goals.

A striking observation is the rise of universities from developing regions, such as the University of Pendidikan Indonesia and University Tun Hussein Onn Malaysia, which demonstrate substantial contributions and, in some cases, outperform well-established institutions from developed countries. This trend highlights the increasing importance of emerging economies in advancing green skills research, driven by local needs for sustainable workforce transformation and growing opportunities for international collaboration. Their strong and sustained output underscores their pivotal role in shaping the global discourse on sustainability.

Figure 7. Most relevant affiliations

Authors' conceptualization based on the information extracted from WoS database

Additionally, institutions such as Cardiff University, University of British Columbia, University of Sydney, and University of Melbourne exhibit steady growth trajectories, reflecting their ongoing commitment to sustainability research. The graph reinforces the global and collaborative nature of this field, with both developed and developing countries contributing meaningfully to its evolution, driven by shared goals and challenges.

The analysis of the most relevant journals (Figure 9) reveals the primary platforms where research on "Green Skills Development" is published, providing valuable insights into the dissemination of knowledge by various affiliations. Sustainability emerges as the leading journal, with 54 publications, highlighting its role as a central outlet for interdisciplinary studies on sustainability. Other prominent journals, such as the Journal of Chemical Education (18 publications) and Journal of Cleaner Production (16 publications), emphasize the focus on education and sustainable practices, aligning with the global push for green workforce transformation. These journals reflect a diverse range of academic interests, from education to industry-specific sustainability practices.

Linking this analysis to affiliations, it becomes evident that institutions like the University of Pendidikan Indonesia, Drexel University, and University Tun Hussein Onn Malaysia are actively contributing to these leading journals. The strong presence of these affiliations in high-impact outlets demonstrates their influence within the academic community and their commitment to advancing research in sustainability and green skills. The alignment of journals and affiliations also underscores shared research priorities, providing a clearer picture of how institutions drive the global discourse on green workforce development. This connection highlights the collaborative and interdisciplinary nature of the field, where institutions and journals work together to address sustainability challenges.

Figure 8. Affiliations' production over time

Authors' conceptualization based on the information extracted from WoS database

Figure 9. Most relevant sources

Authors' conceptualization based on the information extracted from WoS database

4.1 Thematic Evolution

Figure 10 illustrates the evolution of research priorities in "Green Skills Development" from 2012 to 2024, focusing on the emergence and frequency of key terms. The analysis starts in 2012, as prior to this year, the number of articles was relatively low, making earlier trends less significant for detailed thematic analysis. Early years (2012–2016) emphasized foundational themes like sustainable development, policy, and networks, reflecting efforts to establish frameworks for integrating sustainability into various sectors.

From 2017 to 2020, the research focus broadened, with terms like education, innovation, and renewable energy gaining prominence, highlighting the importance of workforce development, institutional practices, and measurable sustainability outcomes. In recent years (2021–2024), attention has shifted toward more applied and industry-specific topics, with terms like firms, adoption, and emissions becoming prominent. The continued focus on education and performance underscores their central role in equipping individuals and organizations to address pressing sustainability challenges, reflecting the global urgency of addressing climate change and advancing sustainable practices.

The word cloud (Figure 11) highlights the primary themes and priorities in "Green Skills Development" research. Key terms like performance (70), impact (54), and education (46) emphasize the importance of evaluating outcomes, integrating education, and managing sustainability practices. High-frequency terms such as green (47), sustainability (37), and skills (34) reflect the field's focus on building frameworks and tools to advance green initiatives.
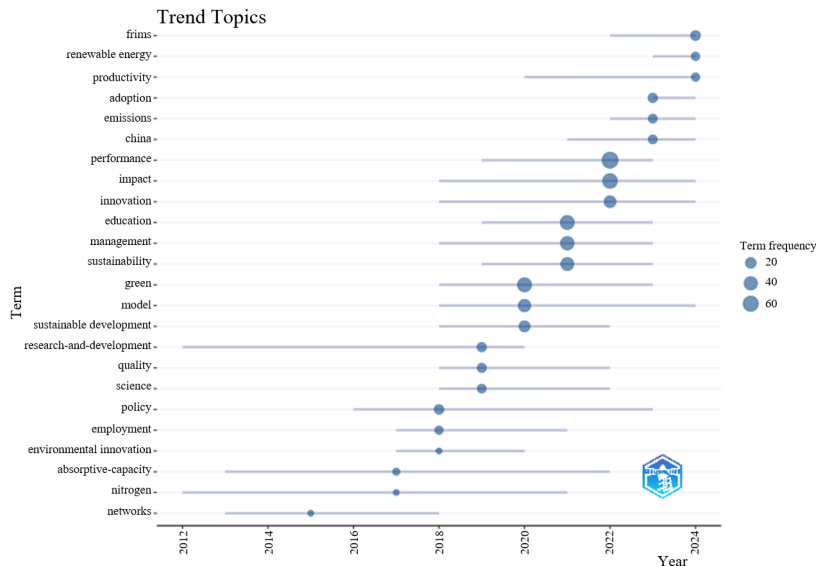

Figure 10. Trend topics

Authors' conceptualization based on the information extracted from WoS database

Figure 11. Word cloud based on frequency of used terms

Authors' conceptualization based on the information extracted from WoS database

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Emerging topics like innovation (27), technology (20), and systems (22) point to the growing role of technological and systemic approaches, while sector-specific terms such as climate change (19), health (19), and energy (11) underscore the urgency of addressing global challenges. The inclusion of students (18), barriers (15), and implementation (15) highlights practical challenges and efforts to integrate green skills into education and the workforce. Overall, the data reflects a balance between conceptual development and practical applications, with a strong emphasis on education, sustainability, and innovation.

5 Discussion

Our bibliometric analysis of "Green Skills Development" aligns with findings from similar studies, emphasizing a significant increase in research output after 2015. This surge corresponds to the global adoption of the SDGs, which highlighted the importance of integrating sustainability into education and vocational training. Fitriyanto et al. [28] similarly observed a substantial rise in green skills research within vocational education between 2018 and 2022, with notable contributions from Europe and America, reflecting the global commitment to sustainable development [29].

In contrast to Fitriyanto et al.'s analysis [28], which focused on Scopus data and a narrower time frame (2018–2022), our study utilized the Web of Science database and analyzed the entire timeline of published documents, starting from the first recorded publication on this topic. This broader approach allows us to provide a more comprehensive view of the field's evolution, highlighting long-term trends and thematic shifts. By including earlier contributions, our analysis captures the foundational stages of green skills research [30], which helps contextualize the recent surge in publications.

Our contribution to the literature lies in this broader temporal and database scope, offering a holistic perspective on how green skills research has grown and adapted over time. By comparing our findings with those of previous studies, we underline the expanding relevance of green skills across disciplines and regions while emphasizing the need for continued efforts to advance this critical area of research.

The thematic evolution identified in our study—from foundational concepts to applied themes like renewable energy and climate change—parallels trends reported by other researchers. For instance, a bibliometric analysis of green entrepreneurship literature [31] noted a shift towards practical applications and sector-specific studies, reflecting the field's maturation and responsiveness to global sustainability challenges.

Our findings also reveal increased contributions from institutions in developing regions, mirroring global research trends. In a previous study [30] regarding green policies in higher education institutions, the article revealed that collaborations between countries on this topic are more extensive than on the topic of green skills. Moreover, nearly the same countries, such as the USA, China, Italy, the UK, and others, show the most interest in topics like green policies in universities and green skills development. A study on green knowledge management highlighted the growing involvement of emerging economies in sustainability research, driven by local needs and international collaboration opportunities [32]. This underscores the universal relevance of green skills development, and the collaborative efforts required to address sustainability challenges worldwide.

6 Conclusions

Since 2015, research interest in green skills development has grown significantly, driven by their critical role in addressing global sustainability challenges. Green skills have become increasingly recognized as essential for transitioning to more sustainable practices in industries such as renewable energy, agriculture, and manufacturing. This growing focus reflects a broader understanding of the need for a skilled workforce capable of implementing sustainable solutions and adapting to emerging technologies. The surge in academic attention also highlights the practical importance of green skills in driving economic growth and environmental stewardship, making them a vital component of the global sustainability agenda.

The analysis highlights that the most prolific countries in "Green Skills Development" research are the USA, China, and the UK, underscoring their leadership in sustainability research and policy. These countries have strong research infrastructures, funding mechanisms, and global influence, which contribute to their high output. However, it is noteworthy that developing countries, such as Romania, also appear in the top 15. This indicates that green skills development is not only a priority in advanced economies but also in emerging ones. Romania's presence in the list reflects the increasing importance of sustainability in the context of EU membership and alignment with global SDGs [33]. This global engagement underscores the universal relevance of green skills as countries across different economic levels contribute to this field [34, 35], driven by local needs and international frameworks like the SDGs.

The Sustainability journal emerges as the preferred platform for publishing research on green skills development, highlighting its interdisciplinary focus and alignment with sustainability topics. The prominence of this journal indicates that it is a central hub for academics and practitioners seeking to advance green skills research. However, the analysis also shows the importance of sector-specific and regional journals, such as the Journal of Cleaner Production (J CLEAN PROD), which has a strong focus on applied research in clean technologies and sustainable

practices. These journals provide diverse platforms to disseminate knowledge, catering to both broad and specialized audiences, ensuring that research findings reach multiple stakeholders globally.

Therefore, we propose some practical recommendations to capitalize on this trend of increasing interest in this field of green skills development. Firstly, we consider it important to invest in education and training programs for green skills. With this regard, governments and educational institutions should prioritize the development of green skills curricula at all levels of education, from primary to vocational training. Monitoring progress allows for the identification of gaps in green skills provision, ensuring that educational and training programs are responsive to the evolving needs of the labor market. By promoting the development of sector-specific green skills, a workforce equipped for sustainability-related roles could be ensured. To strengthen policy frameworks, governments should implement policies that incentivize the adoption of green skills, such as subsidies for green training programs or tax breaks for companies that invest in sustainable practices.

Secondly, we consider that research and innovation are critical for advancing the technologies that will drive sustainability, so countries should invest in local research capabilities to build capacity and adapt global green solutions to local contexts. Also, international collaboration can help bridge gaps between advanced and developing economies, enabling a more inclusive global approach to sustainable development. The solution is to encourage partnerships between leading countries (e.g., USA, China, UK) and emerging economies to share knowledge, expertise, and resources related to green skills development. Thirdly, academics and practitioners should publish green skills-related research in interdisciplinary journals to reach a diverse audience. Close collaboration between academia and industry could ensure that green skills training is both practical and aligned with market demands, enhancing employability and driving economic growth. By adopting these recommendations, governments, businesses, and academic institutions can build a robust infrastructure for green skills development, driving both economic and environmental progress while meeting global sustainability goals.

The limitations of this research primarily stem from the use of the Web of Science database as the sole source of data. While this database is a robust and widely used platform for academic research, it does not encompass all publications, especially those in non-indexed journals, regional databases, or grey literature. The research primarily focuses on published papers, potentially overlooking green skills training occurring outside academic settings. It predominantly covers countries like the USA, China, and the UK, which might result in an incomplete representation of progress in other parts of the world. Additionally, due to language restrictions, as most publications are in English, important studies from countries in Asia or Eastern Europe may be overlooked. As a result, some relevant studies on "Green Skills Development" may have been excluded, potentially creating gaps in the analysis. Furthermore, the reliance on the topic criteria (title, abstract, Keywords Plus, and author keywords) may have restricted the scope to publications explicitly mentioning these terms, overlooking studies that indirectly address green skills. These limitations show that more research is needed for a complete understanding of green skills development.

Future research could address these limitations by incorporating additional databases, such as Scopus or Google Scholar, to capture a wider range of publications and regional perspectives. Additionally, exploring green skills within specific sectors of activity or regions could provide a deeper understanding of their implementation, impact, and barriers, further enriching the discourse on green skills development. By overcoming these limitations, future studies can build on our findings to offer more comprehensive and actionable insights.

Data Availability

The data used to support the research findings are included in the article, further inquiries can be directed to the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest.

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