

Mapping Green Human Capital as a Driver of Sustainability: A Bibliometric Review

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Abstract:

This paper presents a comprehensive bibliometric analysis of the development nexus between green human capital and sustainability. A dataset of 501 relevant studies between 2010 and 2025 was systematically collected from the Web of Science database and analysed using the R package (Bibliometrix via biblioshiny). The finding of the study revealed growth in research, with a sharp increase after 2020, demonstrating rising global attention to sustainability and green transitions. China leads scientific production and citations, followed by the United States and the United Kingdom, while emerging economies such as Malaysia, Pakistan, and Ukraine show increasing engagement. The findings give an in-depth primer on the field and offer insights for scholars, policymakers, and practitioners.

Keywords: Green Human Capital, Sustainability, Green Economy, Bibliometric Analysis, Green Skills.

Jel Classification Codes: Q56, J24, O15

Introduction:

The world's commitment to the 2030 Agenda for Sustainable Development, which is a universal framework for making things more environmentally friendly, was reaffirmed in accordance with the 2015 United Nations General Assembly in New York. This continued call to meet the Sustainable Development Goals (SDGs) has increased scholarly and policy interest in sustainability in many fields. One of the emerged strategies that are raised to drive sustainability is the well-known Green Human Capital (GHC), which includes the knowledge, skills, and values that

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encourage individuals and organizations to adopt environmentally responsible practices (Ni et al., 2023).

The significance of GHC is becoming more and more important in both academic and policy discussions as a vital pathway to move toward sustainability. The effective incorporation of GHC strategies into companies helps them to adopt green technologies that enhance their corporate social responsibility (Saud et al., 2023). Researchers have stressed that funding green education and training is necessary to develop workers ready for the challenges of sustainability transitions (Beisembina et al., 2023). GHC not only helps businesses, but it also helps society as a whole by raising awareness of environmental issues, lowering the negative effects of economic activities, and helping to reach the United Nations SDGs (Lisi, 2024; Malik et al., 2020).

Bibliometric research on GHC and sustainability has expanded considerably in recent years, underscoring the central role of human capital in advancing sustainable development. Much of the literature has focused on Green Human Resource Management. Developed economies dominate contributions, though emerging economies like China and Pakistan are increasingly active (Edinsel & Kara, 2023). Key themes have evolved from green recruitment and training to broader issues of organizational culture, competitive advantage, and environmental performance, with growing attention to green innovation, corporate social responsibility, and the circular economy (Shah et al., 2023). Similarly to the influential reviews of Garrigos-Simon et al., (2018). Despite progress, challenges remain, including the need for interdisciplinary approaches, cross-country comparisons, and exploration of emerging areas such as green leadership and values (Sungaile & Stankeviciene, 2024). Overall, existing studies demonstrate the dynamic evolution of GHC and GHRM scholarship and its crucial contribution to environmental and social sustainability.

This paper aims to systematically address this gap by describing the global scientific output, concentrating specifically on the convergence of GHC and sustainability. A bibliometric analysis that captures the intellectual structure, research trends, and thematic evolution of the field. By examining key authors, institutions, countries, and influential publications, such a study provides insights into the trajectory of GHC research and identifies potential avenues for future scholarship. The research aims to investigate several key questions:

- How has the intersection of green human capital and sustainability literature evolved over time?
- What is the scientific landscape related to this topic, particularly in terms of patterns among countries, journals, articles, and authors?
- What insights can be drawn to guide future research and practical applications of GHC for driven sustainability?

The primary objectives of this bibliometric analysis are to map a comprehensive intellectual structure of the literature on GHC and sustainability, identify key authors, journals, and institutions contributing to the advancement of this field, analyse country-level collaboration networks to highlight global and regional research hubs, trace thematic trends and knowledge evolution within GHC research, and provide actionable insights for future research directions as well as practical

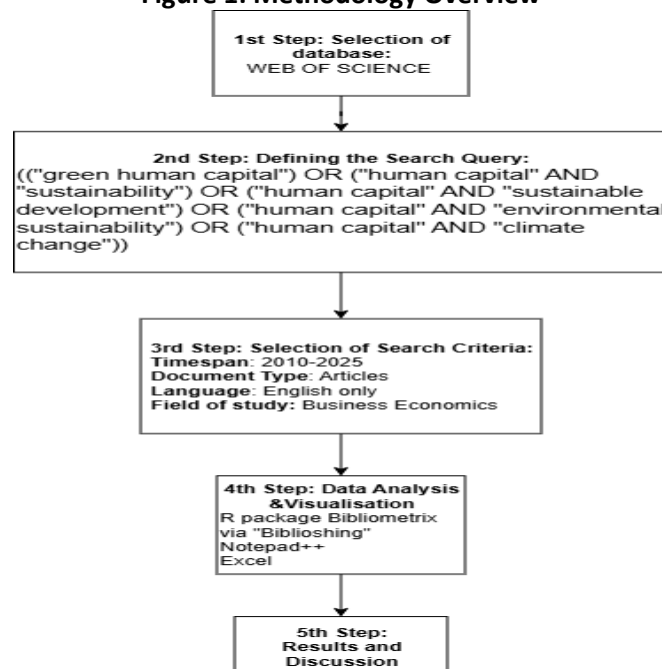
implications for policymakers, educators, and business leaders in leveraging human capital as a driver of green transformation.

The significance of this study lies in its potential to advance both theoretical and practical knowledge. From an academic perspective, it provides a systematic overview of a growing but underexplored field, thereby serving as a foundation for future research agendas. From a policy and business perspective, understanding GHC is critical to designing effective green education systems, workforce development strategies, and corporate sustainability practices.

1. Research methodology

The aim of this bibliometric analysis is to systematically examine the global scientific production on GHC and sustainability. The tool used to retrieve the dataset of the bibliometric is Web of Science database, chosen for its rigorous indexing standards and comprehensive coverage of high-quality publications. Relevant articles were identified using a search protocol. The following figure shows the search strategy used in this bibliometric analysis:

Figure 1: Methodology Overview



Source: Author's construction based on Web of Science output

The dataset was exported as multiple documents in a compatible format (BibTeX) and organized using Notepad++. It was then analysed with the “Bibliometrix: package in R via “Biblioshiny”. The results were subsequently exported to Excel, from which the tables and figures presented in this study were extracted. This process enabled a multifaceted analysis of the field, including:

- Descriptive performance analysis: annual publication trends, most cited papers, leading journals, authors, institutions, and countries.
- Citation and co-citation analysis: to identify influential authors, seminal works, and intellectual foundations of the field.

- Collaboration network mapping: at the levels of authors, institutions, and countries, highlighting patterns of international cooperation.
- Thematic and conceptual structure analysis: using keyword co-occurrence, thematic evolution, and cluster mapping to trace research directions and intellectual development.

By integrating Web of Science (WoS) data with Biblioshiny tools in R, this study provides a transparent, reproducible, and comprehensive mapping of the GHC literature, offering insights into both the social structure (collaboration and knowledge networks) and the conceptual structure (themes and research frontiers) of the field.

1.2 Research structure

This paper is structured into four main sections. The introduction integrates the background, literature review, research gap, and methodology, setting the foundation for the study. The results section presents the bibliometric findings, including trends in publications, key countries, institutions, authors, journals, collaboration patterns, and thematic structures. The implications highlight the study's contributions to academia, practice, and policy. Finally, the conclusion summarizes the main insights, offers recommendations, and outlines future research directions.

2. Results

2.1 Main Information

The bibliometric analysis indicates that, a total of 501 documents were authored by 1468 researchers published related to GHC and sustainability between 2010 and 2025. The publications utilized 1753 unique keywords. These datasets suggest a well-established and actively evolving research area characterized by moderate collaboration, significant global engagement, and impactful scholarly output.

Figure 2: Overview of the Main Information of the Dataset



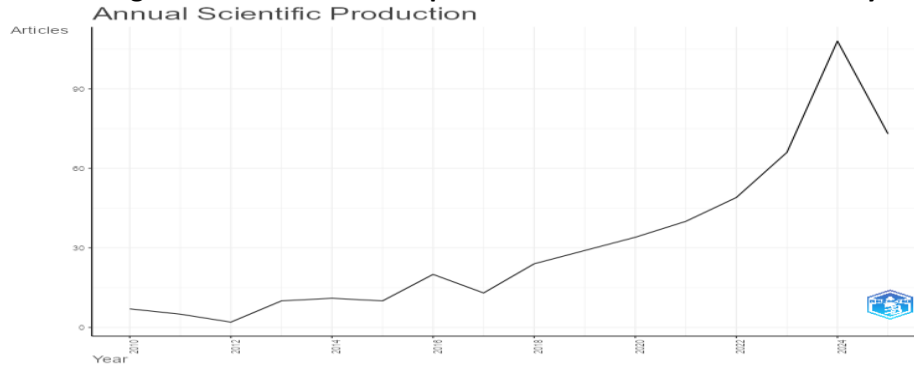
Source: Author's construction based on Web of Science database

2.2 Scientific Production

The analysis of annual scientific production in Fig (3) shows a steady growth trend in publications related to GHC and sustainability. Between 2010 and 2015, the number of publications remained relatively low and stable, with fewer than 20 articles per year, reflecting the emerging stage of research in this domain. From 2016 to 2020, production began to rise more consistently, indicating growing academic interest and recognition of the relevance of sustainability and GHC. A significant surge is observed from 2020 to 2023, with a sharp increase peaking in 2023 at over 90 articles. This rapid growth aligns with the heightened global attention to sustainability issues, climate change policies, and the integration of HC

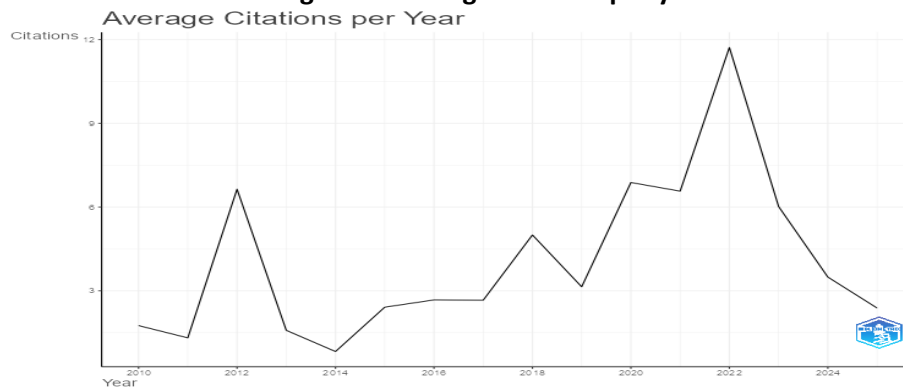
considerations into green transitions. The apparent decline in publications in 2025 compared to previous years can be attributed to the fact that data for the current year remain incomplete.

Figure 3: Annual scientific publication of GHC and sustainability



Source: Author's construction based on Web of Science database

Figure 4: Average citations per year



Source: Author's construction based on Web of Science database

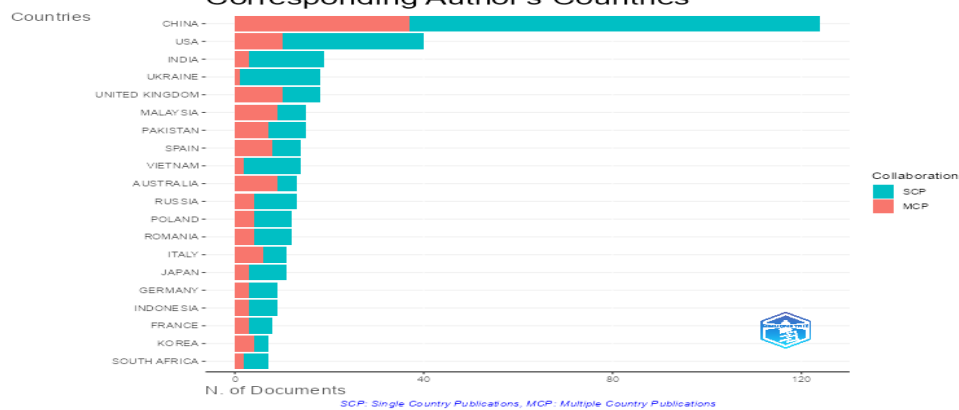
The average citations per year in Fig (4) illustrate the influence of the published works over time. Citation trends show fluctuations, with noticeable peaks in 2012 and 2022. The peak in 2022, reaching nearly 12 average citations, indicates that works published around this period were particularly influential in shaping the academic discourse on GHC and sustainability. From 2023 onwards, a decline in citations is evident, which is common in bibliometric analyses as recently published works typically require time to accumulate citations.

2.3 Country analysis

The analysis of corresponding authors' countries in figure (5) provides insight into the geographical distribution of research on GHC and sustainability. China stands out as the leading contributor with more than 120 publications, reflecting its strong national emphasis on sustainability-related scholarship. The United States and India follow, each contributing a substantial but smaller number of documents compared to China. Other countries such as Ukraine, the United Kingdom, Malaysia, Pakistan, and Spain represent active contributors with moderate outputs, while Vietnam, Australia, Russia, Poland, and Romania also participate but at a lower scale. A second tier of contributors includes Italy, Japan, Germany, Indonesia, France, South Korea, and South Africa, which demonstrate emerging engagement in the field. In

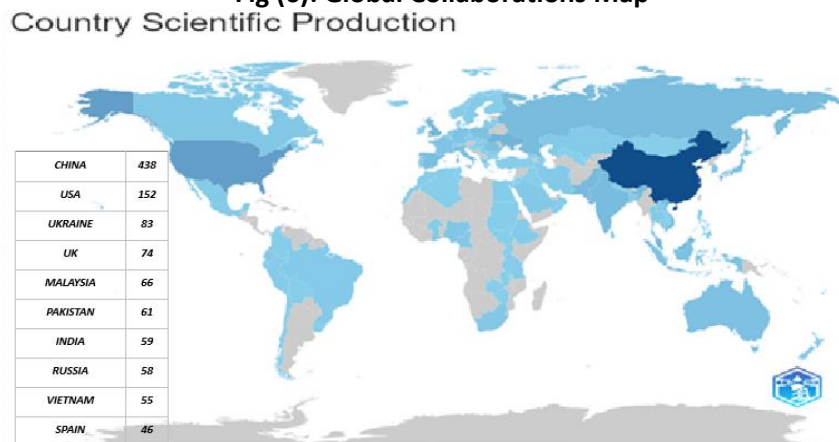
terms of collaboration patterns, the data distinguish between single-country publications (SCP) and multiple-country publications (MCP). The results reveal that China's production is predominantly domestic, with a larger share of SCPs. In contrast, countries such as the United Kingdom, Australia, Spain, Pakistan and Malaysia display higher proportions of MCPs, highlighting their stronger involvement in international collaborations.

Figure 5: TOP 20 most productive countries in research publications
Corresponding Author's Countries



Source: Author's construction based on Web of Science database

Fig (6): Global Collaborations Map

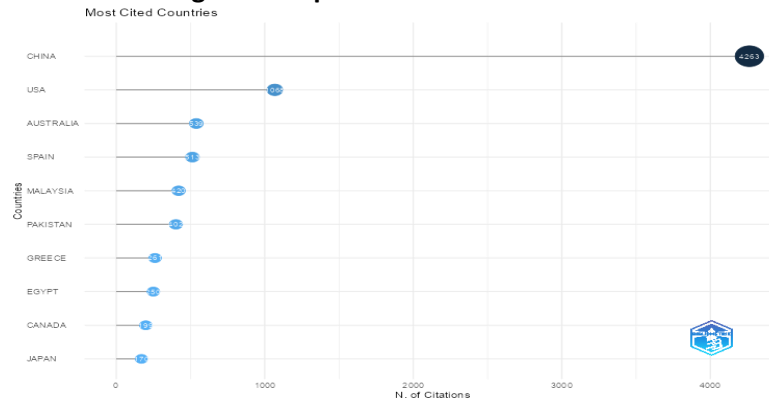


Source: Author's construction based on Web of Science database

The Global Contributions Map, specifically in Fig (6), illustrates the geographic distribution of research contributions. Darker areas indicate higher publication counts, with China leading at 438 publications. This map emphasizes the top 10 most county productive of this field. The bibliometric mapping reveals significant geographical asymmetries in scientific production. China emerges as the dominant contributor (438 publications), followed by the USA (152) and the UK (74), reflecting the concentration of research capacity in established academic hubs. Notably, emerging economies such as Ukraine (83), Malaysia (66), Pakistan (61), India (59), and Vietnam (55) demonstrate increasing engagement, signalling a shift toward broader regional participation in sustainability-related scholarship. In contrast, contributions from Africa and Latin America remain limited, underscoring

persistent gaps in global knowledge diffusion and the need for more inclusive research collaborations.

Figure 7: Top-10 most cited countries



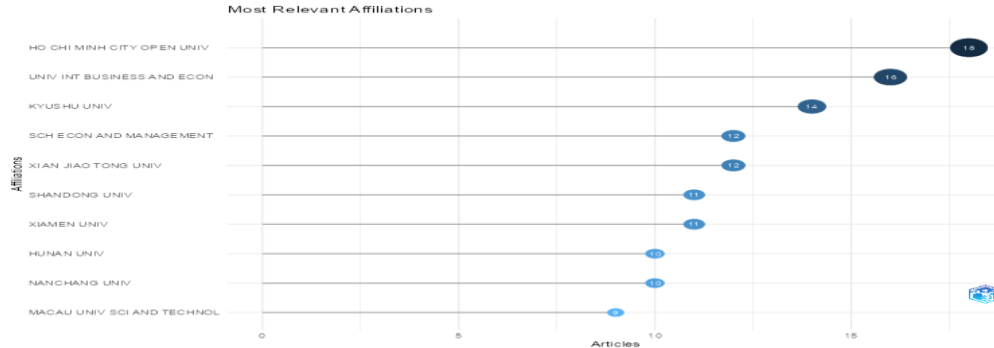
Source: Author's construction based on Web of Science database

The bibliometric analysis indicates that China dominates the field, with 4,263 citations, reflecting its substantial influence and leadership in shaping the research agenda on green human capital and sustainability. The United States follows with 1,065 citations, confirming its role as a key contributor to advancing theoretical and empirical developments. Spain (511), Australia (339), and Pakistan (402) also emerge as important hubs of scholarly impact, despite comparatively lower output volumes. Other countries, such as Malaysia, Greece, Egypt, Canada, and Japan, demonstrate growing visibility, although their citation counts remain modest in comparison. This distribution reveals a concentration of highly cited research in advanced and emerging economies, underscoring the role of international collaboration and policy-driven research initiatives. However, the relatively limited citation impact of many developing countries highlights the need to strengthen global participation and knowledge exchange to advance sustainable human capital practices on a broader scale.

2.4 Source and author analysis

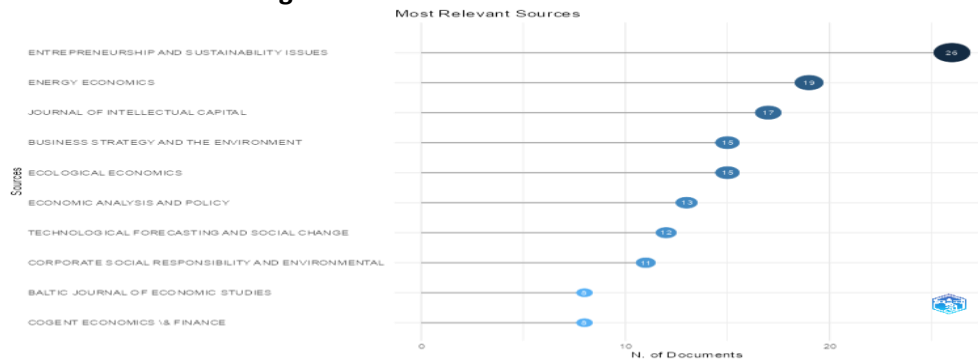
In examining the institutional contributions to research on GHC and sustainability, Fig (8) highlights a group of universities that have emerged as leading producers of knowledge in this domain. The clear leader is Ho Chi Minh City Open University (Vietnam), with a total of 18 publications, followed closely by the University of International Business and Economics (China) with 16 publications. Other notable institutions include Kyushu University (Japan) with 14 publications, School of Economics and Management (12 publications), and Xi'an Jiaotong University (12 publications), each representing a significant node in the global research network.

Figure 8: Top-10 most relevant affiliations



Source: Author's construction based on Web of Science database.

Figure 9: TOP 10 most relevant sources

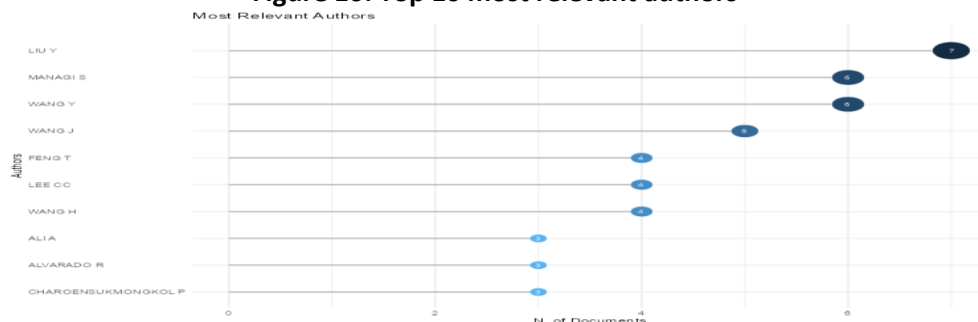


Source: Author's construction based on Web of Science database

Additional institutions such as Shandong University (11), Xiamen University (11), and Hunan University (10) also demonstrate strong engagement, while Wanchang University (10) and Macau University of Science and Technology (9) provide further evidence of the growing diversification of institutional participation.

The advancement of research on GHR and sustainability is shaped by a combination of established academic institutions and emerging regional universities, reflecting regional priorities in sustainable development and the integration of GHC into environmental and economic strategies.

Figure 10: Top 10 most relevant authors



Source: Author's construction based on Web of Science database

Table 1 top 10- most cited paper

Paper	DOI	Total Citations
(Chuang & Huang, 2018)	10.1007/s10551-016-3167-x	325
(Chen et al., 2022)	10.1016/j.jdeveco.2022.102833	273
(Ren et al., 2022)	10.1002/bse.2975	252
(ElMassah & Mohieldin, 2020)	10.1016/j.ecolecon.2019.106490	249
(Yao et al., 2020)	10.1016/j.eneco.2020.104907	212
(Wang & Juo, 2021)	10.1002/bse.2800	203
(Consoli et al., 2016)	10.1016/j.respol.2016.02.007	197
(Apergis et al., 2022)	10.1016/j.eneco.2021.105430	177
(Eastin, 2018)	10.1016/j.worlddev.2018.02.021	176
(Zivin et al., 2018)	10.1086/694177	171

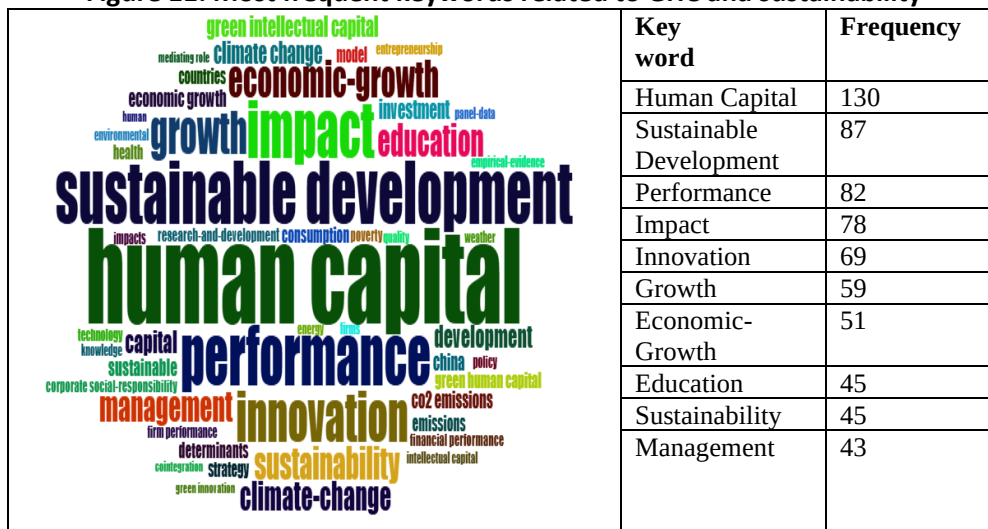
Source: Author's construction based on Web of Science database

2.5 Content Analysis

2.5.1 Keyword Map

Figure (11) illustrates the most frequently occurring keywords, with “Human Capital”, “Sustainable Development”, “Performance”, and “Impact” emerging as dominant terms, reflecting their central role in the research domain. Other significant keywords such as “Innovation”, “Economic Growth”, “Education”, “Sustainability”, “Management”, and “Climate Change” highlight the thematic linkages between human capital, organizational outcomes, and broader sustainability challenges. The visualization suggests that the literature clusters around three main research streams: human capital as a driver of sustainable development, its role in performance, innovation, and management, and its connection with economic growth, education, and climate-related issues.

Figure 11: Most frequent keywords related to GHC and sustainability



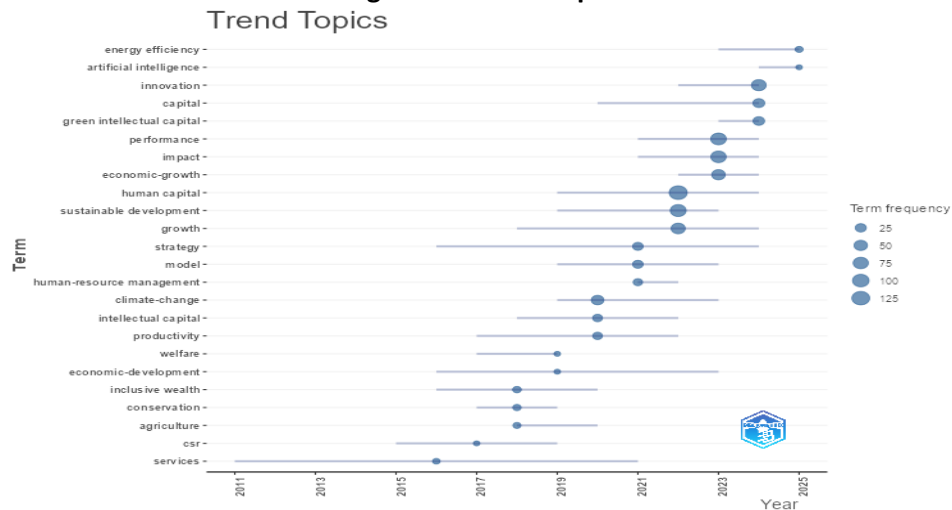
Source: Author's construction based on Web of Science database

2.5.2 Trend Topic

The evolution of research topics indicates a dynamic shift in scholarly attention toward multidimensional aspects of GHC and sustainability. Early studies were closely aligned with concepts such as CSR, services, and agriculture, while more recent years show a surge in high-frequency terms like innovation, green intellectual capital, performance, and economic growth.

Notably, the increasing prominence of artificial intelligence, energy efficiency, and climate change since 2021 reflects the integration of technological and environmental considerations into sustainability discourse. The persistent relevance of human capital and sustainable development highlights their centrality as theoretical and practical anchors in the field, while emerging intersections suggest a progressive broadening of the research agenda.

Figure 12: Trend topics

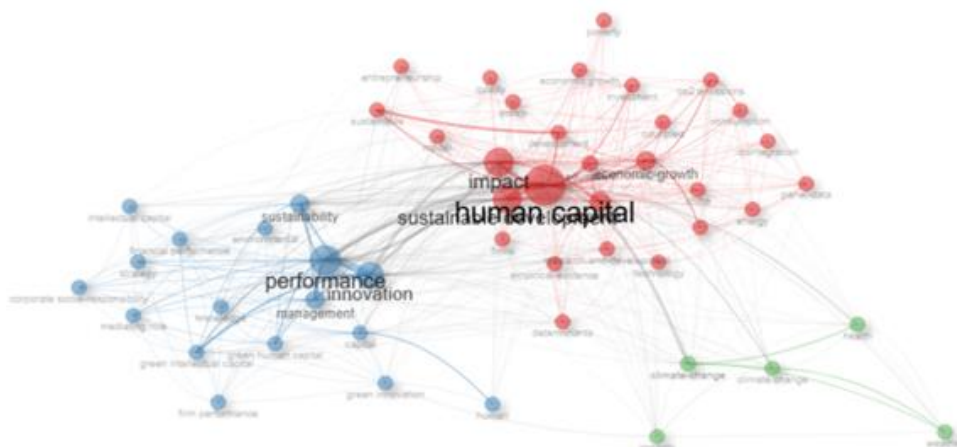


Source: Author's construction based on Web of Science database

2.6 conceptual structure

2.6.1 Co-Occurrence

Figure 13: Co-occurrence Network



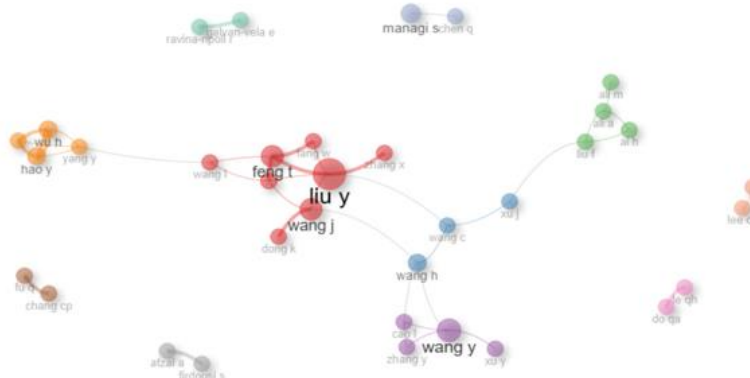
Source: Author's construction based on Web of Science database

Figure 13 represents network visualisation of co-occurrence keywords in GHC and sustainability, nodes represent keywords, while edges indicate their connections in the bibliometric dataset. The network illustrates that research on GHC and sustainability converges around three thematic grouping: macroeconomic development and policy impacts, organizational performance and innovation, and environmental and climate-related issues. This clustering suggests a multidisciplinary field that integrates economics, management, and environmental studies to advance understanding of how human capital supports sustainability transitions. The red cluster centres on “human capital”, “economic growth”. In cluster blue which is structured around “performance”, “innovation”, “management”, and “sustainability”, GHC is viewed as a driver of firm-level competitiveness, innovation, and strategic sustainability practices. The green cluster is structured around “climate change”, pointing to the environmental and social challenges where human capital is linked to climate adaptation, resilience, and well-being.

2.6.2 Co-occurrence Authors

The bibliometric network on Green Human Capital and Sustainability reveals several distinct research clusters with varying degrees of influence and collaboration. At the centre, Liu Y and collaborators such as Wang J and Feng T form the dominant core group, indicating their pivotal role in shaping the intellectual foundation of the field. Surrounding clusters, such as the groups led by Wang Y, Wu H, and Ali M, represent specialized or regional contributions that extend the application of green human capital into diverse sustainability contexts.

Figure 14: Author's Co-occurrence



Source: Author's construction based on Web of Science database

The network also highlights the presence of smaller, peripheral clusters and isolated authors, suggesting emerging voices that are not yet fully integrated into the mainstream discourse. Overall, the figure illustrates a field that is consolidating around central contributors while simultaneously expanding globally through cross-regional collaborations.

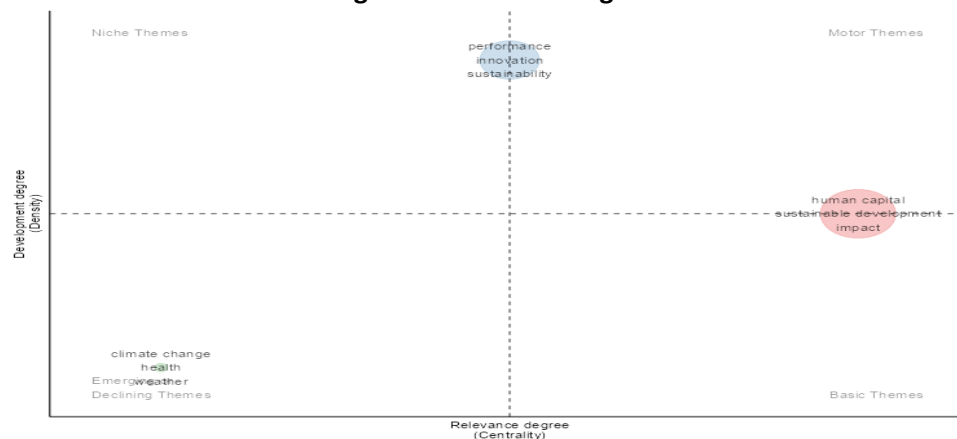
2.6.3 Themes Diagram

The strategic diagram highlights the thematic positioning of research on *GHC* and Sustainability. In the basic themes quadrant, concepts such as human capital, sustainable development, and impact appear as highly central but less developed,

suggesting they are foundational to the field and widely discussed, yet still require further theoretical refinement and integration. The motor themes quadrant is unoccupied, indicating a lack of dominant, well-developed, and highly influential topics driving the field forward. In contrast, the niche themes quadrant shows topics like performance, innovation, and sustainability, which are well-developed but not yet central to the broader discourse, these could represent specialized research streams with potential to gain prominence.

Finally, the emerging or declining themes quadrant includes climate change, health, and weather, which appear less central and underdeveloped, possibly indicating areas of limited focus within this particular research domain or topics at risk of being overshadowed. Overall, the field is grounded in human capital and sustainable development but is evolving, with opportunities to strengthen cross-linkages with innovation and performance for greater impact

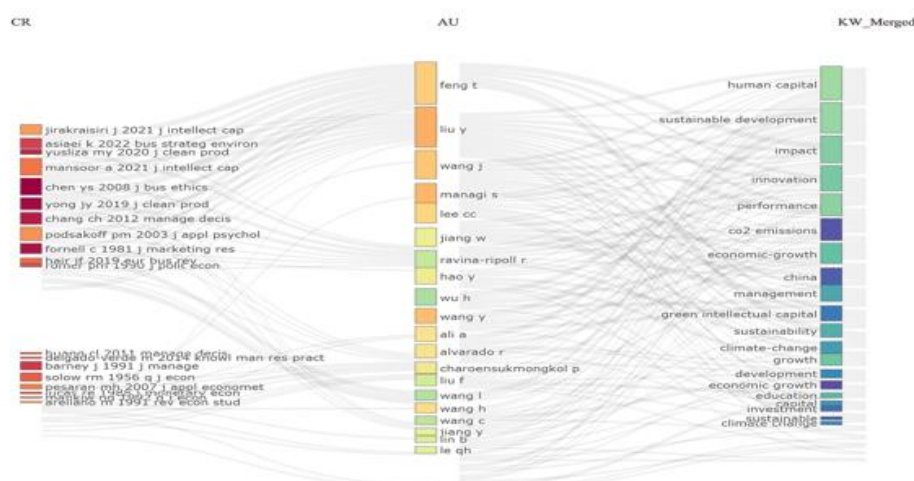
Figure 15: Themes diagram



Source: Author's construction based on Web of Science database

2.6.4 Three-field plot maps

Figure 16: Three-field plot maps



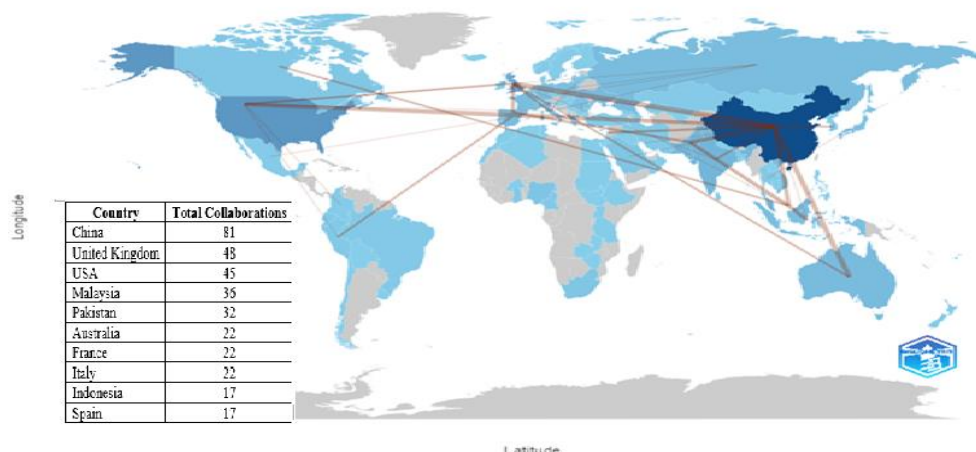
Source: Author's construction based on Web of Science database

The figure (16) represents the three-field plot maps the connections between core references (CR), authors (AU), and merged keywords (KW) in the literature on *GHC* and Sustainability.

- On the left, foundational works such as Jirakraisiri (2021), Asaiei (2022), and Mansoor (2021) serve as critical references shaping the field, while classical contributions from Barney (1991) and Solow (1956) anchor the theoretical and economic foundations.
- In the centre, authors like Feng T, Liu Y, Wang J, and Managi S emerge as central figures bridging these references to thematic areas.
- On the right, the dominant keywords are human capital, sustainable development, impact, innovation, and performance which highlight the thematic priorities, showing that research is heavily oriented toward linking human capital and sustainability outcomes with organizational performance. Secondary themes such as CO₂ emissions, economic growth, and green intellectual capital indicate a strong intersection with environmental and economic dimensions.

2.7 Social Structure

Figure 17: International Collaboration Map



Source: Author's construction based on Web of Science database

The collaboration data reveals a highly uneven but interconnected global research network on green human capital and sustainability. China emerges as the central hub, with the highest number of collaborations (81), far surpassing all others. This reflects China's growing influence in sustainability research and its ability to bridge diverse regions. The United Kingdom (48) and the USA (45) also act as global connectors, strengthening transatlantic and Asia–Europe research ties.

Interestingly, Malaysia (36) and Pakistan (32) stand out as regional leaders in Asia, forming strong links with both neighbouring and distant partners, which suggests their active role in facilitating South–South collaboration. Meanwhile, Australia, France, and Italy (22 each) maintain balanced international partnerships, while Indonesia and Spain (17 each) highlight growing engagement in this field.

Overall, the collaboration map underscores a hub-and-spoke structure, dominated by China, the UK, and the USA, but also shows the rise of emerging regional players like Malaysia and Pakistan, which are helping to diversify the global sustainability research landscape.

3. Implication:

The bibliometric analysis of Green Human Capital and sustainability reveals several significant implications for theory, practice and future research directions. First, the exponential growth in publications, particularly between 2020 and 2024, reflects the rapid maturation of research on the role of human capital in green transitions. This trend highlights the growing need for deeper engagement from both scholars and practitioners. In line with this, a special call for collaboration to advance the understanding of Green Human Resource Management (GHRM) was made in the book *Greening People: Human Resources and Environmental Management*, which invited academicians and practitioners to contribute by writing articles on the subject (Wehrmeyer, 2017). Furthermore, in their seminal work of “*The Central Role of Human Resource Management in the Search for Sustainable Organizations*”, emphasized the importance of integrating HRM with broader organizational management initiatives to support sustainability goals.

Second, the geographical research gap illustrates primary influential contributors like China, the United States, and the United Kingdom while also revealing significant disparities in research capacity and focus. The dominance of certain countries in citation impact, particularly china, United States and Australia, suggests a need for more inclusive international collaboration to ensure diverse perspectives in theory development and practical applications.

Collaboration networks reveal robust international partnerships; however, notable geographical disparities persist, especially with minimal contributions from Africa and Latin America. The study delineates three principal research streams: macroeconomic and policy-oriented perspectives, organizational performance and innovation, and environmental and climate-related issues.

Conclusion:

This research has presented a comprehensive bibliometric analysis at the intersection of green human capital and sustainability from 2010 to 2025. Through systematic analysis of 501 articles authored by 1468 researchers, our research reveals several key insights about the evolution and current state of this research domain.

The temporal analysis demonstrates evidence of a shift from a slow development in 2010-2020 to explosive growth in 2020-2025, marking a paradigm shift in how researchers raise their global interests in sustainability and the incorporation of human capital in green transitions.

Our findings identified significant gaps and opportunities in the current research framework; countries like China, the United States, and the United Kingdom are the predominant donors, although rising economies like Malaysia, Pakistan, and Ukraine are increasingly significant. This concentration of research output in specific geographical regions suggests an opportunity for more diverse perspectives and collaborative research initiatives. Collaboration networks demonstrate robust international connections; yet, notable geographical disparities persist, especially with minimal contributions from Africa and Latin America.

The study highlighted three principal research frameworks: macroeconomic and policy-oriented viewpoints, organizational performance and innovation, and environmental and climate-related challenges.

Our recommendations for future studies ought to broaden data sources beyond the Web of Science, implement comparative and longitudinal methodologies, and

further explore the intersections of GHC with digitalization, artificial intelligence, and climate adaptation. These research directions are not merely academic pursuits but are crucial for understanding and shaping the future of GRH in sustainability strategies which can further enhance both scholarly comprehension and pragmatic approaches for optimizing green human capital in the quest for global sustainability.

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