



TECHNIUM
SOCIAL SCIENCES JOURNAL

www.techniumscience.com



Vol. 67/2025
A New Decade for Social Changes

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COMMUNICATION P



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Communication & PR

Carbon Footprint: A Bibliometric Analysis

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Abstract. Purpose – Recent years have seen a shift in concentration towards global warming and climate change. The global community aims to reduce carbon emissions to address the climate catastrophe. Carbon activities, including carbon footprint and carbon neutrality, have garnered significant attention as essential measures in combating climate change, with various governments establishing their carbon neutrality objectives. Design/methodology/approach – This work aims to employ bibliometric analysis to investigate research hotspots and trends in carbon-related activity. It employs VOSviewer to do a comprehensive study of 59 publications associated with carbon-related activities worldwide. All literature is retrieved via the Scopus database. Findings – The results indicate a significant increase in the volume of publications related to carbon in recent years. Research on carbon neutrality exhibits considerable variation among nations and regions. China and the United Kingdom are the principal catalysts and innovators in carbon neutrality research. Implication/Limitation - Researchers in developing nations can utilize the study's findings as a starting point for their own research on carbon footprints and to highlight current issues in the field. While the amount of study on carbon neutrality in developing nations is rather low, such as in Indonesia, where the local journals do not range in Scopus, there are not so many, can there be future research for researchers in Indonesia. Originality/value – Research has focused on carbon-related activities, including carbon footprint and carbon neutrality, as well as technological, policy, and economic dimensions. Additionally, agricultural practices, low-carbon initiatives, green building, and supply chain management are prominent areas of investigation. Future research may be informed by the findings of this study, which elucidates the present state of carbon-related activity research.

Keywords. Carbon footprint, Bibliometric Analysis, VOSviewer, Carbon Neutrality, Carbon Emmission

1. Introduction

The "carbon footprint" is a major concern in today's world. The CFP is the total amount of greenhouse gases, such as CO₂, that are released into the atmosphere as a result of either direct or indirect human activity [1]. Due to this action, humans are now dealing with severe climate change-related challenges. Sustainable development is becoming more and more demanded by the global community. In this instance, the importance of climate governance through carbon neutrality policies has grown, and several nations have made major efforts to enact related policies [2].

For example, as quoted from CNBC News, recently there was an incident in the form of air pollution levels that occurred in the country of Indonesia, namely in the city of Jakarta, which was also highlighted by the media, both national and international. Based on IQAir, Jakarta's air quality is 156 and it is ranked as the dirtiest city in the world. According to the official website of the Meteorology, Climatology, and Geophysics Agency (BMKG), PM2.5 is an air particle that is smaller than or equal to 2.5 micrometers. PM2.5 particles, which include dust, soot, dirt, smoke, and liquid droplets, can only be seen with an electron microscope. According to IQAir, PM2.5 air pollution is the biggest health threat in the world. Its small size allows PM2.5 to remain airborne for long periods of time and can be absorbed deep into the bloodstream when inhaled. Severe levels of air pollution in Jakarta are thought to be the result of combustion emissions. Minister of Environment and Forestry Siti Nurbaya stated at a limited cabinet meeting at the State Palace, Jakarta, on Monday, August 14, 2023, The transportation sector is the largest consumer of petroleum in Jakarta. The data indicates that the transportation sector accounts for 44% of fuel consumption in Jakarta, followed by the energy industry at 31%, industrial manufacturing at 10%, the residential sector at 14%, and the commercial sector at 1%. The transportation sector is the predominant carbon monoxide (CO) emitter, accounting for 96.36% or 28,317 tons annually, followed by power plants at 1.76% or 5,252 tons per year, and industry at 1.25% or 3,738 tons per year.

Carbon emissions have drawn attention from all around the world as climate change gets worse. China announced in September 2020 that it would achieve "carbon neutrality" by 2060 and "peaking carbon" by 2030. Currently, more than 1,000 businesses have set science-based 1.5°C climate targets spanning 60 countries and 53 industries globally [3]. Because of the pressing need for environmental protection in the current context, there is a great deal of interest in and rapid development of this topic. Analyzing and weighing the results of previous research on this topic in a methodical and productive manner is crucial. Both empirical research and theoretical knowledge have amassed. Researchers from related fields have previously presented some overviews of carbon-related activity from specialized perspectives in a variety of research areas, including studies on agricultural [4];[5];[6], economic[7];[8];[3];[2], low-carbon[9];[10], green building[11];[12];[13];[14], etc.

Consequently, the collected literature data is examined and represented through VOSviewer and bibliometric analysis to offer an extensive overview of the field's dynamic evolution and trends, encompassing collaborative network analysis, keyword clustering analysis, and descriptive statistical analysis, with an emphasis on prominent authors, journals, institutions, and countries, respectively. The discussion of possible future research directions in this field comes next. Lastly, a summary of the work done in this paper is provided, along with projections for how carbon-related activity research will develop going forward.

The remaining sections of the document are organized as follows: The preparation for bibliometric visual analysis—including data acquisition and tool selection—is covered in Section 2. Section 3 presents the findings of the bibliometric analysis, which includes trends in publications and analyses by authors, institutions, countries or regions, categories, and keywords. In Section 4, the major themes identified by the bibliometric analysis of the literature are thoroughly discussed, and future research directions are suggested for future study. We give an overview of the research that is presented in this paper in Section 5.

2. Theoretical Frameworks

2.1 Carbon Footprint

The "carbon footprint" is a major worry in today's globe. The CFP is the total amount of greenhouse gases, like as CO₂, that are released into the atmosphere as a result of either direct or indirect human activities. It is one of the main causes of both resource depletion and global warming. Three distinct emissions must be included when talking about greenhouse gas emissions in an organization [1] These are the following:

1. Direct Emission

It indicates the volume of greenhouse gases emitted into the atmosphere as a direct consequence of various organizational activities, such as energy generation and atmospheric carbon dioxide assessment. The emission of nitrous oxide (N₂O) into the atmosphere due to fertilizer application endangers the ecology. Utilizing environmentally sustainable methods can mitigate all of these pollutants.

2. Indirect emission

Our influence over this kind of emission is not direct. The products or services that a company uses or produces and which thereby reduce CO₂ emissions. The company moves its products or services from one location to another; the quantity of CO₂ released during that movement might be regarded as indirect transmission.

3. Emissions Brought on by Electricity

Every business needs electricity, which they must purchase from many other businesses. While there are many sources of power available, coal, natural gas, and nuclear energy are the three main ones worldwide. Therefore, even though the company has no direct control, they are nonetheless accountable for this pollution.

2.2 Bibliometric Analysis

Recent years have seen a huge increase in the popularity of bibliometric analysis in business research. This can be attributed to two factors: (1) the development, accessibility, and availability of bibliometric software, such as Gephi, Leximancer, and VOSviewer, and scientific databases, such as Scopus and Web of Science; and (2) the cross-disciplinary transfer of bibliometric methodology from information science to business research [15];[16];[17].

Researchers employ bibliometric analysis for many purposes, including identifying new trends in the performance of articles and journals, examining patterns of collaboration and the components of research, and investigating the intellectual framework of a particular field within the body of existing literature. [18];[19];[20].

3. Research Methodologies

3.1. Data Acquisition and Processing

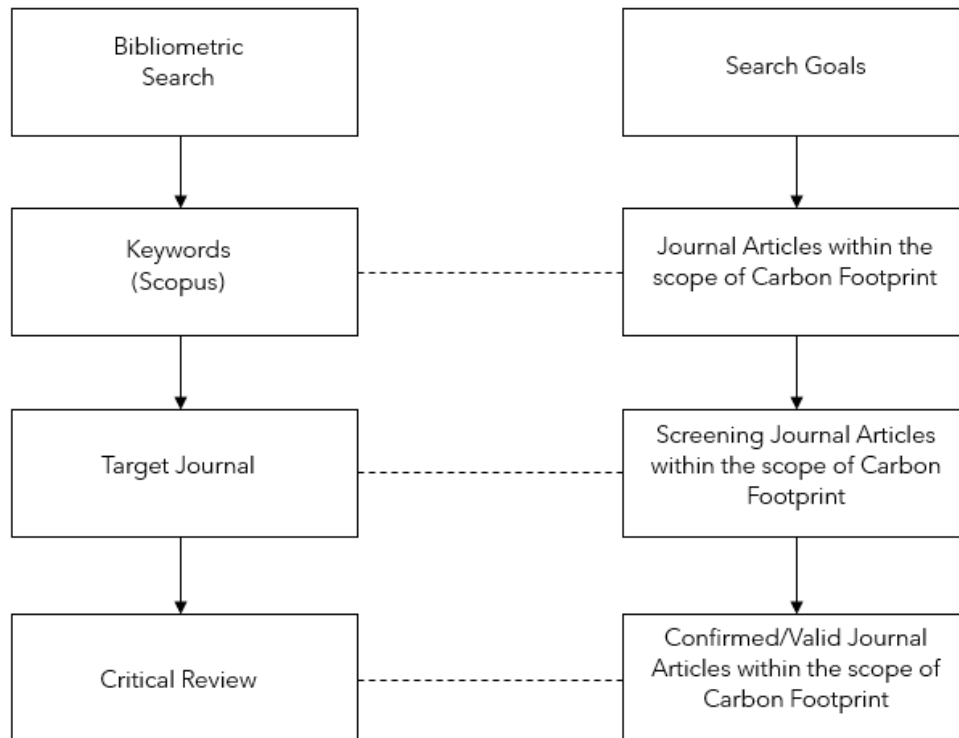


Figure 1. Flow of Bibliometric Process

In this study, we chose the Scopus as the database reference for the examined literature about carbon related journals, with syntax such as:

“PUBYEAR” > 2013 AND < 2023 AND TITLE-ABS-KEY (“Carbon Footprint” OR “carbon footprint) AND TITLE-ABS-KEY (“carbon” OR “CO2”) TITLE-ABS-KEY (“Carbon Emissions” OR “carbon emissions”) TITLE-ABS-KEY (“Carbon Neutrality” OR “carbon neutrality”) AND DOCTYPE (“article” OR “review”) AND LANGUAGE (English) AND SRCTYPE (journal).

Limiting the publication timeframe to the years 2013 through 2023. A total of 59 articles are finally excluded after the irrelevant information is simultaneously assessed during the gathering phase. The abstracts, publication years, keywords, authors, institutions, countries, and references of these works are exported to text files for comprehensive bibliometric analysis.

3.2. Research Methods

Scientific research commonly uses visual analysis techniques of literature because they help us quickly extract relevant information from the literature that is relevant to a particular field of study. The rapid development of literature analysis software applications has led to the rapid appearance of numerous feature-rich applications. The basic metrics and network links for each topic will be visualized in this study using VOSviewer and bibliometric analysis.

4. Results and Discussion

4.1 Publication Trends

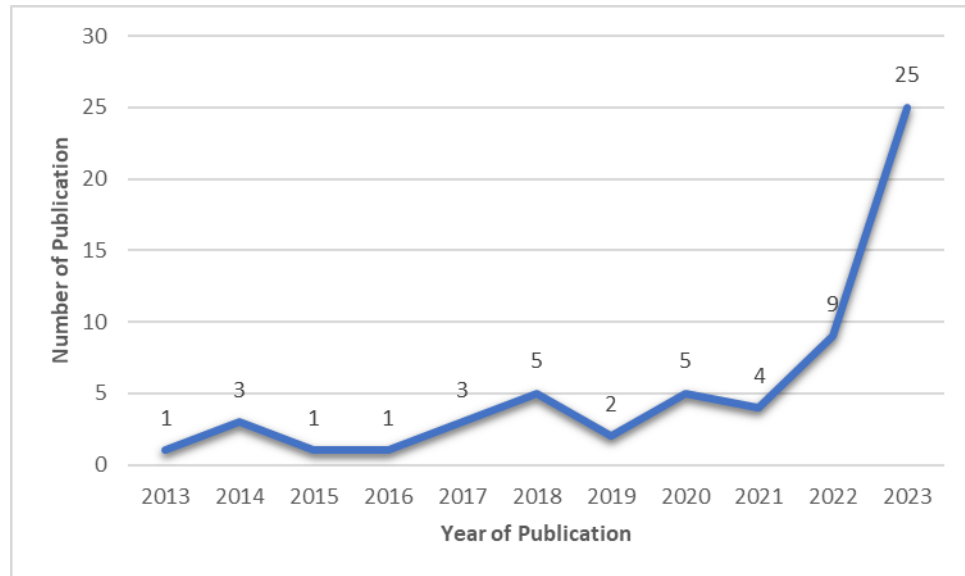


Figure 2 Number of publications from 2013 to 2023

Figure 2 illustrates the progression in the quantity of publications. It is evident up to the year 2020. The volume of papers and citations in this field suggests a relatively stable trajectory. The quantity of articles concerning carbon-related activities has exhibited a notable rise tendency since 2020, escalating from 5 to 25 by 2023. The inaugural citation was released in 2013, illustrating that the domain is proliferating at an unprecedented pace. The domain of carbon has garnered increased attention recently due to the escalating importance of environmental conservation and China's declaration in September 2020 of its objective to attain "carbon neutrality" by 2060. Articles published in 2023 comprise over fifty percent of the total articles in the field. This field is anticipated to yield valuable results in the future.

4.2 Keywords of the Publication

Table 1. Top 5 Keywords

Rank	Keywords	Frequencies
1	Carbon footprint	15
2	Carbon emission	12
3	Sustainability	9
4	Carbon neutrality	6
5	Climate change	6

This subsection is to identify the most used keywords. Table 1 displays the top 5 keywords that contain in the 59 article that been used in this paper. With "carbon footprint" has 15 frequency and followed by "carbon emission" with 12 frequencies. The keywords collaboration graph is shown in Figure 3, with more used keywords being indicated by larger corresponding Nodes in the collaboration network.

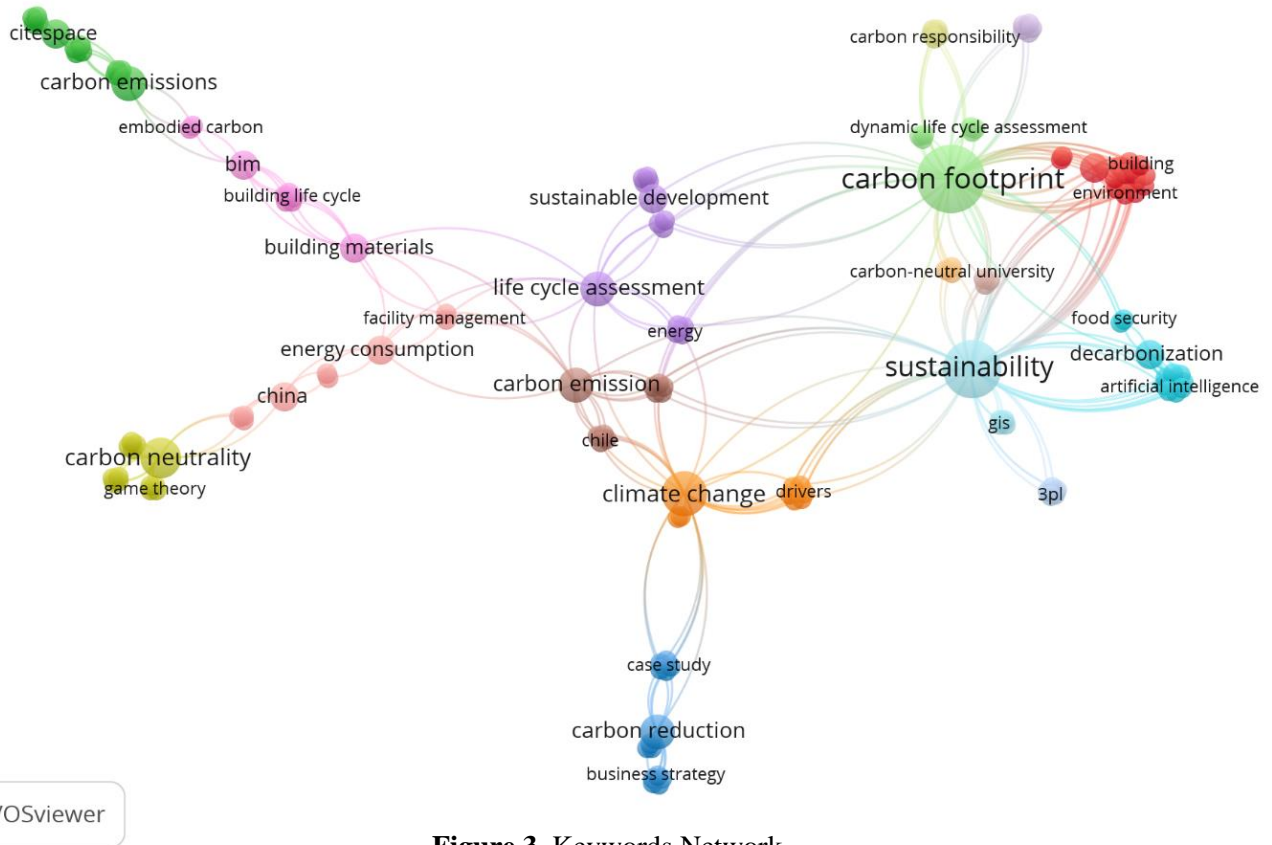


Figure 3. Keywords Network

4.2.1 Sustainability and Carbon Footprint

"Sustainability" is one of the keywords for all types of organizations in the twenty-first century because of its crucial role in both the maintenance of social and environmental value and the economic expansion of businesses. (Corbett and Klassen, 2006; Kolk and Pinkse, 2008). Out of the three pillars of sustainability, environmental degradation is primarily affecting how governments and international businesses operate and formulate policies. The movement first gained traction in the late 1990s as a result of growing public awareness of global warming and the "carbon footprint" (CFP). About 150 countries adopted the Kyoto Protocol (United Nations, 1997) in their industrial policy, asking for a reduction in greenhouse gas emissions in the atmosphere. Moreover, greenhouse gases adversely affect our ecosystem, as indicated by a 2007 assessment study published by the Intergovernmental Panel on Climate Change (IPCC). [1]

There's enough data now to conclude that global warming is occurring. According to Future Climate Change (2013), there will likely be serious repercussions for both people and the environment from the climate changes brought on by global warming. International agencies including NASA, the Environmental Protection Agency, and the United Nations Intergovernmental Panel on Climate Change, among others, gather the data for these estimates. Global leaders have not committed to programs aimed at decreasing greenhouse gas emissions, notwithstanding the worldwide UN Kyoto Protocol. Organizations have increased their voluntary efforts to reduce carbon emissions in response to the global inaction. Organizations

are pledging to reduce their emissions in an attempt to become carbon neutral for a variety of reasons, such as environmental stewardship or green branding. [21]

4.2.2 Climate Change and Carbon Footprint

The main causes of climate change are the continuous increase in global warming, the release of carbon dioxide, nitrous and methane oxide, and natural resources that cause variations in temperature, precipitation, droughts, floods, and degradation of the land and water. Depending on the region, the effects of climate change might be neutral, positive, or negative. Numerous empirical research on developed economies has been conducted due to the global nature of this phenomenon. Consequently, owing to their heightened vulnerability and capacity for resilience to climate change, tropical and subtropical developing nations were monitored following the recognition of the detrimental impacts of an elevated carbon atmosphere and ecological disruption.[6]

"Climate change that is caused directly or indirectly by human activity that changes the structure of the global atmosphere and which is in addition to natural climate variability noticed over corresponding years" is how the United Nations defines climate change. Economic activities such as the use of fossil fuels, deforestation, degradation of the soil, and land use, among others, cause climate change. Stern (2006);[6]. The composition of greenhouse gas (GHG) emissions in our environment is shifting as a result of these activities. More importantly, GHG-related environmental degradation indicators are heavily influenced by water vapors, methane, carbon footprint (CO₂ emissions), nitrous oxide, and ecological footprint; an increase in any of these indicators will cause the concentration of global warming to rise [22].

The total greenhouse gas (GHG) emissions produced by agricultural fields over the course of their life cycle are measured by their carbon footprint (CF). According to the Food and Agriculture Organization of the United Nations (FAO, 2015); maize planting, 37% of the Earth's land surface is covered by agricultural land, and agriculture is responsible for 52% and 84% of the world's anthropogenic methane and nitrous oxide emissions, respectively. The world community's main concern is rising greenhouse gas (GHG) emissions, which cause climate change and global warming [23];[5].

4.3 Author of the Publication

Table 2. Top 5 most publications authors

Rank	Name of Author	NP
1	Weihua Liu	2
2	Yongzheng Gao	2
3	Ana Regina de Aguiar Dutra	2
4	José Baltazar Salgueirinho Osorio de Andrade Guerra	2
5	Liziane Araújo da Silva	2

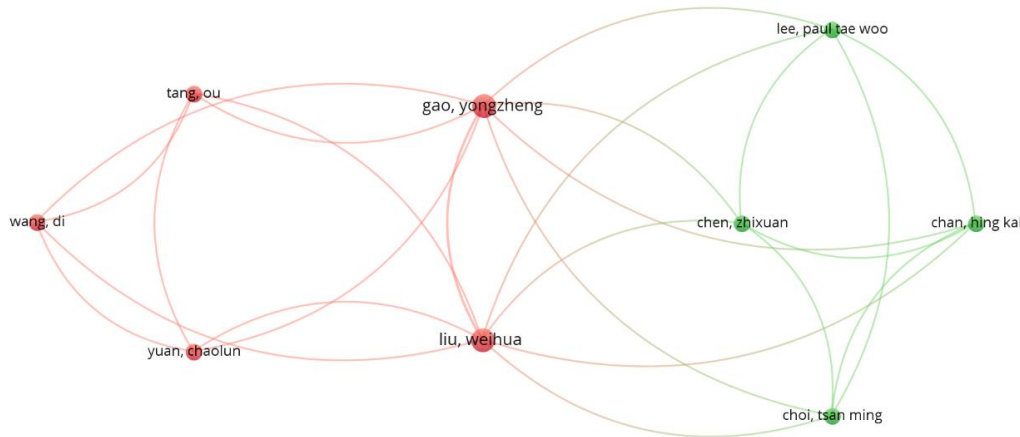


Figure 4. Authors' Cooperation Network

This subsection examines publication authors to identify the most influential and productive authors. The main metric used in this paper to assess the authors' contributions is the quantity of publications. Table 2 displays the top 5 out of the 203 authors in the 59 journals analyzed. Weihua Liu, Yongzheng Gao, Ana Regina de Aguiar Dutra, José Baltazar Salgueirinho Osorio de Andrade Guerra, and Liziane Araújo da Silva are at the top, as we can see, with a maximum of two publications. We then use the VOSviewer program to visually analyze author collaboration in the field, as this contributes to the creation of more outstanding works. The author collaboration graph is shown in Figure 4, with more co-authored publications being indicated by larger corresponding Nodes in the collaboration network.

4.4 Source of the Publication

Table 3. Top 10 most contributive journals

Rank	Name of Journals	NP
1	International Journal of Climate Change Strategies and Management	10
2	International Journal of Sustainability in Higher Education	6
3	Engineering, Construction and Architectural Management	4
4	Industrial Management & Data Systems	2
5	International Journal of Contemporary Hospitality Management	2
6	International Journal of Operations & Production Management	2
7	Management of Environmental Quality: An International Journal	2
8	Social Responsibility Journal	2
9	Supply Chain Management: An International Journal	2
10	Other Journal with Number of Publication less than two	27

This segment analyzes publication sources to determine the most prominent and representative source journals. Table 3 displays the top 10 journals from which the 59 publications referenced in this paper were sourced. Notably, 10 of these publications originate from the “International Journal of Climate Change Strategies and Management,” while 27 publications come from journals that each have fewer than 2 publications.

4.5 Institutions of Publication

Table 4. Top 5 University/Institutions with the Most Publications

Rank	Name of University/Institutions	NP
1	University of Southern Santa Catarina	8
2	University of Michigan	7
3	Sichuan University	6
4	Tianjin University	6
5	Universiti Teknologi Malaysia	6

Selecting the research institutes comes next. An analysis of publication research institutions is facilitative in comprehending the research institutions that are presently producing substantial contributions and in augmenting institutional collaboration. Based on the quantity of publications and their output, Table 4 presents the top 5 of the total institutions he analyzed from 59 publications. Brazil's University of Southern Santa Catarina has eight publications, then followed by the US's University of Michigan with seven publications.

4.6 Regions/Countries of the Publications

Table 5. Top 5 Country of Authors

Rank	Country/Nation	Number of Authors
1	China	75
2	United Kingdom	19
3	Brazil	16
4	United State	14
5	India	11

Examining national and regional collaboration is a fundamental method for understanding the global distribution and development of research. The top 5 countries determined with the most authors are displayed out of a total of 203 authors from 59 total publications. Overall, Table 5 demonstrates that the authors would rather collaborate with fellow national scholars than those from other nations. With 75 authors, China ranks first, far ahead of other countries.

4.7 Insights Gained via Bibliometric Analysis

1. This report presents a bibliometric analysis of 59 papers in the Scopus database that include "carbon" in their titles. The inaugural publication appeared in 2013, and since 2020, there has been a significant surge in the volume of publications, with those from 2023 constituting about half of the total count.

2. The majority of publications by leading authors consist of 2 articles each, among a total of 203 writers over 59 publications, including Weihua Liu, Yongzheng Gao, Ana Regina

de Aguiar Dutra, José Baltazar Salgueirinho Osorio de Andrade Guerra, and Liziane Araújo da Silva. In the collaborative network of authors with at least one publication, Weihua Liu and Yongzheng Gao have pivotal positions.

3. The 59 selected publications originate from 36 journals, with the International Journal of Climate Change Strategies and Management, the International Journal of Sustainability in Higher Education, and Engineering, Construction and Architectural Management ranking as the top three journals by publication count.

4. The top five institutions are the University of Southern Santa Catarina (Brazil), the University of Michigan (UK), Sichuan University (China), Tianjin University (China), and Universiti Teknologi Malaysia (Malaysia). Although Brazil ranked first in institutions, China has the highest number of authors, totaling 75, followed by the United Kingdom with 19 authors, out of a total of 203 authors across 59 articles. The publication's findings indicate that there are much more developed countries than developing countries.

5. The examination of carbon-related activity is an interdisciplinary domain that integrates knowledge from other disciplines.

4.8 Future Research Direction

Artificial intelligence (AI) has revolutionized humankind in recent years and is playing a bigger role in accelerating the transition to carbon neutrality. Conventional methods have found it difficult to deal with the ambiguity and uncertainty associated with carbon neutrality energy systems due to their complexity and uncertainty. Important advancements in carbon-neutral green technology include those related to forecasting, diagnostic monitoring, and hydrogen generating can be facilitated by AI [24].

AI algorithms that rely on extensive data rather than intricate models may mitigate the challenges posed by the heightened scale and uncertainty of significant decisions during the shift from traditional to carbon-neutral grids, facilitating a carbon-neutral transition. [25]. As artificial intelligence (AI) advances and is used more widely, research on the complex ways in which AI and carbon neutrality are integrated should be a major subject of future study in the field of carbon neutrality.

5. Conclusion and Limitation

The goal of reviewing of journal papers on carbon-related activities such as carbon neutrality and carbon footprint aims to uncover some facets of the problem that have not yet been explored or may be looked into more thoroughly. This research gives a thorough and methodical analysis of the literature on carbon activity using the VOSviewer software and bibliometric analysis. By offering a quantitative and visual examination and discourse on the published data about carbon activity, which also facilitates future research endeavors.

At first, researchers examine 59 Scopus publications based on authors, publications, countries/regions, journals, keywords, and research focal points. Since 2020, there has been a notable rise in publications regarding carbon-related activities. The foremost contributing writers and institutions globally are distributed, with China leading in publication volume, followed by the United Kingdom, while developing nations exhibit lower research output.

Second, the researchers examine the interconnections within the collaborative network and discover that China and the UK occupy a central position in a global cooperation network for national collaboration, with the top five authors identified by publication volume.—Weihua Liu, Yongzheng Gao, José Baltazar Salgueirinho Osorio de Andrade Guerra, Ana Regina de Aguiar Dutra, and Liziane Araújo da Silva—had established a significant collaboration

network. Furthermore, of the 20 journals that contributed to the 59 selected papers, the three with the most publications are "International Journal of Climate Change Strategies and Management," "International Journal of Sustainability in Higher Education," and "Engineering, Construction and Architectural Management." The most cited and influential journal in the topic is "International Journal of Climate Change Strategies and Management."

The five leading research institutions in publishing are situated in China, Brazil, the United States, and Malaysia. With Sichuan University, Tianjin University, University of Southern Santa Catarina, University of Michigan, and Universiti Teknologi Malaysia, there is a robust network of collaboration amongst institutions. Additionally, term co-occurrence analysis, word cloud analysis, and cluster analysis are used to identify "carbon footprint," "sustainability," and "carbon emission" as popular and trending research subjects. The information gained from the literature's bibliometrics is then compiled, examined, and new study avenues are proposed.

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