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Trends, Hotspots, and Future Prospects: The Evolution of Green Intellectual Capital Bibliometric Analysis (2008-2024)

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ABSTRACT

This study uses bibliometric analysis to systematically review 894 scientific publications on green intellectual capital from 2008 to 2024. The study is based on Scopus database and analyzed by keyword, author, country, citations, publications, universities and journals. The findings reveal that research interest has grown dramatically since the notion of green intellectual capital was originally introduced in 2008, particularly following the COVID-19 outbreak. Malaysian author Yusliza Mohd Yusoff, as well as Spanish authors Bartolome Marco-Lajara and Eduardo Sanchez-Garcia, have written numerous high-quality works in this topic, making them prolific authors. Furthermore, Malaysian and Chinese institutions studying green intellectual capital have a big number of papers and a diverse range of academic influence. China has contributed the most funding for green intellectual capital initiatives. According to keyword co-occurrence analysis, green innovation, environmental performance, and sustainable development are the three main issues of green intellectual capital research. This study also discovers that countries with more green intellectual capital projects receive higher financing support for these initiatives.

Keywords: Bibliometric analysis; meta-analysis; green intellectual capital; Scopus; VOSviewer; BiblioMagika; OpenRefine; Biblioshiny; R studio

INTRODUCTION

Green Intellectual Capital (GIC) is a novel concept that combines intellectual capital and environmental performance, designed to meet stringent international environmental regulations and consumer demand for sustainability (Haldorai et al. 2022). GIC is the knowledge, expertise, and relationships companies apply to grow and set themselves apart in environmentally friendly projects (Jiao et al. 2023). Green human capital (the knowledge and skills of employees that are utilized for environmental management and sustainable practices) (AlKetbi & Rice 2024; Jiao et al. 2023; Mahmood & Nasir 2023), green structural capital (the systems, policies, and technologies within a company that support green innovation and sustainable practices) (Abdelwahed et al. 2022; Ali et al. 2021; Al-Khatib & Shuhaiber 2022), and green relational capital (the ties and networks that a company builds with external stakeholders that help to its environmental achievement) (Ali et al. 2021; Al-Khatib & Shuhaiber 2022; Asiaei et al. 2022; Haldorai et al. 2022).

Investments in GIC have been demonstrated to boost the competitive advantages of organizations (Ali et al. 2021; Chen 2008; Jiao et al. 2023). Companies that actively develop GIC not only meet environmental standards (Abdelwahed et al. 2022), but also gain superior market positioning and financial success through innovative approaches (Asiaei et al. 2022; Jiao et al. 2023). Incorporating GIC into corporate strategy fosters a culture of sustainability, which is an important driver of long-term performance and resilience (Asiaei et al. 2022). Research shows that GIC components have a beneficial impact on corporate green innovation adoption and long-term performance (Abdelwahed et al. 2022; Jiao et al. 2023; Mahmood & Nasir 2023). This includes improvements in economic, environmental, and social outcomes (Jiao et al. 2022; Malik et al. 2020). Furthermore, green relational capital has been identified as a vital aspect in accomplishing environmental objectives and promoting social innovation (Ali et al. 2021).

The concept of GIC was first introduced in 2008 (Chen 2008). At this point, the extant literature on the study of GIC is rather tiny, but we can see that scientific research on this area is rising year after year. Following COVID-19 in 2020, research on GIC increased significantly, indicating that GIC is an inspiring and promising topic. With increased environmental concerns and resource shortages, corporations are becoming more aware of the significance of implementing green and sustainable practices (Ali et al. 2021; Malik et al. 2020). Understanding and improving GIC can aid in their transition to more sustainable forms of functioning. Although research on "green intellectual capital," "green human capital," "green structural capital," and "green relational capital" exists, as does SLR for green intellectual capital (Ahlawat et al. 2023), but there is a lack of study on bibliometrics analysis.

The purpose of this study is to do a meta-analysis of GIC research from 2008 to 2024 using bibliometric metadata. Field analyses will be conducted based on variables such as keywords, authors, countries, citations, publications, universities, and journals, using the following questions:

1. What are the publication trends in the field of green intellectual capital, and how have they changed over time?
2. Who are the most prolific authors in the field, and what are the key themes and topics in their research?
3. What are the most influential institutions in the field of green intellectual capital, and how have they contributed to the development of the field?
4. What are the most active countries in the field of green intellectual capital, and how does this vary across different regions and time periods?
5. What are the most highly cited documents in the field of green intellectual capital, and what are the key themes and topics that they address?
6. What are the most common keywords and themes in the literature on green intellectual capital, and how have they evolved over time?
7. What are the patterns of co-authorship in the field of green intellectual capital, and how do they vary across different regions, institutions, and research topics?
8. What are the key themes and topics that emerge from co-occurrence analyses of author keywords and title/abstract terms in the literature on green intellectual capital?

Bibliometric examination of GIC involves multiple implications. It enables academics to quantitatively assess literature using mathematical and statistical tools, allowing them to quickly grasp the field's evolution and cutting-edge topics. Visualization facilitates macro-level field dynamics comprehension. Bibliometric analysis may also evaluate the influence of authors, institutions, and journals in the industry, demonstrating how GIC contributes to economic value and sustainable development, assisting managers and investors in making decisions. It can also indicate research gaps and underexplored concerns, forecast field trends, and introduce academics to new study areas and opportunities. Compared to SLR, bibliometric analysis can quantify the structure, influence, and trends of a research field from a macro perspective, making it particularly suitable for exploring the overall landscape of broad fields or tracing developmental trajectories, rather than focusing solely on in-depth analysis of a small number of studies.

This study examined all relevant scientific publications published from 2008 to July 2024 using bibliometric methods and highlighted the key research questions and important entities in the research field. The remaining sections of this work are summarized as follows: research methodology; results and discussion; conclusion on future work.

A BRIEF OVERVIEW OF PREVIOUS LITERATURE REVIEW STUDIES

Green human capital significantly impacts enterprises' environmental sustainability by improving employees' environmental knowledge and attitude and motivating green behaviors, highlighting its central role in promoting environmental sustainability (Shoaib et al. 2021). The researchers also show the evolution, antecedents, and results of GIC in promoting industrial sustainability, showing that it has a positive impact and can improve industrial environment sustainability through innovative green technologies and management strategies, providing new perspectives and ideas for sustainable industrial development (Damaianti 2022). The systematic literature review also thoroughly examines GIC and its future development providing a theoretical foundation for firms to build environmental policies (Ahlawat et al. 2023). The literature review concludes that GIC improves corporate environmental performance by enhancing organizational learning, innovation and employee environmental awareness and provides practical guidance for enterprises (Benevene et al. 2021).

In Table 1, some studies have used literature analysis to navigate GIC. However, a thorough literature analysis reveals significant research gaps that offer chances for further study:

DATA SOURCE SPECIFICITY

Previous literature review research on GIC generally relied on databases such as the Web of Science (Ahlawat et al. 2023; Benevene et al. 2021), Science Direct (Damaianti 2022), and Scopus (Ahlawat et al. 2023), and tended to be exclusive. Such uniqueness may limit the extent and depth of the study, especially in reflecting the richness and diversity of research on the topic. Our research will employ the Scopus database, which is noted for its thorough coverage of interdisciplinary research publications, to provide a broader and accurate view of the green intellectual capital literature (Agarwal et al. 2016; Hirsch 2005).

LANGUAGE LIMITATIONS

Some previous studies have been limited to English articles (Ahlawat et al. 2023; Benevene et al. 2021; Shoaib et al. 2021). While these studies provide valuable insights, they may not fully represent the global contribution to GIC. This study will include articles from around the world, with no specific language restrictions, thus providing a more global perspective.

TIME SPAN OF LITERATURE

As shown in Table 1, the existing studies have different coverage periods, and some do not specify the time frame. Our study addresses this gap by providing continuous and comprehensive coverage from 2008 to 2024 when the concept of GIC first emerged. This approach will help us shed light on green intellectual capital's detailed progress and evolution.

TOTAL DOCUMENTS EXAMINED

The existing literature review only selected some literature for analysis, and the number was no more than 35. This paper analyzes 894 literatures, which is more comprehensive.

ANALYSIS SOFTWARE

In terms of analysis software, most current literature reviews use single tool to analyze literature data (Ahlawat et al. 2023; Djeki et al. 2022). However, single analytical approach may not disclose all of the literary data's deep structure and associations. This study employs several analytical tools, including biblioMagika, VOSViewer, and biblioshiny, to conduct a thorough visual examination of literature material from multiple perspectives.

EXTENSIVE OF STUDY SCOPE

The existing literature reviews focus on the analysis of research content (Ahlawat et al. 2023; Benevene et al. 2021; Shoaib et al. 2021), and on this basis, this study analyzes the funding support, language, and document types, so that readers can have a comprehensive understanding of the existing research in this field.

TABLE 1. Summary of previous studies related to literature review and green intellectual capital

Author & Year	Title	Time Span of Literature	Data Source & Coverage	Research Gaps	Total Documents Examined
Paula Benevene et al. 2021	Management of Green Intellectual Capital: Evidence-Based Literature Review and Future Directions	2008-2020	Web of Science, Scopus	Focus on quantitative research	33
Muhammad Shoaib et al. 2021	Green Human Resource Management and Green Human Capital: A Systematic Literature Review	2008-2020	Secondary data from academic journals	Only green human capital is studied	25
Deepika Ahlawat et al. 2023	A systematic literature review of current understanding and future directions on Green Intellectual Capital	2008-2022	Scopus, Web of Science	Small sample size and no visualization	31

RESEARCH METHODOLOGY

RESEARCH DESIGN

This study is carried out in relation to the analysis approach based on bibliometric data from research publications dealing with GIC. The analysis is divided into two parts: (1) bibliometric mapping to investigate trends in green intellectual capital, and (2) analysis of author keywords indexed in papers to identify research groups and comprehend the research themes associated with GIC.

OBTAINING DATA SET

Scopus, a bibliographic database published by Elsevier in November 2004 (Scopus 2024), was chosen to meet the current study objectives. Scopus is a massive database that covers global research in various areas, including science, technology, health, social sciences, and humanities. It contains 27,950 titles from over 5,000 publishers (Scopus 2024). As Fig 1 shows, this study began by querying the Scopus database using the online TITLE-ABS-KEY ("green intellectual capital" OR "green human capital" OR "green human resource" OR "green structural capital" OR "green relational capital" OR "sustainable intellectual capital" OR "sustainable human capital" OR

"sustainable structural capital" OR "sustainable relational capital" OR "environmental intellectual capital" OR "environmental human capital" OR "environmental structural capital" OR "environmental relational capital." 244 publications with incomplete data or irrelated were removed, leaving 894 results. Filtering the final search string provided 894 articles for bibliometric analysis. As of July 2024, the study covered all papers in the Scopus database that were associated with and classified as "green intellectual capital."

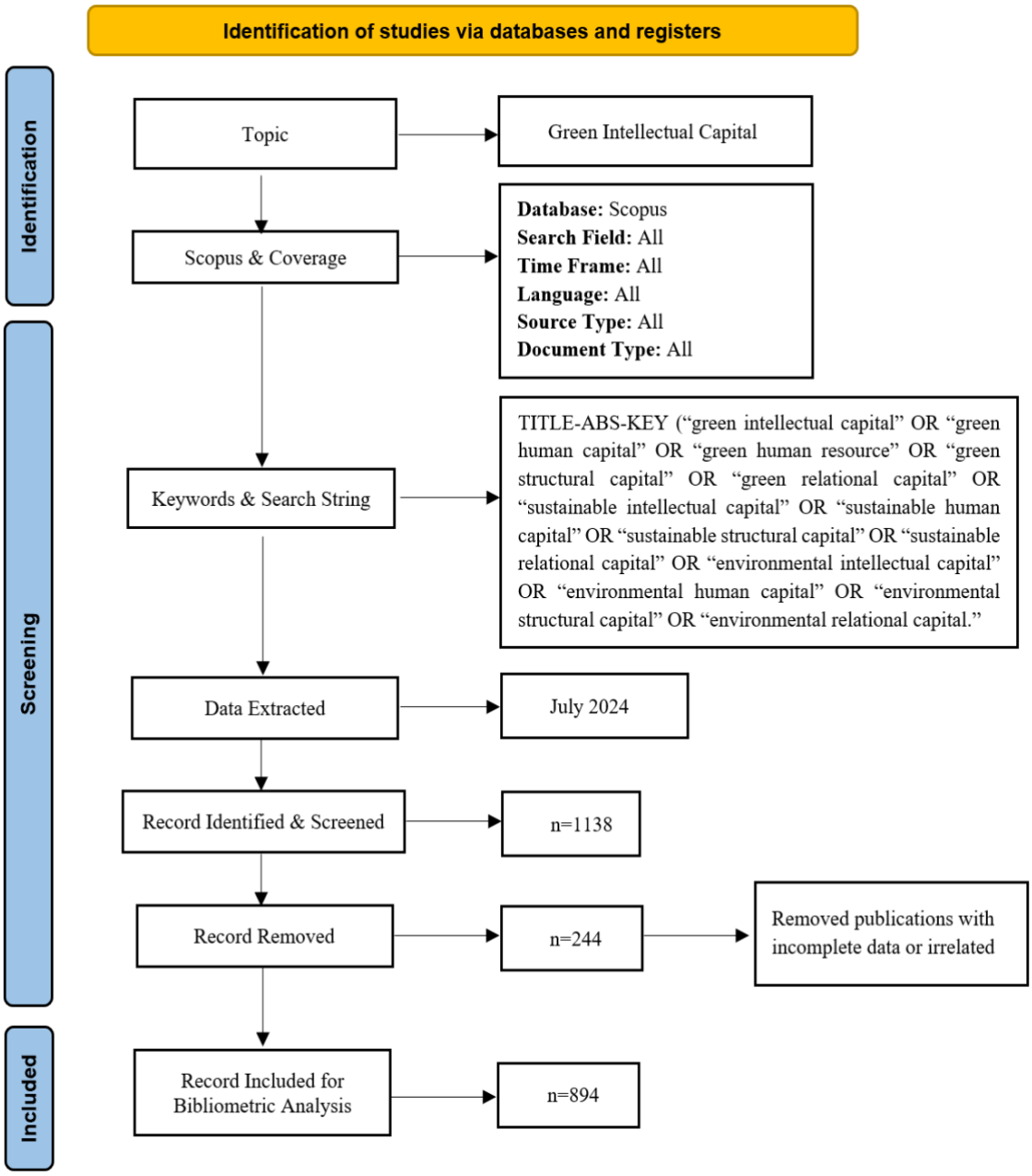

FIGURE 1. Flow diagram of the search strategy

DATA CLEANING AND HARMONIZATION

The first step was cleaning data using BiblioMagika 1.6, BiblioMagika 2.5.1, and OpenRefine. Data cleaning is a key stage in removing errors, duplication, and inconsistencies, which ensures the accuracy of the information used for analysis (Maharana et al. 2022; Petrova-Antonova & Tancheva 2020). These two applications were designed to clean and standardize complex data including author names, affiliations, keywords, and other critical bibliographic information. Given the range of research outputs and potential data inconsistencies, these technologies are crucial for ensuring data accuracy and consistency (Punj et al. 2023). The initial phase in data cleaning involves acquiring Scopus datasets in .csv format. The chosen datasets undergo a cleansing procedure where columns like keywords, author names, and affiliations are refined using the capabilities of clustering tools. During this stage, OpenRefine plays a pivotal role, streamlining the normalization of data and significantly

enhancing its precision (Petrova-Antonova & Tancheva 2020). BiblioMagika is a tool that facilitates an in-depth bibliometric analysis by generating an array of metrics (Ahmi 2023). Furthermore, BiblioMagika discovers missing data, allowing us to manually fill empty spaces during cleaning and harmonization tasks (Ahmi 2023). Following the initial cleaning, this study thoroughly evaluates all filtered and changed keywords to verify accuracy. To maintain data consistency, multi-valued cells were linked, and the original segmentation separators were re-entered. Finally, the cleaned and harmonized data was kept in its original format for further investigation. The harmonization and cleaning process also increases the dataset's quality and clarity, ensuring the credibility of future studies and research findings.

DATA ANALYSIS

This study outputs data after biblioMagika cleanup analysis and applies a website named iipmaps.com to visualize the publication of green intellectual capital research across countries. VOSviewer software was used to analyze bibliometric meta-data for co-authorship, bibliographic coupling, keyword co-occurrence, and citation. Bibliographic coupling refers to the relationships between objects such as publications, journals, and authors. The examination of keyword co-occurrence illustrates how the domain evolved over time (Marrone et al. 2020). It is regarded an excellent approach for selecting hot topics in a certain study domain. Citation analysis enables scientists to identify popular research themes and articles that other researchers are working on (Colavizza et al. 2020). This study uses BiblioShiny to identify major themes and trends in the literature. BiblioShiny can generate word clouds, trend charts and other charts to help users intuitively understand research hotspots and developments in the scientific research field (Ahlawat et al. 2023a).The analysis results are given as a table or a network visualization map.

RESULTS AND DISCUSSION

DOCUMENTS PROFILES

Table 2 shows publications and citations in the field of green intellectual capital from 2008 to 2024. During that time, there were 894 publications involving 3,050 authors. 694 papers were cited by other papers, bringing the total number of citations to 29,888. On average, each paper was cited 33.43 times, while each cited paper was cited 43.07 times. There are an average of 1,868 citations per year and an average of 9.80 citations per author. The average number of authors per paper was 3.41. In addition, papers within the h-core were cited 15,142 times, with an h-index of 50 and a g-index of 57.

Table 2. Citation metrics

Main Information	Data
Publication Years	2008 - 2024
Total Publications	894
Citable Year	17
Number of Contributing Authors	3050
Number of Cited Papers	694
Total Citations	29,888
Citation per Paper	33.43
Citation per Cited Paper	43.07
Citation per Year	1868.00
Citation per Author	9.80
Author per Paper	3.41
Citation sum within h-Core	15,142
h-index	50
g-index	57
m-index	2.94

Table 3 reflects the diversity of literature types in the field of green intellectual capital, with articles being the dominant type. Specifically, articles are the most common type of literature, totaling 733, which accounts for 81.99% of the total. Books and letters each account for 0.22%, with 2 entries each. Book chapters make up 6.15%, totaling 55. Conference papers represent 8.17%, with 73 entries. Data papers, editorials, errata (Erratum), and retracted articles each account for 0.11%, with only 1 entry each. Lastly, reviews constitute 2.80%, with 25 entries.

TABLE 3. Document type

Document Type	TP	Percentage (%)
Article	733	81.99
Book	2	0.22
Book chapter	55	6.15
Conference paper	73	8.17
Data paper	1	0.11

Editorial	1	0.11
Erratum	1	0.11
Letter	2	0.22
Retracted	1	0.11
Review	25	2.80
Total	894	100

shows the frequency of different languages used in the study of green intellectual capital. Arabic appeared twice, accounting for 0.22% of the total; Chinese appeared once, accounting for 0.11%; English appeared 887 times, accounting for 99.22%; German, Farsi, Portuguese and Russian appeared once each, accounting for 0.11% each. A total of 894 times, accounting for 100% of the total.

Table 4. Languages

Language	TP	Percentage (%)
Arabic	2	0.22
Chinese	1	0.11
English	887	99.22
German	1	0.11
Persian	1	0.11
Portuguese	1	0.11
Russian	1	0.11
Total	894	100

Table 5 illustrates the distribution of research of green intellectual capital across various academic disciplines. The "Business, Management and Accounting" field has the most extensive application, accounting for 20.36% of the total, making it the leading discipline. Following closely is the "Social Sciences" field, accounting for 11.19%. The "Environmental Science" field also has a notable proportion, at 5.37%. Other fields, such as "Economics, Econometrics and Finance," "Energy," "Computer Science," "Engineering," and "Decision Sciences," have some research or application, but the proportions are relatively lower. Additionally, fields like "Arts and Humanities," "Psychology," "Chemical Engineering," "Mathematics," "Medicine," "Agricultural and Biological Sciences," "Biochemistry, Genetics and Molecular Biology," "Earth and Planetary Sciences," and "Materials Science" have relatively limited research or application, each accounting for less than 1%. Lastly, the "Multidisciplinary" field has some research or application, accounting for 0.34%. Overall, the research or application of green intellectual capital shows a certain degree of diversity and variability across different academic disciplines.

TABLE 5. Subject area

Subject Area	TP	Percentage (%)
Business, Management and Accounting	182	20.36
Social Sciences	100	11.19
Environmental Science	48	5.37
Economics, Econometrics and Finance	29	3.24
Energy	24	2.68
Computer Science	18	2.01
Engineering	16	1.79
Decision Sciences	15	1.67
Arts and Humanities	11	1.23
Psychology	6	0.67
Chemical Engineering	3	0.34
Mathematics	3	0.34
Medicine	3	0.34
Agricultural and Biological Sciences	2	0.22
Biochemistry, Genetics and Molecular Biology	2	0.22
Earth and Planetary Sciences	1	0.11
Materials Science	1	0.11
Multidisciplinary	3	0.34

China, Malaysia and Saudi Arabia are the top three countries supporting green intellectual capital funding. Table 6 highlights the various sponsors and their respective contributions to the funding of green intellectual capital research. The National Natural Science Foundation of China (NSFC) is the leading sponsor, contributing 55 projects, followed by the Ministry of Higher Education of Malaysia (MOHE) with 27 projects. Other notable sponsors include the National Office for Philosophy and Social Sciences (NPOPSS) in China with 18 projects, the Deanship of Scientific Research in Saudi Arabia with 12 projects, the Fundamental Research Funds for the Central Universities in China with 8 projects, and King Faisal University in Saudi Arabia, also with 8 projects.

TABLE 6. Funding sponsor

Funding Sponsor	Sponsor Country	TP
National Natural Science Foundation of China, NSFC	China	55
Ministry of Higher Education, Malaysia, MOHE	Malaysia	27
National Office for Philosophy and Social Sciences, NPOPSS,China	China	18
Deanship of Scientific Research, Saudi Arabia	Saudi Arabia	12
Fundamental Research Funds for the Central Universities, China	China	8
King Faisal University, Saudi Arabia	Saudi Arabia	8
National Social Science Fund of China, NSSFC	China	8

PUBLICATION TRENDS

Table 7 is a comprehensive analysis of various bibliometric indicators for publications on green intellectual capital from 2008 to 2024. "TP" refers to the total number of papers published each year, with 2023 having the highest at 277 papers, accounting for 30.98% of the total publications. "NCA" and "NCP" represent the number of cited articles and cited publications, respectively, which have shown a stable growth trend in recent years. "TC" is the total number of citations, peaking in 2020 with 6,331 citations. "C/P" and "C/CP" are the average number of citations per publication and per cited publication, respectively. The "h-index," "g-index," and "m-index" indicate research impact, with significant increases in 2018 and 2019, showing that the research impact has grown over time. Additionally, the total number of citations increased from 464 in 2008 to 2,260 in 2023. However, it is also noted that despite the continued increase in the number of published papers after 2021, some indicators such as the average citations per paper and the h-index have declined, which may suggest fluctuations in the quality or impact of recent research.

TABLE 7. Publication by year

Year	TP	%	NCA	NCP	TC	C/P	C/CP	h-index	g-index	m-index
2008	1	0.11%	1	1	464	464.00	464.00	1	1	0.059
2010	1	0.11%	1	1	27	27.00	27.00	1	1	0.067
2011	2	0.22%	8	2	544	272.00	272.00	2	2	0.143
2012	2	0.22%	4	2	152	76.00	76.00	2	2	0.154
2013	7	0.78%	13	7	1440	205.71	205.71	5	7	0.417
2014	2	0.22%	7	2	185	92.50	92.50	2	2	0.182
2015	6	0.67%	20	5	379	63.17	75.80	4	6	0.400
2016	13	1.45%	40	13	2031	156.23	156.23	11	13	1.222
2017	12	1.34%	30	12	1808	150.67	150.67	10	12	1.250
2018	26	2.91%	59	25	2806	107.92	112.24	16	24	2.286
2019	46	5.15%	133	43	4003	87.02	93.09	21	27	3.500
2020	74	8.28%	249	69	6331	85.55	91.75	8	8	1.600
2021	93	10.40%	327	90	3489	37.52	38.77	1	0	0.250
2022	154	17.23%	532	146	3675	23.86	25.17			0.000
2023	277	30.98%	985	215	2260	8.16	10.51			0.000
2024	178	19.91%	641	61	294	1.65	4.82			0.000
Total	894	100.00%	3050	694	29888	33.43	43.07	84	105	4.941

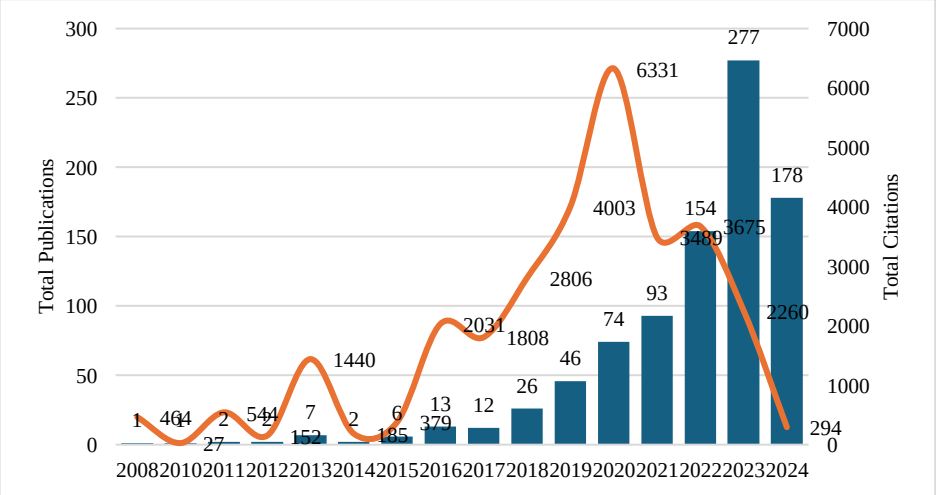

FIGURE 2. Total publications and citations by year

PUBLICATIONS BY AUTHORS

As can be seen from Table 8, the most published author is Yusliza Mohd Yusoff, from the Universiti Malaysia Terengganu in Malaysia, with 17 publications. This was followed by Bartolome Marco-Lajara, from Universitat d'Alacant in Spain, who published 13 papers. In third place is Eduardo Sanchez-Garcia, also from the University of Alicante in Spain, with 10 publications. It is worth noting that the first few high-yielding authors are mainly concentrated in universities in Spain and Malaysia, which indicates that academic institutions in these two countries have high research output and academic influence in related fields.

TABLE 8. Most productive authors

Author's Name	Current Affiliation	Country	TP	NCP	TC	C/P	C/CP	h	g	m
Yusliza, Mohd Yusoff	Universiti Malaysia Terengganu	Malaysia	17	16	1177	69.24	73.56	8	17	1.333
Marco-Lajara, Bartolomé	Universitat d'Alacant	Spain	13	6	285	21.92	47.50	5	13	1.250
Sánchez-García, Eduardo	Universitat d'Alacant	Spain	10	4	78	7.80	19.50	3	8	1.500
Martínez-Falcó, Javier	Universitat d'Alacant	Spain	10	5	126	12.60	25.20	4	10	1.333
Nisar, Qasim Ali	Taylor's University	Malaysia	9	9	309	34.33	34.33	5	9	1.250
Ramayah, T.	Universiti Sains Malaysia	Malaysia	9	7	988	109.78	141.14	6	9	1.000
Yong, Jing Yi	Taylor's University	Malaysia	9	9	1176	130.67	130.67	8	9	0.889
Chaudhary, Richa	Indian Institute of Technology Patna	India	7	6	508	72.57	84.67	5	7	0.714
Pham, Nhat Tan	International University - Vietnam National University	Vietnam	7	7	891	127.29	127.29	5	7	0.714

TABLE 9. Productivity patterns of authors and research contributions

Document Written	N. of Authors	Proportion of Authors	Total N. of Contributions	Lotka's Law
1	2002	65.64%	2002	60.00%
2	528	17.31%	1056	15.00%
3	210	6.89%	630	6.67%
4	108	3.54%	432	3.75%
5	75	2.46%	375	2.40%
6	36	1.18%	216	1.67%
7	14	0.46%	98	1.22%
9	27	0.89%	243	0.74%
10	20	0.66%	200	0.60%
13	13	0.43%	169	0.36%
17	17	0.56%	289	0.21%
Grand Total	3050	100.00%	5710	92.61%

Table 9 shows the authors' productivity patterns and their research contributions. The data showed that the authors who wrote a document were the most, accounting for 65.64% of the total authors, and the total number of contributions was 2002, accounting for 60% of the total contributions. The authors who wrote two documents accounted for 17.31%, and the total number of contributions was 1056, accounting for 15% of the total contributions. As the number of documents increases, the number of authors and the proportion of contributions gradually decrease. Overall, 3,050 authors contributed a total of 5,710 contributions, and 92.61% of the contributions were consistent with Lotka's law, indicating that a small number of authors contributed most of the research results, while the majority contributed less. Figure 3 shows a comparison of the authors' productivity patterns, which further validates Lotka's law.

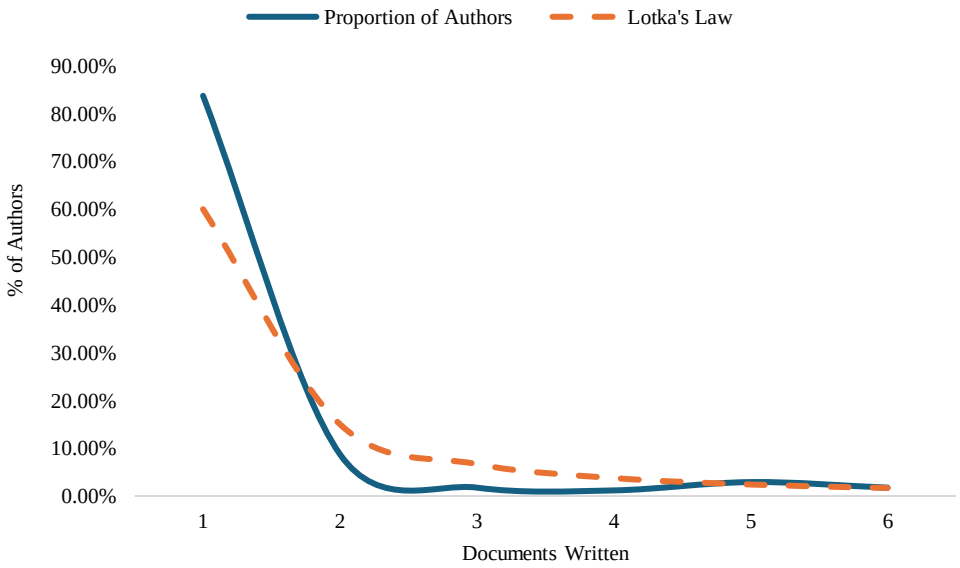

FIGURE 3. Proportion of authors and Lotka's law

TABLE 10. Number of author(s) per document

Author Count	Frequency
1	94
2	189
3	217
4	174
5	127
6	69
7	18
8	2
9	1
10	2
11	1
Total	894

Table 10 shows the distribution of the number of co-authors in the research literature. Specifically, Table 10 shows that 94 articles were written by a single author, accounting for 10.51% of the total. The number of articles co-authored by two persons was the largest, with 189 articles, accounting for 21.14% of the total. The number of articles co-authored by the trio was next, with 217, accounting for 24.28% of the total. With the increase in the number of co-authors, the number of literatures gradually decreased, for example, there were 18 articles co-authored by seven people, accounting for 2.01% of the total.

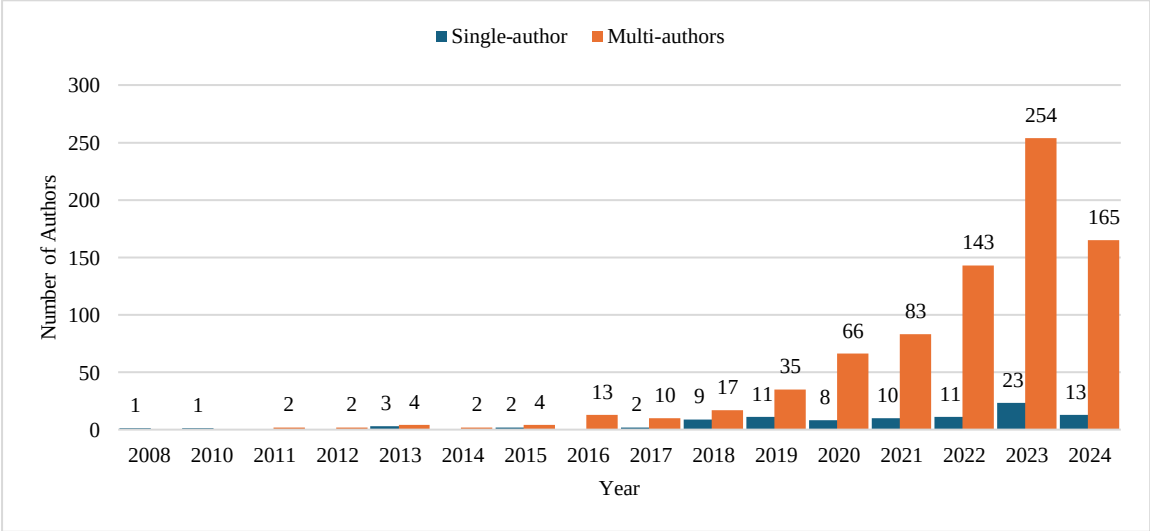

FIGURE 4. Single-author vs. multi-authors

Figure 4 shows the change in the number of single-author and multi-author papers between 2008 and 2024. Overall, the number of multi-author papers is significantly higher than single-author papers, especially in recent years. In 2023 and 2024, the number of multi-author papers reached its highest at 254 and 165, respectively. By comparison, the number of single-author papers is relatively small, peaking at 23 in 2023. This trend shows that, over time, scientific research is increasingly dependent on teamwork.

PUBLICATIONS BY INSTITUTIONS

Table 11 explains that Universiti Malaysia Terengganu and Universiti Sains Malaysia are the two institutions with the most outstanding performance, with 26 and 25 papers respectively, and the total number of citations (TC) is 1976 and 1949, respectively. It shows its high influence in the academic world. Universiti Putra Malaysia also performed well, with 15 papers and 265 citations. King Faisal University and Islamic Azad University have 12 and nine papers, respectively, but their total citations are relatively low, showing that there is room for improvement in terms of impact. At the national level, Malaysia is the most prominent performer, with the number of papers and citations of several universities indicating its important position in academic research. At the same time, some universities in China also show good academic research strength. The year of publication analysis shows that academic research activities have increased in recent years, and the publication year of most institutions began in 2016 and later, and some institutions have obtained a high academic influence in a short period of time.

TABLE 11. Most productive institutions with minimum of five publications

Institution	Country	TP	TC	NCP	C/P	h	g	Pub. Year Start	m
Universiti Malaysia Terengganu	Malaysia	26	1976	23	76	13	26	2016	1.444
Universiti Sains Malaysia	Malaysia	25	1949	21	77.96	14	25	2016	1.556
Universiti Putra Malaysia	Malaysia	15	265	14	17.67	7	15	2015	0.7
King Faisal University	Saudi Arabia	12	139	7	11.58	6	11	2021	1.5
Islamic Azad University	Iran	9	38	7	4.22	4	6	2016	0.444
Universiti Utara Malaysia	Malaysia	9	256	8	28.44	6	9	2020	1.2
Qatar University	Qatar	8	297	8	37.13	7	8	2020	1.4
Amman Arab University	Jordan	8	37	3	4.63	2	6	2019	0.333
Universiti Teknologi MARA	Malaysia	8	251	5	31.38	3	8	2018	0.429
Universiti Kebangsaan Malaysia	Malaysia	7	30	4	4.29	3	5	2020	0.6
Wuhan University of Technology	China	6	48	5	8	3	6	2021	0.75
The Superior University	Pakistan	6	122	5	20.33	4	6	2022	1.333
Daffodil International University	Bangladesh	6	82	5	13.67	5	6	2022	1.667
Abu Dhabi University	UAE	6	1045	5	174.17	4	6	2020	0.8
Universiti Teknologi Malaysia	Malaysia	6	84	5	14	5	6	2017	0.625
Prince Sattam Bin Abdulaziz University	Saudi Arabia	6	89	6	14.83	5	6	2018	0.714
Wuhan University	China	5	96	5	19.2	4	5	2021	1
Tongji University	China	5	374	5	74.8	5	5	2020	1
Prince Sultan University	Saudi Arabia	5	59	5	11.8	3	5	2021	0.75
Deakin University	Australia	5	580	5	116	4	5	2018	0.571
Multimedia University	Malaysia	5	105	5	21	3	5	2019	0.5
Jadara University	Jordan	5	38	3	7.6	2	5	2021	0.5
University of Malaya	Malaysia	5	248	5	49.6	5	5	2021	1.25
University of Bahrain	Bahrain	5	10	2	2	2	3	2020	0.4

PUBLICATIONS BY COUNTRIES

Table 12 displays the academic output and impact indicators in a specific research field by country. China and Pakistan have published the most papers in the field of green intellectual capital since their involvement, totaling 176 and 153 papers respectively, with high citation counts and influence. Malaysia also stands out with significant academic output and impact; since starting research in 2015, it has published 138 papers with a total of 5104 citations. The United Kingdom and the United States were among the first to start research in green intellectual capital in 2011, with 55 and 31 papers respectively, showing high levels of academic influence with total citations of 4211 and 2214 respectively. China has been active since 2012, publishing 176 papers with a total of 7070 citations, demonstrating strong research capability and influence. Indonesia and Thailand have entered the field since 2019, publishing 65 and 20 papers respectively, indicating rapid development of green intellectual capital in Southeast Asia. Ghana and Bangladesh, starting their research in 2020, have published 18 papers each; despite the shorter time frame, their research activity and impact are on the rise. France and Italy show high citation rates of 115.22 and 104.88 respectively, indicating high-quality research results. Saudi Arabia and the UAE are also very active in the Middle East, publishing 64 and 28 papers respectively, with total citations of 1506 and 1440. Figure 5 visualizes the global distribution of academic publications on green intellectual capital.

TABLE 12. Top 20 Countries contributed to the publications

Country	TP	TC	NCP	C/P	C/CP	h	g	Pub. Year Start	m
China	176	7070	153	40.17	46.21	38	84	2012	2.923
Pakistan	153	4942	132	32.30	37.44	38	70	2016	4.222
Malaysia	138	5104	117	36.99	43.62	34	71	2015	3.400
India	109	2079	72	19.07	28.88	21	45	2014	1.909
Indonesia	65	281	39	4.32	7.21	10	16	2019	1.667
Saudi Arabia	64	1506	50	23.53	30.12	18	38	2015	1.800
United Kingdom	55	4211	51	76.56	82.57	22	55	2011	1.571
Australia	46	3500	42	76.09	83.33	24	46	2016	2.667
France	36	4148	33	115.22	125.70	22	36	2016	2.444
Spain	35	1232	23	35.20	53.57	13	35	2011	0.929
United States	31	2214	29	71.42	76.34	14	31	2011	1.000
Turkey	29	576	23	19.86	25.04	11	24	2017	1.375
United Arab Emirates	28	1440	20	51.43	72.00	14	28	2015	1.400
Italy	26	2727	24	104.88	113.63	15	26	2016	1.667
Jordan	26	253	16	9.73	15.81	8	15	2018	1.143
Iran	25	704	21	28.16	33.52	10	25	2016	1.111
Egypt	23	286	15	12.43	19.07	9	16	2018	1.286
Thailand	20	816	17	40.80	48.00	9	20	2019	1.500
Ghana	18	361	15	20.06	24.07	8	18	2020	1.600
Bangladesh	18	386	17	21.44	22.71	9	18	2020	1.800

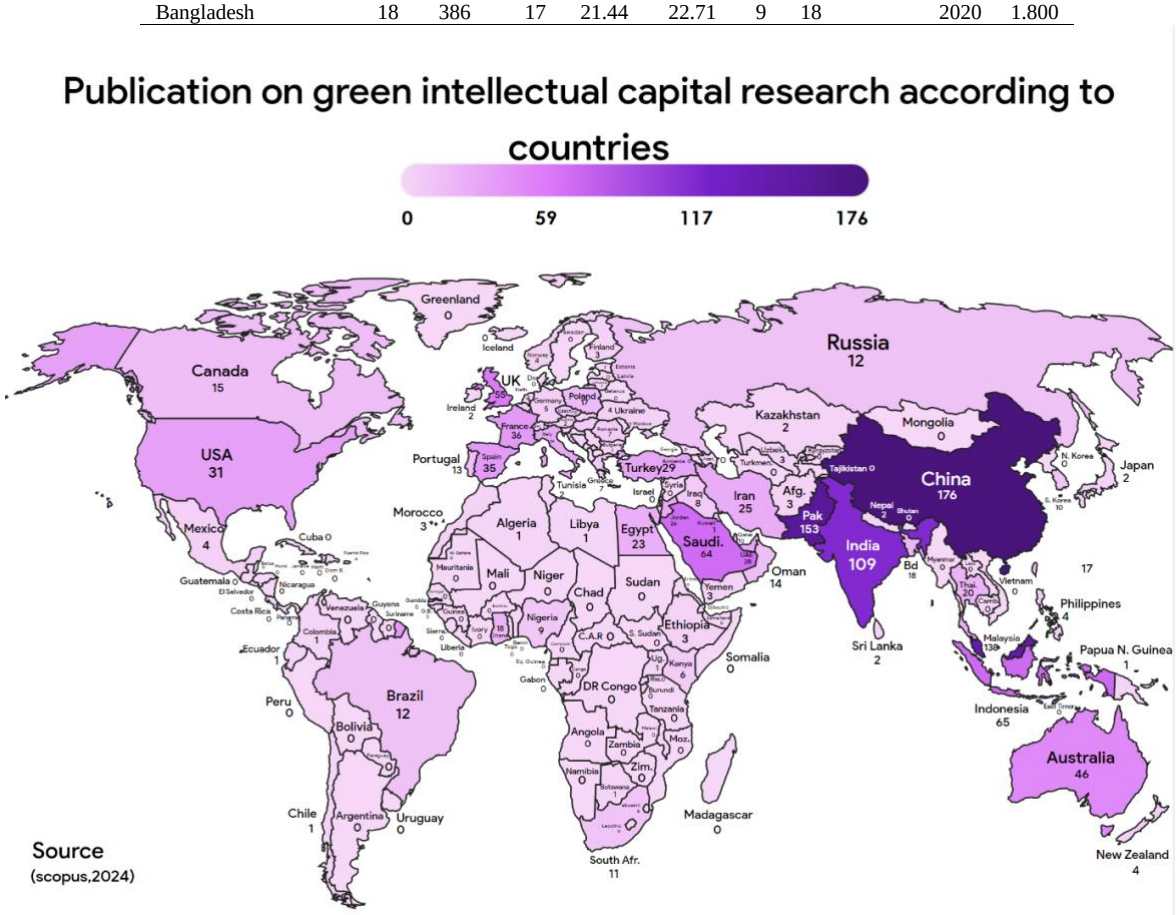

FIGURE 5. Worldwide scientific production indexed by Scopus on green intellectual capital.
Generated using iipmaps.com/

PUBLICATIONS BY SOURCE TITLES

Table 13 shows the research output of different academic journals in the field of environmental protection and corporate sustainability. Journals such as Sustainability (Switzerland) and Journal of Cleaner Production perform well in terms of total publications (TP) and total citations (TC), reflecting their high impact. The journals listed all belong to Bradford's Law Zone 1, indicating that they are core journals in their respective fields, with high visibility and citation rates. The "m" value, a measure of consistency and impact over time, shows an annual increase in the impact factor, underscoring the continued relevance of these journals in advancing their academic disciplines.

TABLE 13. Most active source titles that published 8 or more documents

Source Title	TP	TC	NCP	NCA	h	g	C/P	Bradford's Law Zone	m
Sustainability (Switzerland)	64	1761	60	251	25	46	30.64	Zone 1	5.714
Journal of Cleaner Production	32	4545	32	124	24	32	142.03	Zone 1	3.556
International Journal of Manpower	26	1299	25	106	17	26	49.96	Zone 1	5.200
Business Strategy and the Environment	24	1728	23	96	16	24	72.00	Zone 1	1.714
Environmental Science and Pollution Research	24	410	21	96	9	20	17.08	Zone 1	5.000
Corporate Social Responsibility and Environmental Management	21	1554	16	72	13	21	74.00	Zone 1	3.500
Journal of Intellectual Capital	19	467	18	69	11	19	24.58	Zone 1	4.750
International Journal of Sustainable Development and Planning	13	57	12	40	5	7	4.38	Zone 1	1.750
Benchmarking	13	681	12	54	9	13	52.38	Zone 1	2.167
Cogent Business and Management	12	553	8	41	7	12	46.08	Zone 1	1.200
Heliyon	11	25	7	41	3	4	2.27	Zone 1	2.000
Frontiers in Psychology	11	147	11	45	7	11	13.36	Zone 1	2.750
International Journal of Organizational Analysis	10	410	8	28	6	10	41.00	Zone 1	1.000
International Journal of Hospitality Management	9	1160	9	34	8	9	128.89	Zone 1	1.500
Quality - Access to Success	9	11	3	31	2	3	1.22	Zone 1	0.750
Uncertain Supply Chain Management	9	60	8	38	4	7	6.67	Zone 1	1.750
International Journal of Human Resource Management	8	969	8	26	7	8	121.13	Zone 1	0.889
Business Strategy and Development	8	146	6	31	5	8	18.25	Zone 1	1.600
Frontiers in Environmental Science	8	93	7	38	5	8	11.63	Zone 1	2.667

FIGURE 6. Most active source titles

HIGHLY CITED DOCUMENTS

Table 14 shows high-impact academic research on green intellectual capital. The papers cover research from 2008 to 2016 on topics such as the positive impact of green intellectual capital on a firm's competitive advantage, the relationship between sustainable development and intangible capital, and the current and future direction of green human resource management. According to the data, the study on green human resource management published by Renwick et al. in International Management Review was cited the most, reaching 1118 times, indicating its important influence in this field. In addition, Chen Y.-S. 's research published in the Journal of Business Ethics has also received high attention and has been cited 464 times.

TABLE 14. Top 20 highly cited documents

No.	Author(s)	Title	Source Title	TC	C/Y	DOI
1	Chen Y.-S. (2008)	The positive effect of green intellectual capital on competitive advantages of firms	Journal of Business Ethics	464	27.29	10.1007/s10551-006-9349-1
2	López-Gamero M.D.; Zaragoza-Sáez P.; Claver-Cortés E.; Molina-Azorín J.F. (2011)	Sustainable development and intangibles: Building sustainable intellectual capital	Business Strategy and the Environment	97	6.93	10.1002/bse.666
3	Liu C.-C. (2010)	Developing green intellectual capital in companies by AHP	SCMIS 2010 - Proceedings of 2010 8th International Conference on Supply Chain Management and Information Systems: Logistics Systems and Engineering	27	1.80	0
4	Jackson S.E.; Renwick D.W.S.; Jabbour C.J.C.; Muller-Camen M. (2011)	State-of-the-Art and Future Directions for Green Human Resource Management: Introduction to the special issue; [Forschungsstand und entwicklungsmöglichkeiten für umweltorientiertes personalmanagement: Einführung in das schwerpunktheft]	Zeitschrift fur Personalforschung	447	31.93	10.1688/1862-0000_ZfP_2011_02_Jackson
5	Chang C.-H.; Chen Y.-S. (2012)	The determinants of green intellectual capital	Management Decision	149	11.46	10.1108/00251741211194886
6	Renwick D.W.; Redman T.; Maguire S. (2013)	Green Human Resource Management: A Review and Research Agenda*	International Journal of Management Reviews	1118	93.17	10.1111/j.1468-2370.2011.00328.x
7	Chen Y.-S.; Chang C.-H. (2013)	Utilize structural equation modeling (SEM) to explore the influence of corporate environmental ethics: The mediation effect of green human capital	Quality and Quantity	76	6.33	10.1007/s11135-011-9504-3
8	Liu J.-X.; Liu B. (2012)	An empirical research on the relationship among entrepreneurial green human capital, social responsibility and customer equity in the high-tech enterprises	International Conference on Management Science and Engineering - Annual Conference Proceedings	3	0.23	10.1109/ICMSE.2012.6414268
9	Liu T.; Xie P. (2013)	Research on dynamic implementation of green human resources management	Lecture Notes in Electrical Engineering	5	0.42	10.1007/978-1-4471-4805-0_11
10	Wagner M. (2013)	'Green' Human Resource Benefits: Do they Matter as Determinants of Environmental Management System Implementation?	Journal of Business Ethics	191	15.92	10.1007/s10551-012-1356-9
11	Banerjee P.M. (2013)	Sustainable human capital: Product innovation and employee partnerships in technology firms	Cross Cultural Management	16	1.33	10.1108/13527601311313481
12	Milliman J. (2013)	Leading-Edge Green Human Resource Practices: Vital Components to Advancing Environmental Sustainability	Environmental Quality Management	30	2.50	10.1002/tqem.21358
13	Lungu C.I.; Caraiani C.; Dascălu C. (2013)	Sustainable intellectual capital: The inference of corporate social responsibility within intellectual capital	Intellectual Capital Strategy Management for Knowledge-Based Organizations	4	0.33	10.4018/978-1-4666-3655-2.ch009

14	Mishra R.K.; Sarkar S.; Kiranmai J. (2014)	Green HRM: Innovative approach in Indian public Enterprises	World Review of Science, Technology and Sustainable Development	100	9.09	10.1504/WRSTSD.2014.062374
15	Delgado-Verde M.; Amores-Salvadó J.; Martín-De Castro G.; Navas-López J.E. (2014)	Green intellectual capital and environmental product innovation: The mediating role of green social capital	Knowledge Management Research and Practice	85	7.73	10.1057/kmrp.2014.1
16	Guerci M.; Carollo L. (2016)	A paradox view on green human resource management: Insights from the Italian context	International Journal of Human Resource Management	112	12.44	10.1080/09585192.2015.1033641
17	Matherly L.L.; Al Nahyan S.S. (2015)	Building competitiveness through effective governance of national-expatriate knowledge transfer and development of sustainable human capital	International Journal of Organizational Analysis	14	1.40	10.1108/IJOA-04-2015-0855
18	Guerci M.; Longoni A.; Luzzini D. (2016)	Translating stakeholder pressures into environmental performance – the mediating role of green HRM practices	International Journal of Human Resource Management	304	33.78	10.1080/09585192.2015.1065431
19	Haddock-Millar J.; Sanyal C.; Müller-Camen M. (2016)	Green human resource management: A comparative qualitative case study of a United States multinational corporation	International Journal of Human Resource Management	195	21.67	10.1080/09585192.2015.1052087
20	Scully-Russ E. (2015)	The Contours of Green Human Resource Development	Advances in Developing Human Resources	16	1.60	10.1177/1523422315600839

CO-AUTHORSHIP ANALYSIS

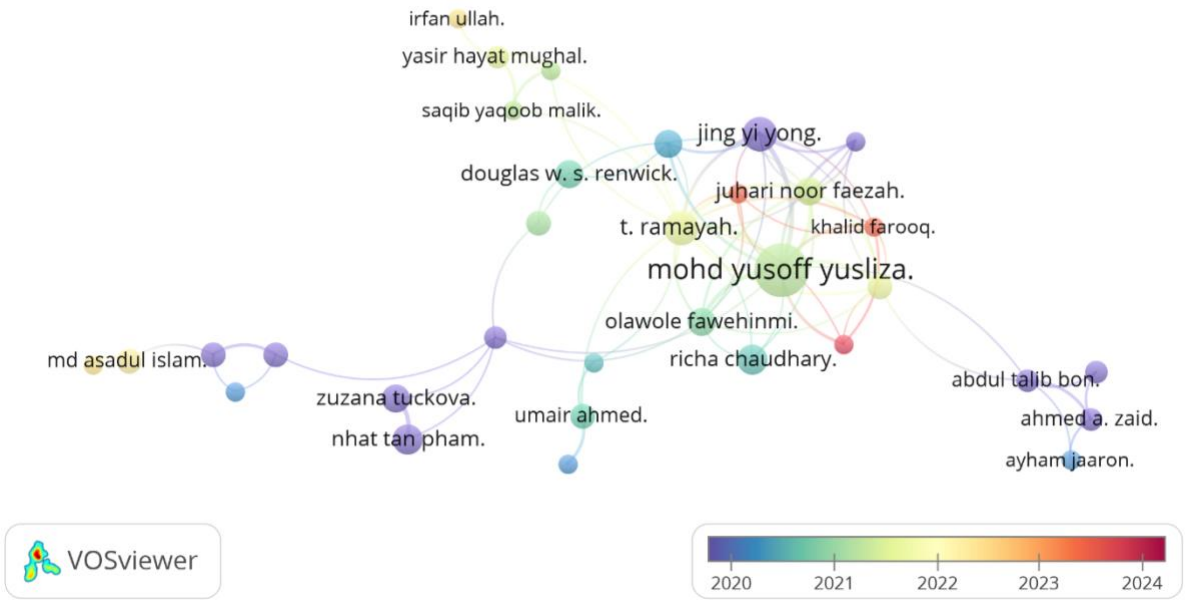

FIGURE 7. Network visualization map of author co-author overlay

For the analysis of collaboration between authors on green intellectual capital, authors with at least 3 publications were included, enabling 134 authors to meet the thresholds. The analyses showed that six groups were linked (see Figure 7), and only a few researchers provided this link. The largest group is purple, and it has 12 authors namely Abdur Rachman Alka, Charbel Jose Chiappetta jabber, Jing Yi Yong, Johari Noor Faizah, Khalid Farooq, M. Imran Tanveer, Mohd Yusof Yulia, Muhammad Imran Tanveer, Olawale Fawehinmi, Richa Chaudhary, T. Ramaiah, Zikri Muhammad. The second largest cluster contains 5 authors which are Ana Beatriz lopes de Souza, Charbel Jose Chiappetta Jabber, Douglas w. s. Renwick, Nhat Tan Pham, Zuzana Tuckova. The

third largest cluster contains 5 items, which are Daisy Mui Hung Kee, Mahfuzur Rahman, Md Asadul Islam, Mehran Nejati, Yusmani Mohd Yusoff. The fourth largest cluster is consisting of Abdul Talib Bon, Ahmed A. Zaid, Ayham Jaaron. And the cluster 5 contains Irfan Ullah, Saqib Yaqoob Malik, Yasir Hayat Mughal, Yukon Cao. The last cluster included Syed Mir Muhammad Shabir, Umair Ahmed, Waheed Ali Umrani.

KEYWORDS CO-OCCURRENCE ANALYSIS

A total of 894 publications about green intellectual capital contained 858 author keywords. According to the co-occurrence analysis done on the author keywords, only 111 authors' keywords appear in more than 5 publications. The co-occurrence analysis revealed that the keywords are organized into 5 clusters, as illustrated in Figure 8. The keywords in the clusters give information about similar study subjects (Goksu 2021). The largest group is red and it has 52 items namely ability-motivation-opportunity theory, artificial intelligence, bibliometric analysis, business performance, china, circular economy, eco-friendly behavior, emerging economy, employee eco-friendly behavior, employee environmental commitment, employee performance, entrepreneurship, environmental performance, green culture, green human resource management, green practices, green supply chain management, green values, hospitality, hotel industry, human capital, human resource management, human resources, Indonesia, innovation, institutional theory, ISO14001, job satisfaction, Jordan, malaysia, management, manufacturing sector, organizational commitment, organizational environmental culture, organizational identification, organizational performance, organizational reputation, pakistan, palestine, PLS-SEM, responsible leadership, smart pls, social exchange theory, social sustainability, stakeholder theory, structural equation modeling, supervisory support, sustainability, systematic literature review, top management commitment, training, work engagement. The second largest cluster is green and it contains 23 author keywords, namely competitive advantage, corporate environmental ethics, corporate social responsibility, digitalization, ESG, green competitive advantage, green corporate citizenship, green environment, green innovation, green intellectual capital, green knowledge sharing, green logistics, green management, green organizational culture, green passion, green relational capital, green structural capital, green technological innovation, knowledge management, natural resource based view theory, small and medium enterprises, Vietnam, voluntary green behavior. The third largest cluster is blue and it contains 22 items, which are employee green behavior, ethical leadership, extra-role green behavior, green behavior, green commitment, green creativity, green employee empowerment, green psychological climate, green recruitment and selection, green reward and compensation, green self-efficacy, green training, green work engagement, harmonious environmental passion, higher education institutions, in-role green behavior, India, individual green values, organizational citizenship behavior (OCBE), perceived organizational support, pro-environmental behavior, psychological ownership. The fourth largest cluster is yellow, consisting of developing country, employer branding, green ability green motivation, green opportunity. The fifth cluster is purple, covering economic performance, financial performance, operational performance, social performance, wine industry.

In summary, this section outlines five major clusters in the field of green intellectual capital, namely green business practices and performance, corporate social responsibility and ethics, employee green behavior, green capabilities and motivations, and economic and financial performance. While these clusters are well-defined and each focuses on specific areas, their integration with one another is still lacking. The research also needs to be deepened, especially through in-depth analysis of certain topics and the incorporation of emerging trends and technologies. Additionally, research from cross-cultural and international perspectives remains scarce. In the future, it is necessary to further explore the differences and impacts of green practices in different cultural and economic contexts to promote the integration and deepening of this field.

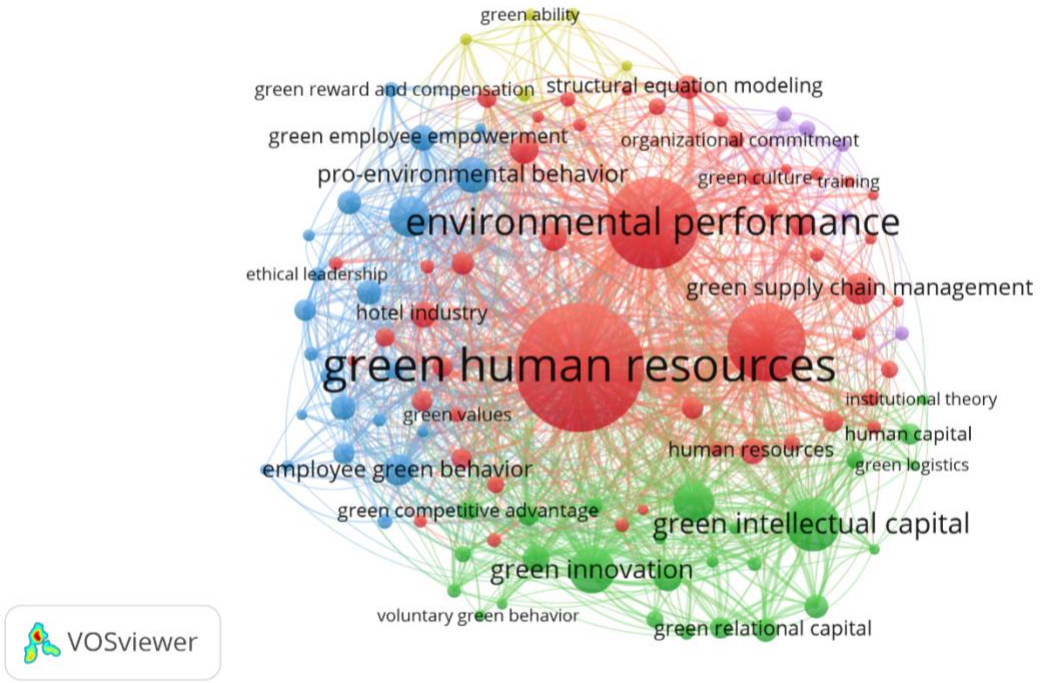

FIGURE 8. Network visualization map of author keywords' co-occurrence

The overlay map generated from the keyword co-occurrence analysis illustrates the trend throughout the years, i.e., from 2020 to 2023, and gives an insight into research subjects' tendencies (Goksu 2021). Figure 9 shows the change of research hotspots over time, with the most recent ones represented in yellow or orange, including green innovation, green knowledge sharing, and green management.

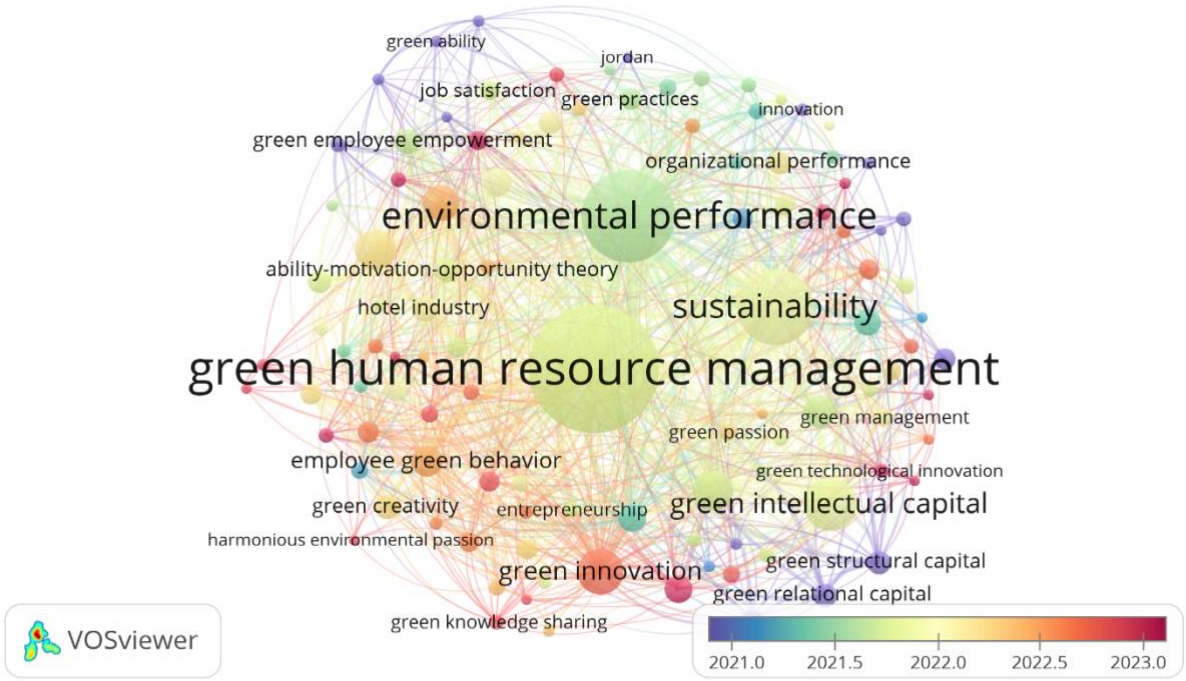

FIGURE 9. Overlay visualization map of author keywords according to year

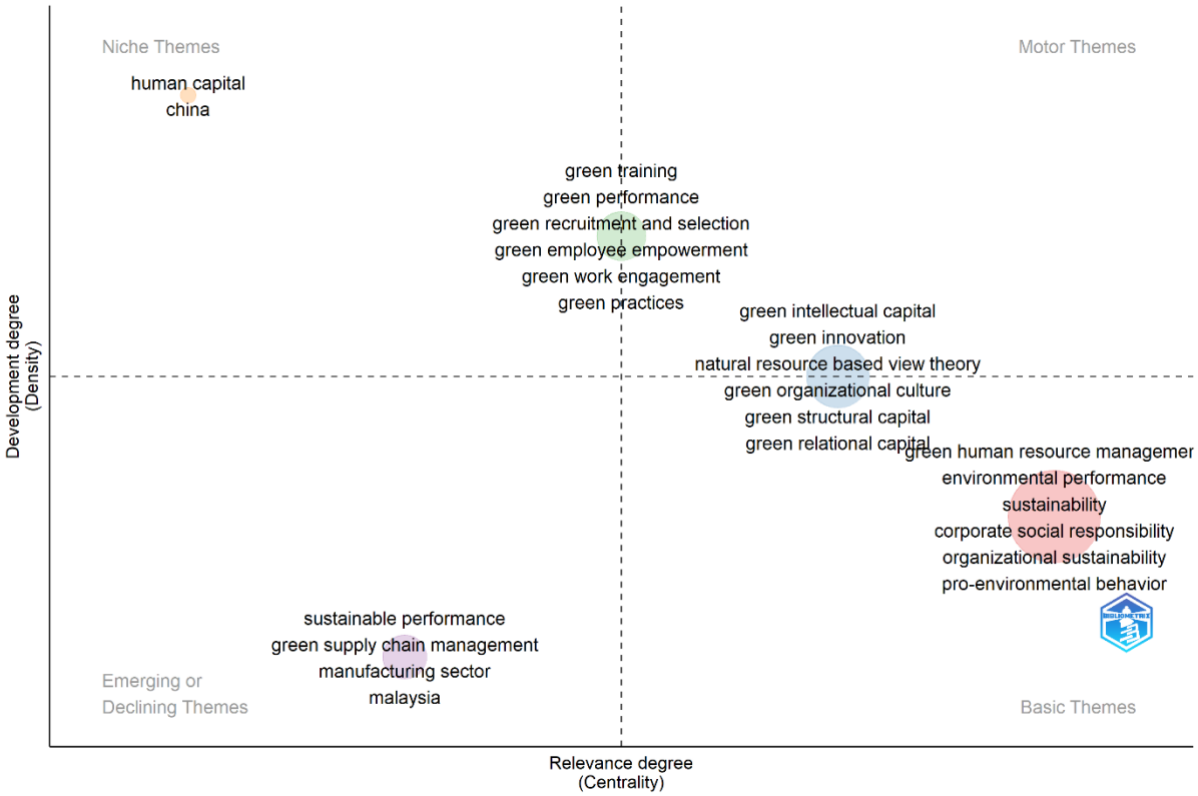

FIGURE 10. Trend evolution of green intellectual capital

Figure 10 shows the development trend of green intellectual capital, clearly depicting the evolution of different topics in terms of importance and development through matrix form. In the figure, emerging and developing topics such as "green training," "green performance" and "green innovation" are located at the top right of the matrix, indicating that these topics have high importance and development potential at present. At the same time, some basic but equally important topics such as "human capital" are at a lower level, but their role as cornerstones cannot be ignored. In addition, the chart highlights the key role of themes such as "green organizational culture" and "green structural capital" in driving organizational sustainability.

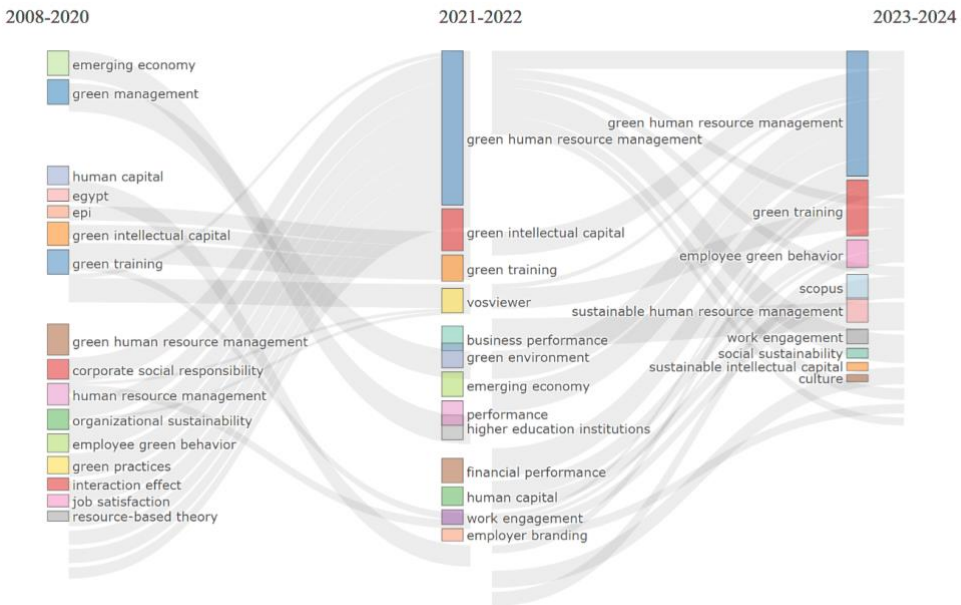

FIGURE 11. Thematic evolution of green intellectual capital

Figure 11 shows the evolution of green intellectual capital across different themes and time periods. From 2008 to 2024, we can see significant growth in the data on topics such as "emerging economy," "green management," "green human resource management," "green training" and "sustainable human resource management." In particular, the theme of "green intellectual capital" has received a great deal of attention in recent years, reflecting society's increasing emphasis on environmental protection, sustainable development and the value of human resources. The bar charts in the chart visually show the activity and development trends of each theme over different time periods through color coding and size changes. In addition, the chart also reveals the correlation between green intellectual capital and key factors such as business performance, work engagement, and corporate social responsibility, highlighting the important role of green practices in enhancing organizational sustainability and performance.

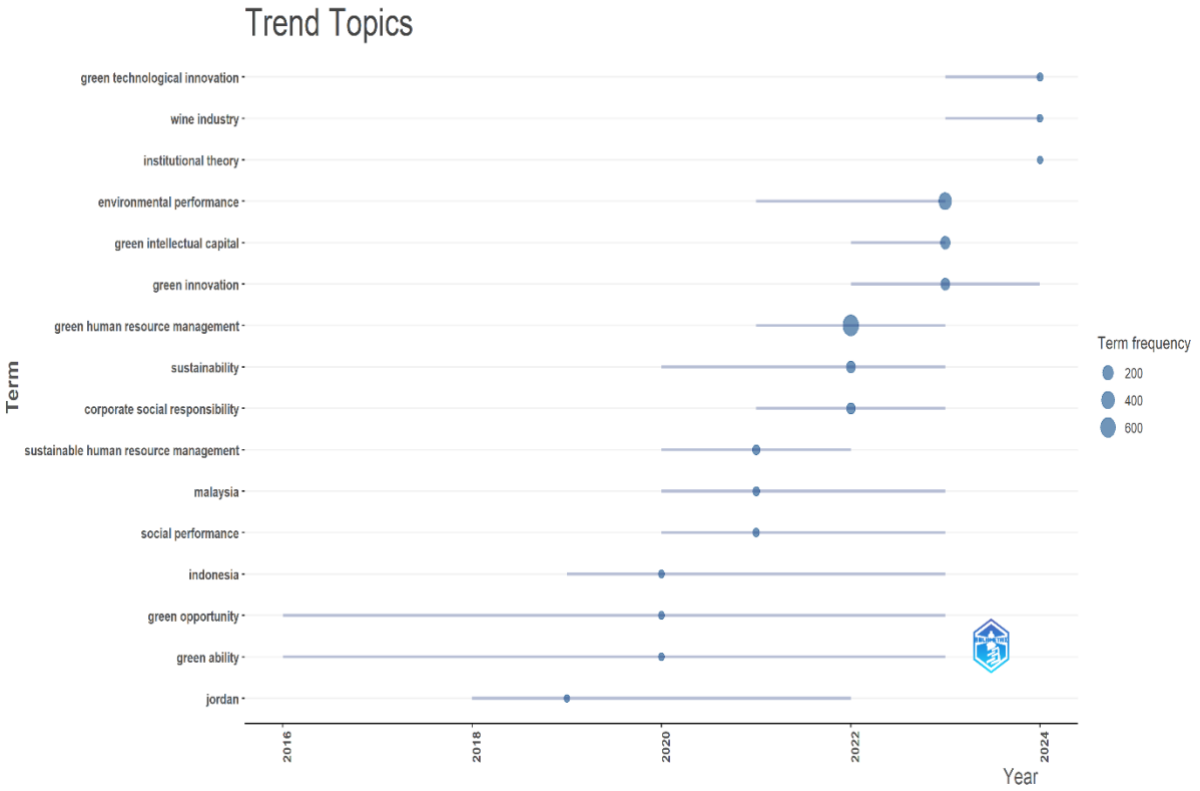

FIGURE 12. Trend topics of green intellectual capital

Figure 12 details trends in word frequency on green intellectual capital and related topics from 2014 to 2024. Among them, "green human resource management" as the core theme, its word frequency has remained high in the past ten years, highlighting its significant position in the study of green intellectual capital. At the same time, topics such as "sustainability," "corporate social responsibility" and "green innovation" also show a high word frequency, indicating that these fields also occupy an important position in the study of green intellectual capital. In contrast, topics such as "green intellectual capital" itself and "social performance" have relatively low word frequency, which may mean that these topics have not received sufficient attention in current research.

FIGURE 13. Word cloud of green intellectual capital

This word cloud map focuses on green intellectual capital and its multiple dimensions related to sustainable development. Figure 13 highlights the concept of "green intellectual capital," around which a series of keywords related to green economy, corporate social responsibility and environmental protection are developed. Words like "sustainability," "green innovation," "corporate social responsibility," Together, we have built a framework for a broad discussion on green development and long-term corporate performance. The size and color variations of the word cloud reflect the importance or relevance of different words in the subject matter, thus underscoring the central role of green intellectual capital in driving organizational sustainability. In addition, the figure also involves green recruitment, green training, green behavior and other practical levels, further demonstrating the application and influence of green intellectual capital in practical operation.

CONCLUSION

Through bibliometric analysis, this study reveals that since the introduction of GIC, the number of studies has increased year by year, especially after the epidemic, GIC research has become increasingly reliant on teamwork. The major contributing countries include Malaysia, China and Pakistan. Green human capital, structural capital and relational capital have important effects on organizational competitiveness and environmental performance. Malaysian authors and institutions ranked first in the number of papers published in the field of GIC. Meanwhile, Malaysia ranked second in terms of support for GIC funds. It shows that the government and related institutions attach importance to GIC have a promoting effect of research quantity and results. However, there are still gaps in the study of social performance and emerging economies. The increase in publications reflects the growing prominence of green intellectual capital research in the academic literature, particularly since 2020. This reflects a shift in organizational mindset recognizing that intellectual capital in combination with environmental considerations has moved from being optional to being a fundamental element of sustainable operations.

The study also revealed that, while English remains the dominant language for scholarly communication, the universal relevance of green intellectual capital transcends linguistic boundaries, with contributions in diverse languages such as Portuguese and Russian. This global discourse is paralleled by the vast array of document types, from articles to conference papers, indicating a multifaceted engagement with the topic across various platforms of knowledge dissemination.

This study has limitations. Firstly, we only collected data from Scopus, which does not contain all academic publications. Secondly, we excluded recent articles (those received after July 2024) that were not indexed in Scopus. Nonetheless, these limitations are unlikely to have influenced the study's outcomes.

To comprehensively promote the future growth of the field of GIC, this study makes the following recommendations. First, topics such as "green training," "green performance," and "green innovation" currently hold significant importance and development potential, making them key focuses for future research. Secondly, in view of the multidisciplinary nature of GIC research, interdisciplinary cooperation should be expanded to combine theories and methods in business management, accounting, social science and environmental science to fully analyze the multidimensional effect of GIC. In addition, government policies play a key role in promoting the development of GIC, and it is necessary to strengthen support and guidance for GIC, encourage enterprises to increase investment through tax incentives, financial subsidies and project funding, and promote the realization of Sustainable Development Goals.

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