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Green Skills and Labor Market Transformation: A Bibliometric Analysis of Global Research Trends

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Abstract

The rapid transition towards a green economy has led to heightened attention on the acquisition of green skills and sustainable education structures responsive to expanding labour market demands. At this point, the interlinkages among environmental literacy, vocational training, and employability have formed the focal point of global policy and research debates. This study offers a bibliometric mapping of global scholastic literature on green skills and labour market change. On the basis of data extracted from the Web of Science Core Collection and run through bibliometric mapping tools, this study captures the intellectual terrain, top researchers, thematic clusters, and time trends characterising this topic.

The review detects an increasingly expanding body of literature with significant contributions from interdisciplinary areas, particularly environmental sciences, education, and labour economics. Emerging themes are such as just transition policies, green sector skill mismatch, and mainstreaming sustainability competence in formal and vocational schooling. Co-authorship networks and collaboration patterns at the country level also support the global nature of the debate. This study offers valuable guidance for policymakers, educators, and researchers focused on connecting workforce development policy to the demands of economic and ecological sustainability.

Keywords: Green skills, green education, labor market, bibliometric analysis

1. Introduction

Climate change, biodiversity loss, and environmental degradation have emerged as some of the most pressing global challenges of the 21st century. Addressing these threats requires the integration of sustainability into the core of economic development strategies, rather than treating it as a separate or secondary concern. Today, many countries are restructuring their production models, decarbonizing their energy systems, and preparing their labor markets for the demands of a low-carbon economy (Bluedorn et al., 2023; Ham et al., 2025). In this context, the shift toward a greener economy demands not only technological change, but also a significant transformation of workforce skills and capacities.

One of the most comprehensive policy responses to this global transition is the European Green Deal, announced by the European Commission in 2019. This roadmap aims to make Europe the first climate-neutral continent by 2050 through far-reaching reforms across energy, transport, industry, agriculture, and finance. More importantly, the strategy emphasizes that the green transition must be socially inclusive and equitable—what it terms a "just transition." As part of this vision, the EU introduced the European Skills Agenda, which promotes reskilling and upskilling measures to equip the workforce with the competencies required in a green economy (European Commission, 2020). In this framework, green skills have become central not only to environmental policy, but also to labor and education strategies across the continent.

Green skills comprise a diverse range of technical, cognitive, and behavioral capabilities that contribute to sustainable practices. These include energy efficiency, eco-friendly production, environmental awareness, and circular economy principles (ETF, 2023; CISL, 2020). Importantly, they are not limited to green-specific jobs; rather, they are increasingly relevant across traditional sectors such as construction, manufacturing, logistics, services, and agriculture (Keshminder & Cheng, 2020). For this reason, green skills are essential not only for emerging roles but also for transforming existing occupations. Narrow definitions that associate green skills solely with environmental jobs fail to capture the broader structural transformation underway in labor markets and skill development systems.

Yet, national strategies for identifying, developing, and disseminating green skills vary significantly. In India, for example, institutions like the Skill Council for Green Jobs actively shape green training frameworks, while in Poland, sector-specific analyses have been used to map regional green labor markets (Gajdos & Antczak, 2024). In contrast, Turkey is still in the early phases of constructing a green skills agenda, with much room to align with international models and adopt more systemic approaches. In this regard, understanding how the academic literature on green skills has

evolved globally can offer valuable insight for decision-makers, educators, and institutions aiming to build responsive and inclusive policies.

Recent research highlights the multifaceted impacts of green skills on labor market dynamics. Green jobs are often associated with higher educational levels, better wages, and stronger urban concentration (Bluedorn et al., 2023; Ham et al., 2025). However, such trends may inadvertently exclude workers from rural areas or those in traditional carbon-intensive industries. As such, green transition should not be viewed solely as an economic necessity, but also as a social responsibility (Tūtlys, 2022). Without deliberate efforts to ensure inclusion, the green economy could reinforce rather than reduce existing inequalities.

Against this backdrop, the present study conducts a bibliometric analysis of academic publications that focus on the keywords "green skills," "green education," and "labor market." Based on data retrieved from the Web of Science Core Collection, the analysis maps out the intellectual landscape of the field, revealing thematic clusters, international collaboration networks, disciplinary concentrations, and research gaps. The findings aim to contribute to theoretical debates while offering practical guidance for education providers, labor market institutions, and policymakers involved in shaping the future of work in a green economy.

2. Literature Review

2.1. Green Skills: Definitions and Conceptual Frameworks

The emergence of green skills as a critical concept has mirrored global shifts toward ecological sustainability and low-carbon economic models. These skills broadly encompass the ability to support environmental protection, promote sustainable use of natural resources, and adapt to clean technologies. According to Ismail et al. (2019), green skills represent a multidimensional competency profile that integrates technical know-how, problem-solving capacities, and environmentally conscious behaviors aligned with sustainability agendas. Similarly, Popp et al. (2021) frame green skills as an essential extension of environmental literacy, supporting workforce resilience amid ecological and economic transformation.

Importantly, the demand for such competencies is not restricted to industries traditionally labeled as “green”. Instead, there is a growing need for environmental proficiency in diverse sectors such as construction, manufacturing, logistics, and public services. This widening scope calls for a broader theoretical model one that captures the role of green human capital across the full spectrum of economic activity.

2.2. Integration into Education and Training Systems

The integration of green skills into formal education and vocational training systems is widely acknowledged as a prerequisite for successful green transition policies. The adaptability of Technical and Vocational Education and Training institutions in designing curricula that meet emerging environmental needs has become a key determinant of progress. Efforts in Southeast Asia underscore the importance of aligning training content with labor market trends in sustainable sectors (Keshminder, 2020). Likewise, Poland is incorporating green skill components into national qualification structures and occupational standards (Gajdos & Antczak, 2024).

Despite these advancements, many regions still lack well-defined curricular models that codify green competencies. Ismail et al. (2019) emphasize the need for modular, outcomes-based curricula and instructor training mechanisms centered on sustainability principles. Furthermore, the "Emerging Environmental Industries" report suggests that even where technical frameworks are in place, delivery inconsistencies hinder their impact, especially at the institutional level.

2.3. Labor Market Outcomes and Socioeconomic Impacts

Green competencies are increasingly seen as influencing both employment structures and broader socioeconomic indicators. Empirical findings suggest that green-oriented occupations often offer superior employment conditions—higher average wages, longer job tenure, and increased urban employment density. In their U.S.-based study, Popp et al. (2021) find that workers in green roles tend to fare better economically than those in traditional positions.

However, the green transformation does not benefit all equally. Tūtlys, V. (2022) caution that without inclusive and accessible retraining programs, certain segments—especially older and low-skilled workers in polluting industries—could be marginalized. This underscores the importance of designing transition policies that balance growth with equity and mitigate structural vulnerabilities within the workforce.

2.4. Mapping the Field: Role of Bibliometric Analysis

While scholarly attention toward green skills have grown, the academic literature remains dispersed across disciplines and lacks a comprehensive synthesis. Most existing studies concentrate on policy assessment, educational practices, or labor outcomes, with relatively few offering meta-level insights. As Kozar & Sulich (2023) note, bibliometric tools such as co-citation analysis and keyword clustering offer robust means to systematically map the research landscape and trace thematic evolution.

Given the interdisciplinary character of the topic—which spans environmental science, education, labor economics, and policy analysis—bibliometric mapping provides clarity on influential contributions, knowledge gaps, and research frontiers. This study employs such an approach using the Web of Science dataset, aiming to visualize the global structure and trajectory of academic inquiry on green skills and employment transformation.

3. Methodology

The selection of articles included in this study followed systematic procedures frequently adopted in bibliometric analyses, as outlined by Zhong and Pei (2023). Accordingly:

- **i.** Only articles published in journals indexed by the Social Sciences Citation Index (SSCI), the Science Citation Index Expanded (SCIE), or the Emerging Sources Citation Index (ESCI) within the Web of Science Core Collection were considered;
- **ii.** The search was restricted to peer-reviewed, full-length research articles published in English. Other document types such as research notes, editorials, book chapters, reviews, and conference proceedings were excluded;
- **iii.** Eligible publications were required to focus on the intersection of green skills, green education, sustainable skills development, or environmental literacy with employment or the labor market.

To identify relevant literature, a comprehensive search was conducted using the following Boolean query in the title, abstract, and keyword fields:

TS=("green skills" OR "green education" OR "sustainable skills development" OR "environmental literacy")
AND TS=("employment" OR "labor market")

The search was filtered to include documents classified as “article” and written in English. The final search was executed on 15 June 2025.

The retrieved results were exported in Text File (.txt) format for processing and visualization using VOSviewer, a widely adopted software tool for bibliometric mapping. VOSviewer enables the construction of country-level collaboration maps based on co-authorship data, as well as keyword co-occurrence networks that reveal thematic clusters and research hotspots. The software is particularly useful for generating complex visualizations involving multiple nodes and connections across diverse bibliographic dimensions.

Through its integrated features for data mining, clustering, and visualization, VOSviewer facilitates the grouping of publications retrieved from bibliographic databases, allowing researchers to explore intellectual structures and emerging trends within the selected corpus (Rahmawati & Subardjo, 2022). In this study, bibliometric patterns were visualized to identify dominant research themes, key contributing countries, and frequently co-occurring terms within the field of green skills and labor market transformation.

4. Results

According to the search criteria specified in the methodology section, 32 articles were reached. The number of publications by year is presented in Figure 1. As can be seen in the graph, the highest number of publications was in 2024 with 7. In 2025, the number is 5. This number may increase further as the year ends.

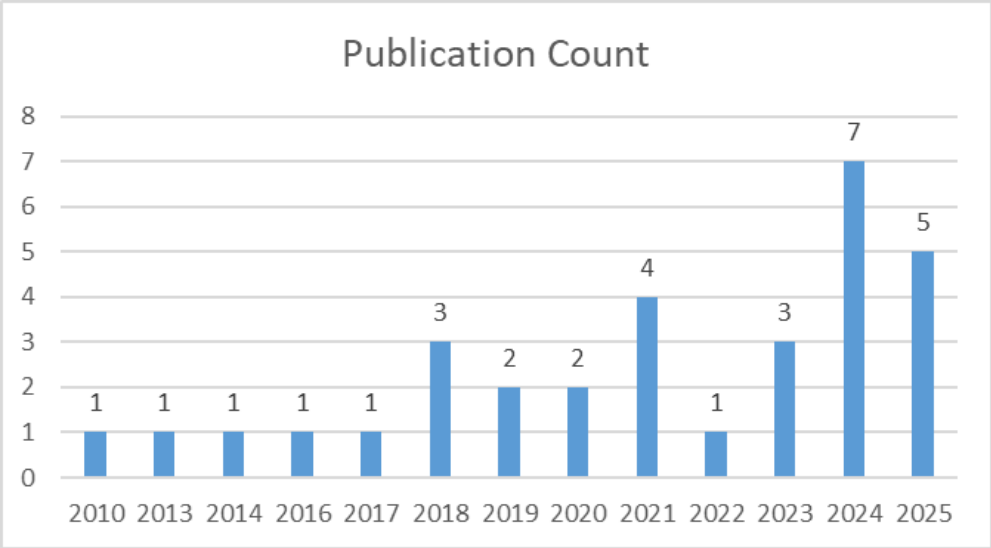

Figure 1: Number of Publications by Year

According to the WoS category, the most publications were made in the field of Environmental Studies, as seen in Figure 2, followed by the fields of Education-Educational Research and Environmental Sciences.

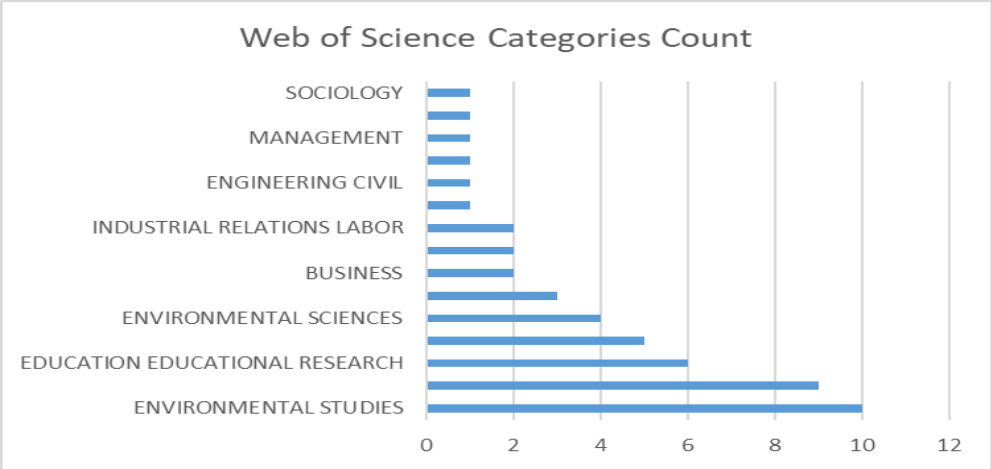

Figure 2: Number of Publications by WoS Categories

As illustrated in Figure 3, an analysis of publication distribution based on the authors' country affiliations reveals that the highest number of publications originated from the United States. This is followed by Italy and Australia, which also demonstrate considerable scholarly output on green skills and labor market transformation. Notably, several European Union (EU) member states—such as France, Finland, and Belgium—are among the top contributors, collectively accounting for a substantial portion of the literature.

When aggregated, the total number of publications from EU countries represents approximately 27.7% of the dataset, surpassing other regions. Meanwhile, contributions from China (including the People's Republic of China entry) make up around 18.6%, while the United States accounts for roughly 12.6%. These figures highlight the dominant role of Europe and Asia-Pacific countries in advancing research on sustainable workforce development.

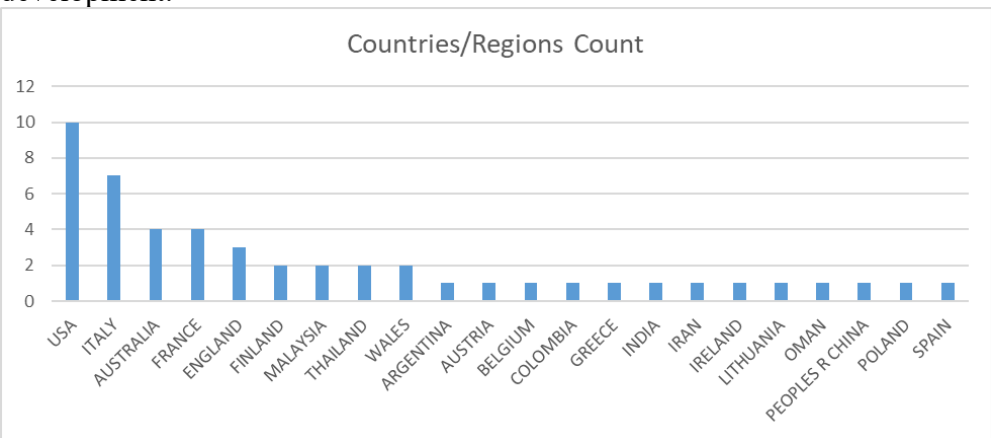

Figure 3: Number of Publications Based on Country/Region

As shown in Figure 4, the analysis of funding agencies supporting research on green skills and labor market transformation indicates that the European Union (EU) plays a leading role in this domain. Specifically, the European Union (EU) and the European Commission's Joint Research Centre were the most prominent funders, accounting for the highest number of supported publications within the dataset. Other funding bodies such as the UK Research and Innovation (UKRI), the Strategic Research Council of Finland, and the Hong Kong Research Grants Council also contributed to individual studies, although at significantly lower frequencies.

Figure 4: Number of Publications Based on Funding Agencies

Figure 5 presents a keyword co-occurrence network derived from the analyzed corpus using VOSviewer. The visualization highlights how frequently and closely certain terms appear together within titles, abstracts, and keywords of selected publications. Each node in the network represents a distinct keyword, with the size of the circle indicating the frequency of its occurrence across the dataset.

The colored clusters reflect thematic groupings: red nodes focus on macro-level transitions such as "green job," "transition," and "green economy"; green nodes are centered around applied labor concepts like "skill," "labor market," and "development"; while blue nodes reflect education and policy-related themes including "education," "study," and "government." The proximity between nodes suggests semantic similarity, and the thickness of the connecting lines represents the strength of their co-occurrence. Shorter distances and thicker lines indicate stronger and more frequent associations.

Overall, the map reveals three dominant research clusters: one related to policy and education, another emphasizing labor and skills, and a third on green economic transition. This clustering structure not only illustrates the

interdisciplinary nature of green skills research but also provides insight into the intellectual structure and emerging focal points within the field.

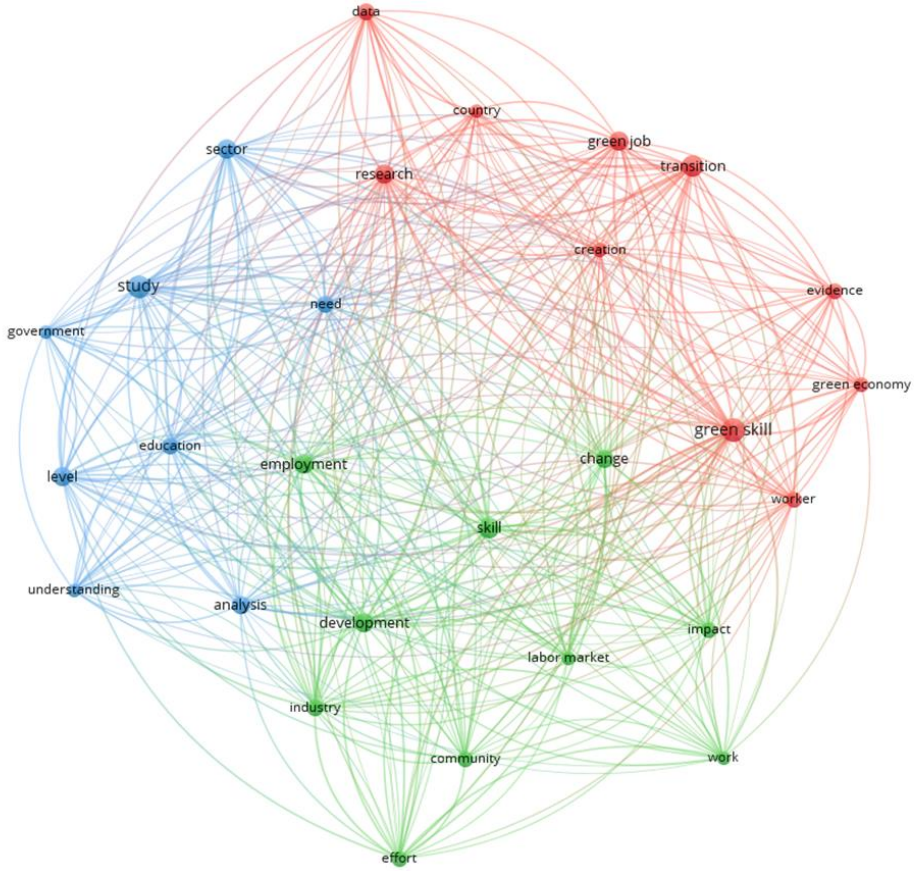

Figure 5: Thematic Clusters of Green Skills Research Based on Keyword Co-occurrence

Conclusion

The concept of green skills has gained remarkable momentum over the past few years, especially in light of ongoing environmental and economic transformations. This study has aimed to capture the main patterns and intellectual developments in this emerging field through a bibliometric examination of scientific publications indexed in the Web of Science. The analysis provides valuable insights into where the academic interest is concentrated and how research themes have evolved.

Results indicate that green skills are no longer limited to narrow environmental occupations. Instead, they are becoming foundational to a wide range of sectors including education, construction, energy, and manufacturing. A key finding is the prominent attention paid to vocational education systems, workforce transition policies, and broader sustainability

frameworks. These areas are strongly interconnected in the literature, forming dense clusters of research activity.

European countries appear as the most active contributors both in terms of output and institutional support. The involvement of organizations such as the European Commission and national skill councils demonstrates a structured and policy-driven approach to embedding sustainability into labor systems. In contrast, participation from developing countries remains modest, pointing to a need for more inclusive global engagement.

The network analysis also revealed that scholarly discussions are centered around three core themes: educational integration of sustainability, policy responses to labor market shifts, and the socioeconomic implications of transitioning to a green economy. Despite this progress, important blind spots persist—particularly in examining equity-related challenges, such as access to green training for marginalized groups or the transition pathways for fossil fuel-dependent workers.

In sum, this research highlights not only the growth but also the complexity of the green skills landscape. By offering a structured map of the academic dialogue, it helps to clarify where the field is headed and where further attention is needed. As climate and labor systems continue to converge, it becomes increasingly important to ensure that skill development frameworks are adaptable, inclusive, and responsive to long-term sustainability goals.

Conflict of Interest: The author reported no conflict of interest.

Data Availability: All data are included in the content of the paper.

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