JOURNAL OF TOURISM AND GASTRONOMY STUDIES

A Bibliometric Analysis of the Carbon Footprint Studies in Tourism

* Mustafa Murat KIZANLIKLI [a,b] iD

[a] Ankara Hacı Bayram Veli University, Faculty of Tourism, Department of Tourism Guidance, Ankara/Türkiye
[b] Kyrgyz-Turkish Manas University, Faculty of Tourism, Department of Tourism and Hotel Management, Bishkek/Kyrgyztan

Abstract

In recent years, carbon footprint (CF) has been studied as an important research topic. Increasing the number of CF studies is important for reducing the environmental impact of tourism and raising awareness on sustainable tourism. This study examines the number of studies on CF in tourism, investigates the connections between authors, institutions, resources, and countries, and explores the dominant key issues in the studies. "Carbon footprint" and "tourism" keywords were used to identify studies that take place together in all fields. A total of 393 studies published between 2007 and 2024 were identified using the Web of Science Core Collection, and VOSviewer was used to analyze the co-authorship, co-occurrence, citation, bibliographic coupling, co-citation networks, and themes. According to the findings, researches on CF in tourism have increased, especially after 2018. The University of Queensland, Bournemouth University, and the Chinese Academy of Sciences have the highest numbers of papers on CF in tourism. Moreover, according to the countries of affiliation and the most cited authors, Australia was the most dominant country. On the other hand, Sustainability, Journal of Cleaner Production, and Journal of Sustainable Tourism have the highest number of CF studies in tourism.

INTRODUCTION

The tourism sector is a rapidly growing sector that has different social, cultural and economic impacts on countries and regions. International tourism export revenues, encompassing both receipts and passenger transport, totaled USD 1.7 trillion in 2023, restoring approximately 96% of pre-pandemic levels when adjusted for inflation. Tourism's direct GDP contribution bounced back to pre-pandemic levels by 2023, totaling an estimated USD 3.3 trillion, which accounts for approximately 3% of the world's GDP. In contrast, approximately 285 million foreign visitors travelled during the firts three months of 2024, representing a 20% increase compared to the same period in 2023 (UNWTO, 2024). As global economic development advances, consumer demand for travel has increased at a significantly faster rate than consumers' consumption of other goods and services, particularly in high-income nations and regions undergoing rapid economic expansion (Lenzen et al., 2018). On the other hand, the constant increase in travel movements brings with it some problems. Unplanned tourism development, uncontrolled resource usage and rapid consumption, and over tourism can be expressed as some of these. Also, tourism makes a significant contribution to climate change due to the use of fossil fuels that lead to greenhouse gas emissions (Rico et al., 2019). The tourism sector, which is intertwined with various industries, including trade, logistics, lodging, dining, and entertainment, contributes to environmental degradation by releasing substantial amounts of greenhouse gases (Moutinho et al., 2015) and the industry contributes approximately 8% of global carbon dioxide (CO_2) emissions (Lenzen et al., 2018; Streimikiene et al., 2021).

Globally, governments are growingly concerned about the adverse effects of tourism, and many are trying to decrease the environmental impact of tourism. Decarbonization of the transportation industry is a crucial component of this solution (UNWTO, 2019). In line with this purpose, at the 77th IATA Annual General Meeting in Boston on October 4, 2021, IATA member airlines voted in favor of a resolution that obliged them to reduce their operational carbon emissions to net-zero by 2050 (IATA, 2024). So, sustainable tourism has gained increasing attention from policymakers, practitioners, and researchers since the 1990s (Chen & Peng, 2023). Sustainable tourism, often referred to as eco-tourism or responsible tourism, aims to reduce negative impacts on the environment, help local people and promote cultural preservation (Kumar et al., 2024). Sustainability has been seen as offering significant potential for addressing the adverse effects of tourism and ensuring its long-term sustainability (Liu, 2003: 460). Climate change's potential future impacts on tourism have garnered attention from global, regional, and national institutions as well as academic and research circles (Moutinho et al., 2015).

By the way, the increase in research on carbon footprint in recent years is very important to draw attention to reducing the environmental impact of tourism and increasing awareness of sustainable tourism. Moreover, tourism carbon footprint is the most popular topic in the field of tourism footprint research (Chen et al. 2023). On the other hand, bibliometric analysis of these studies is important in revealing the general trend. There are many bibliometric studies on carbon footprint in various fields such as global carbon footprint (Yue et al., 2020), environmental footprint family (Xie et al., 2020), higher education (Li et al., 2021), buildings (Raza et al., 2021), carbon neutrality (Zhang et al., 2022), climate change and energy use (Cao et al., 2023), household carbon footprint (Shen et al., 2023), environmental degradation (Ali et al., 2024), public acceptance of carbon pricing (Nazari et al., 2024) and urban development (Valderrama et al., in press). Also, in tourism literature, there are some bibliometric studies on ecotourism (Khanra et al., 2021), tourism and hospitality education (Menon et al., 2022), sustainable tourism and

biodiversity (Harish & Rao, 2024; Pahrudin et al., 2022), agritourism and sustainability (Ndhlovu and Dube, 2024). However, there are fewer researches (Chen et al., 2023) that focused on carbon footprint in tourism through bibliometric review. And unlike other studies (Chen et al., 2023) bibliographic coupling analyses were used in this study. Finally, the aim of the study is to review and bring out the bibliometric assessment of publications focusing on carbon footprint in tourism. The main reason of the choosing bibliometric methods was based on the need for a robust and systematic approach to examine the literature on carbon footprint in tourism from past to present (Nazari et al., 2024). In this review, data was extracted from the Web of Science (WOS) Core Collection and the publications from 2007 to 2024 (N= 393) and analyzed by VOSviewer.

Carbon Footprint in Tourism

The concept of the carbon footprint (CF) originated from the ecological footprint proposed by Wackernagel and Rees in 1997 (Yue et al., 2020). They defined ecological footprints as the "area of land and water in various ecological categories that is claimed by participants in this economy to produce all the resources they consume, and to absorb all their wastes they generate on a continuous basis, using prevailing technology" (Wackernagel & Rees, 1997). Carbon footprint is a concept that has been developed and used over time and is considered in a versatile way within the ecological framework. The carbon footprint is the total CO_2 emitted by a product or service system throughout its life cycle. On the other hand, it is the total amount of CO_2 emitted directly and indirectly during an activity, including by individuals, organizations, governments, and industries (Shen et al., 2023). The level of tourism-related carbon emissions serves as a key indicator of the environmental impact of tourism activities. Effective low-carbon tourism is a crucial foundation for sustainable tourism growth, and a tourism sector's carbon footprint can accurately assess the level of its low-carbon tourism efforts (Luo et al., 2020). Tourism services such as accommodation, transportation, food and beverage and leisure activities require a lot of energy from fossil fuels, which causes the release of high amounts of greenhouse gases (Cadarso et al., 2016). Also, while transport alone accounts for 75% of tourism's total carbon emissions (Michailidou et al., 2015), aviation is the transportation mode that contributes the most (40%) to this share (Miralles et al., 2023). When national carbon emissions are compared to tourism emissions, tourism would be the 5th largest polluter worldwide; furthermore, emissions from tourism are expected to more than double by 2035 compared to 2005 (Rico et al., 2019).

The UNWTO forecasts a 25% rise in tourism-related carbon emissions from transportation, escalating from 1,597 million tons in 2016 to 1,998 million tons by 2030. During this time, the number of international and domestic visitors is predicted to rise from 20 billion to 37 billion, driven primarily by a surge in domestic tourist arrivals (growing from 18.8 billion to 35.6 billion) and to a lesser extent, international arrivals (projected to increase from 1.2 billion to 1.8 billion). On the other hand, while transportation-related emissions from tourism represented 5% of all man-made emissions in 2016, this rate is estimated to be 5.3% by 2030. While tourism-related transportation emissions represented 22% of all transport emissions in 2016, it is reported that it will continue to remain at a similar rate in 2030 (21%) (UNWTO, 2019). Tourism is a sector with high income flexibility; therefore, as economic development increases, consumers also increase their demand for tourism faster than other products and services (Miralles et al., 2023).

UNWTO recognized the bi-directional relationship between tourism and climate change in the 2003 Djerba Declaration. Accordingly, while climate change has an impact on tourist destinations and tourist flows, on the other

hand, tourism has a significant contribution to climate change due to the use of fossil fuels that cause greenhouse gas (GHG) emissions (Rico et al., 2019). Global tourism's carbon footprint is primarily influenced by two key elements: the demand for and the carbon intensity of goods and services related to tourism (Lenzen et al., 2018). Typically, the assessment of tourism's carbon footprint is based on production, consumption, or destination (Sun et al., 2020). Several methodologies have been used by practitioners to assess the environmental impacts of tourism. For the Carbon Footprint (CF), there are many methodologies, guidelines and standards being used in tourism assessments. The most commonly used methods are; ISO 14067, the GHG Protocol, Ecological Footprint Analysis (EFA), Life Cycle Assessment (LCA) and Input-Output (IO) approaches, the UK Department of Environment, Food and Rural Affairs (DEFRA) and PAS 2050 Standard (Miralles et al., 2023; Yang & Guo, 2024).

Rico et al. (2019) assessed the carbon footprint (CF) of tourist activity in Barcelona and found that transportation associated with arrivals and departures accounted for approximately 95.6% of the city's carbon emissions, with aviation being a particularly significant contributor. In contrast, according to data from the destination, a tourist's one-night stay in a five-star hotel can produce over eight times the daily emissions of local people, according to data from the destination (Rico et al., 2019). Moreover, Osorio et al. (2023) demonstrated that the carbon footprint of tourism in Spain fell by 63% in 2020 compared to pre-pandemic levels with the fall of visitors.

The impact of tourism development on climate change in general, and carbon emission status in particular, has attracted increasing attention from scholars. The carbon footprint of tourism has triggered debate among scientists, especially in recent years (Herrero et al., 2022). Therefore, it is very important to identify research hotspots around the carbon footprint of tourism, to elaborate on the influencing factors and potential research directions in this field (Chen et al., 2023).

The study is expected to significantly contribute to the literature in several key areas: Firstly, this study allows the visualization of a network describing the interactions of 393 publications and the results offer a comprehensive summary of the current status of the concept of CF in tourism, outlining key contributors, institutions, and authors. Secondly, it enables easy viewing of emerging trends in carbon footprint studies in tourism and specific points related to the studies. Finally, it can contribute to the identification of some gaps in carbon footprint studies and enable studies to be concentrated in these areas.

In this study, the following research questions are addressed:

1- What are the annual publishing trends, contributing sources and affiliations for CF researches in tourism?

2- What are the global research collaboration networks of co-authorship & co-citation for CF researches in tourism?

3- What are the basic concepts and bibliographic couplings on which carbon footprint research in tourism focuses?

Data and Methodology

Bibliometric analysis is a useful method for identifying ongoing research trends, future research concepts, and existing research gaps based on literature (Ye et al., 2014). Bibliographic assessment enables organizations to monitor key aspects of literature and the scholarly output of authors, journals, countries, and institutions (Raza et al., 2021;

Si et al., 2019). Bibliometric analysis has been employed to identify the contributions of environmental science research from various fields, subfields, and specific topics (Xie et al., 2020). Bibliometric analysis is used to extract data and insights about academic research, connect literature, discipline trends, and impact through data exploration and visualization to inform the current and future directions of scholarly work (Chen et al., 2023).

Bibliometric was defined as "the quantitative study of bibliographic material" (Broadus, 1987). Bibliometric analysis is based on a variety of calculations, such as citation counts or publication counts by author, institution or country, keyword occurrence or co-occurrence, or co-authorship (Mas-Tur et al., 2021). In this study, data was extracted from the Web of Science (WOS) Core Collection database. The WOS is a prominent digital platform known for its high standards and is frequently used for bibliometric analysis and research (Gaviria-Marin et al., 2019). The selection of the WoS Core Collection as the database for the study emphasizes the reliability and academic importance of the sources in the database (Martínez Falcó et al., 2024). Web of Science database contains tens of thousands of multidisciplinary, high-impact, international, and comprehensive academic journals and it is a worldwide authoritative source of cited information (Yue et al., 2020). Journal articles, book chapters and conference proceedings published from 2007 to 2024 (N= 393) were identified using the Web of Science Core Collection. "Carbon footprint" and "tourism" keywords were used to identify studies that take place together in all fields and the data was extracted on 12th June 2024. The VOSviewer software was employed to examine co-authorship, co-occurrence, citation, bibliographic coupling, co-citation, and themes.

In the interpretation of the findings, there were two standard weight attributes, which were the "links" attribute and the "total link strength" attribute. For a specific item, the concept of "links" pertained to the number of connections it had with other items, while "total link strength" represented the combined number of these connections and the overall weight or value of those links with other items (van Eck and Waltman, 2023: p.6).

Results

According to the data in the Fig. 1; studies on carbon footprint in tourism show a significant increase, especially after 2018. Although the number of studies conducted in recent years is quite high, the highest number of publications was made in 2023. By the 15th June 2024, 34 publications had been recorded about CF in tourism on WOS database. Considering the number of publications in the first half of the 2024, it can be stated that this year has a high potential based on the number of publications.
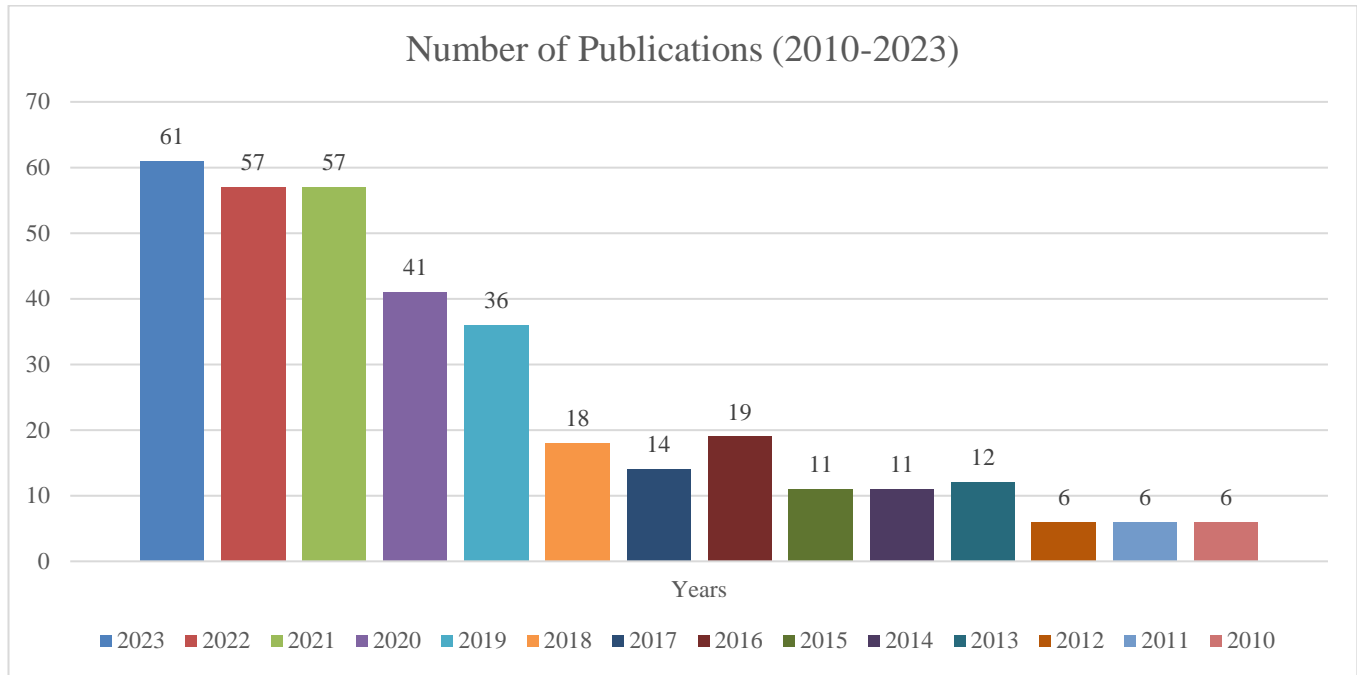
Figure 1. Number of publications of CF on tourism (2010-2013)

Journal articles, book chapters and conference proceedings had been published from 2007 to 2024 (N= 393) were identified using the Web of Science Core Collection. According to the Table 1, Top 10 journals have published 162 carbon footprint papers on tourism which accounted for 45.8% of the totally articles. And the highest-ranking journal was Sustainability with 52 publications and Journal of Cleaner Production (35).

Table 1. Contributing sources (Top 10)

Publication Titles	Number of Publications	Journal Citation Indicator (2022)	Category Quartile
Sustainability	52	0,67	Q2/Q3
Journal of Cleaner Production	35	1,53	Q1
Journal of Sustainable Tourism	23	1,67	Q1/Q2
Tourism Management	16	3,05	Q1
Environmental Science and Pollution Research	8	0,91	Q1
Science of the Total Environment	7	1,68	Q1
Environment Development and Sustainability	6	0,72	Q2/Q3
Annals of Tourism Research	5	3,56	Q1
Journal of Hospitality and Tourism Management	5	1,89	Q1
Journal of Travel Research	5	2,1	Q1

According to the Table 2, the top 10 organizations have published 135 carbon footprint papers related to tourism and this accounted for 34.3% of the total publications. As for the main institutions, University of Queensland leads the researches on CF in tourism with 52 publications, followed by the Bournemouth University with 16 publications, Chinese Academy of Sciences with 12 publications (12) have the highest numbers of published papers. Thus, of the top 10 institutions in terms of scientific production, Australia, China and UK are the countries with the highest number of institutions, with 2 institutions. Australia also dominated the countries of the most cited authors (Table 3).

Table 2. Distributions by the affiliations (Top 10)

Affiliations	Country	Number of Publications	Year of establishment
University of Queensland	Australia	52	1909
Bournemouth University	UK	16	1992
Chinese Academy of Sciences	China	12	1949
Hong Kong Polytechnic University	China	10	1937
Griffith University	Australia	9	1971
Universidad de la Laguna	Spain	8	1913
Universidade de Aveiro	Portugal	8	1973
University of Surrey	UK	8	1966
Linnaeus University	Sweden	6	2010
National Cheng Kung University	Taiwan	6	1931

According to the findings in Table 3, Sun, Y.Y. was the most cited author with 1254 citations in 15 documents. Faturay, F. Geschke, A., Lenzen, M., Malik, A. and Ting, Y.-P. were the second with 772 citations in two studies. Filimonau, V. was the third with 603 citations in 15 papers on carbon footprint in tourism. And then Robbins, D. (390 citations), Gossling, S. (315 citations) and Dolnicar, S. (314 citations) were in the ranking respectively. On the other hand, according to the countries where the authors' institutions are located, Australia is the country with the most institutions in the Top 15 (Table 3):

**Table 3.** Most cited authors in CF studies on tourism (Top 15)

Authors	Affiliations	Country	Number of Citations	Number of Publications[1]	h-index
Sun, Ya-Yen	The University of Queensland	Australia	1254	15	18
Faturay, Futu	The University of Queensland	Australia	772	2	8
Geschke, Arne*	The University of Sydney	Australia	772	2	27
Lenzen, Manfred*	The University of Sydney	Australia	772	2	75
Malik, Arunima	The University of Sydney	Australia	772	2	33
Ting, Yuan-Peng	National Cheng Kung University	Taiwan	772	2	5
Filimonau, Viachaslau	University of Surrey	UK	603	15	30
Robbins, Derek	University of East London	UK	390	5	15
Gossling, Stefan	Linnaeus University / Western Norway Res. Inst.	Sweden / Norway	315	7	61
Dolnicar, Sara	The University of Queensland	Australia	314	6	59
Juvan, Emil	University of Primorska / University of Queensland	Slovenia / Australia	306	5	13
Prideaux, Bruce	Central Queensland University / Prince of Songkla University	Australia / Thailand	269	2	28
McKercher, Bob	The University of Queensland	Australia	269	3	47
Dickinson, Janet	Bournemouth University	UK	257	3	23
Hall, C. Michael*	University of Canterbury	New Zealand	236	3	67
Dwyer, Larry	University of Technology Sydney	Australia	207	3	38

1 The number of CF studies on tourism in the WOS, *highly cited researcher on WOS

The Findings on Co-Authorship, Co-Occurrence and Citation Analyses

By co-authorship analysis of authors, minimum number of documents of an author and minimum number of citations of an author were determined as 3, and of the 1234 authors, 57 met the thresholds (Fig. 2). The total linkage strength for each of the 57 authors was determined by calculating the combined strength of their citations to other authors. The authors with the highest total link strength were identified. The largest network of interconnected elements comprised 109 items with 1366 links. A citation link is essentially a reference connection between two

items, with one item referencing the other (van Eck and Waltman, 2023: 27). Sun, Y.Y. has the greatest total link strength (399) with other authors and followed by Filimonau V. (363), Robbins, D. (259) and Dickinson, J. (208).
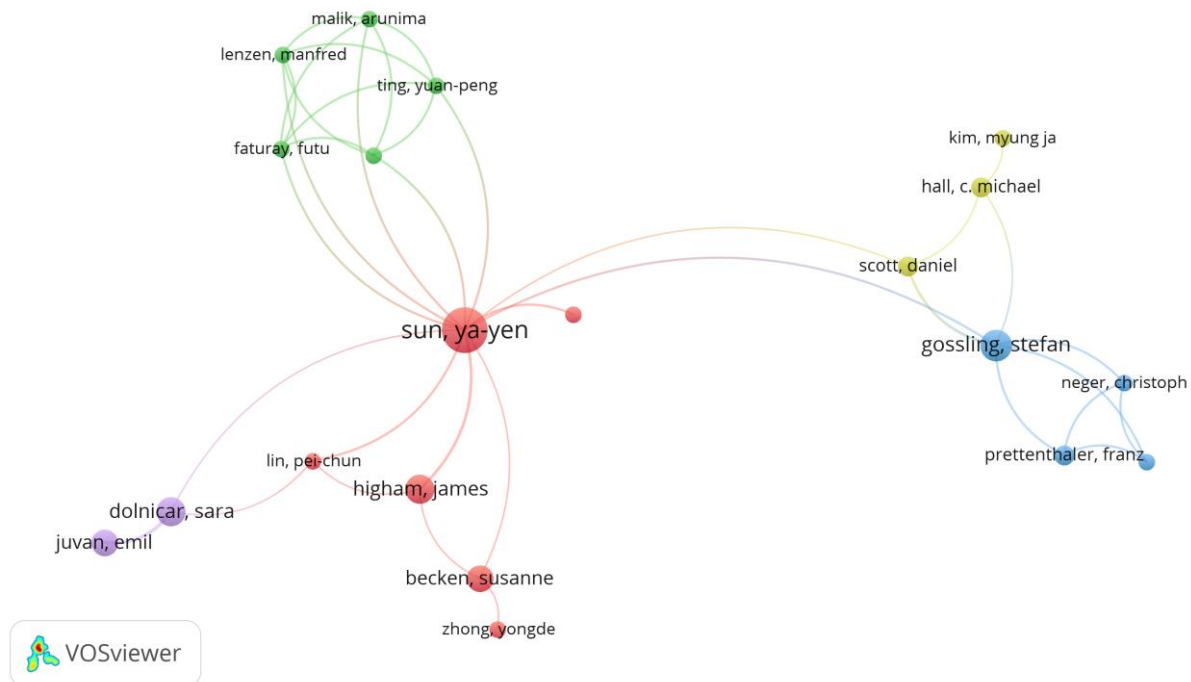
Figure 2. Network visualization of co-authorship analysis of authors

The "links" attribute in co-authorship data indicates the number of co-authorship relationships that a researcher shares with other researchers. The "total link strength" attribute reflects the cumulative strength of co-authorship connections between a specified researcher and other researchers (van Eck and Waltman, 2023: 6). According to the findings in Fig. 2, totally 1234 authors have participated in the publication of carbon footprint papers on tourism. While analyzing, to emphasize the more important collaborations among authors, minimum number of documents of an author was determined as 2 and minimum number of citations of an author was determined as 5. And of the 1234 authors, 138 met the thresholds. By the analysis performed on 20 authors that are linked to each other, via 37 links and total link strength were determined as 69. For each of the 138 authors, the total strength of the co-authorship links with other authors as calculated. According to the findings; Sun, Y.Y. had the 12 authorship links and 22 the total strength of the co-authorship links with other researchers. And second author was the Gössling, S. with 6 co-authorship links and 12 total link strength with 7 publications.
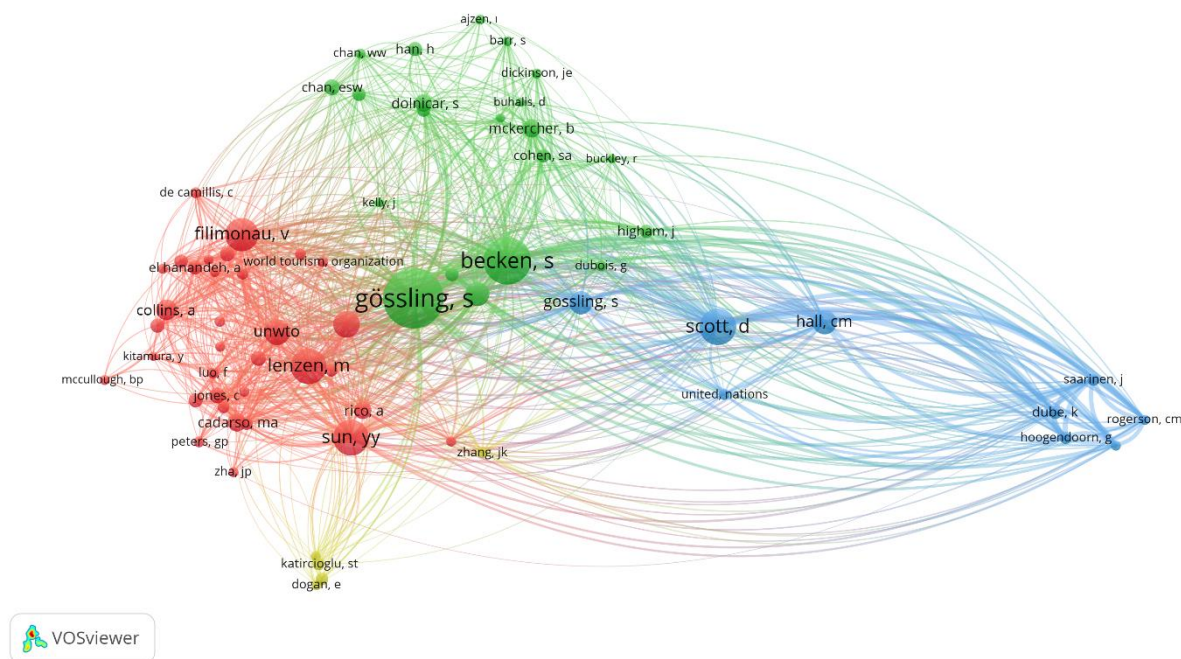
Figure 3. Density visualization of the citation analysis of publications

The item density visualization displays colors that transition from blue to green and yellow. The more items surrounding a point and the greater their respective weights, the color of the point will be closer to yellow (van Eck and Waltman, 2023: 11). While the analyzing, minimum number of citations of a document was determined as 5 and of the 393 documents, 220 met the threshold. For each of the 220 documents, the count of citation links was determined, and the publications with the highest number of links was selected. The citations attribute indicates the number of citations made to cited publications (van Eck and Waltman, 2023: 38). According to the findings (Fig. 3), Lenzen et al. (2018) was the first source with 88 links, and followed by Dwyer et al. (2010) with 56 links, Sun (2014) with 41 links and Rico et al. (2019) with 35 links. Lenzen et al. (2018) was also the most cited references according to the co-citation analysis of the cited references (Fig. 7).

Table 4. The most cited articles on CF in tourism (Top 10)

Publications	Number of citations	Links
Lenzen, M., Sun, Y. Y., Faturay, F., Ting, Y. P., Geschke, A., & Malik, A. (2018). The carbon footprint of global tourism. *Nature Climate Change*, *8*(6), 522-528.	770	123
Dwyer, L., Forsyth, P., Spurr, R., & Hoque, S. (2010). Estimating the carbon footprint of Australian tourism. *Journal of Sustainable Tourism*, *18*(3), 355-376.	204	70
McKercher, B., Prideaux, B., Cheung, C., & Law, R. (2010). Achieving voluntary reductions in the carbon footprint of tourism and climate change. *Journal of Sustainable Tourism*, *18*(3), 297-317.	197	34
Koçak, E., Ulucak, R., & Ulucak, Z. Ş. (2020). The impact of tourism developments on CO2 emissions: An advanced panel data estimation. *Tourism Management Perspectives*, *33*, 100611.	190	3
Khan, I., & Hou, F. (2021). The dynamic links among energy consumption, tourism growth, and the ecological footprint: the role of environmental quality in 38 IEA countries. *Environmental Science and Pollution Research*, *28*(5), 5049-5062.	170	3

Table 4. The most cited articles on CF in tourism (Top 10) (cont.)

Gössling, S. (2013). National emissions from tourism: An overlooked policy challenge?. *Energy Pol icy*, *59*, 433-442.	142	1
Filimonau, V., Dickinson, J., Robbins, D., & Huijbregts, M. A. (2011). Reviewing the carbon footprint analysis of hotels: Life Cycle Energy Analysis (LCEA) as a holistic method for carbon impact appraisal of tourist accommodation. *Journal of Cleaner Production*, *19*(17-18), 1917-1930.	135	40
Rico, A., Martínez-Blanco, J., Montlleó, M., Rodríguez, G., Tavares, N., Arias, A., & Oliver-Solà, J. (2019). Carbon footprint of tourism in Barcelona. *Tourism Management*, *70*, 491-504.	128	51
Juvan, E., & Dolnicar, S. (2017). Drivers of pro-environmental tourist behaviours are not universal. *Journal of Cleaner Production*, *166*, 879-890.	125	6
Murshed, M., Saboori, B., Madaleno, M., Wang, H., & Doğan, B. (2022). Exploring the nexuses between nuclear energy, renewable energy, and carbon dioxide emissions: the role of economic complexity in the G7 countries. *Renewable Energy*, *190*, 664-674.	121	0

According to the Table 4., the most cited article (Lenzen et al., 2018) was published in 2018 and then next two most cited articles (Dwyer et al., 2010; McKercher et al., 2010) were published in 2010. Of the top 10 most cited articles, four were published in Journal of Cleaner Production and Journal of Sustainable Tourism.

Figure 4. Density visualization of the co-occurrence analysis of the keywords

VOSviewer links the keywords that appeared in studies, and a keyword density indicates the frequency of occurrences for the keyword (Khanra et al., 2021). Bibliometric research often employs co-occurrence analysis to elucidate the connections between keywords or concepts that frequently co-appear in literature (Ndhlovu and Dube, 2024). By analyzing, minimum number of occurrences of a keyword was determined as 3 and of the 1211 keywords, 80 met the threshold. According to the findings in Fig. 4, carbon footprint was the most stated keywords (115), and other keywords respectively were tourism (65), climate change (46), sustainability (29) and sustainable tourism (24).

Findings on Bibliographic Coupling Analyses and Co-Citation Analyses

Two studies are considered bibliographically coupled if both cite the same document. Two publications are bibliographically linked if there exists a third publication that cites both of them. The bibliographic coupling is essentially related to the overlap of references in the bibliographies of publications (Kessler, 1963). On the other hand, co-citation occurs when two documents are cited by the same third document. Author co-citation analysis offers a deeper understanding of how domain experts, namely authors, link concepts across various published studies (Chen et al., 2001). Co-citation analysis of the literature can efficiently and conveniently identify the important data base in the field from a large amount of cited reference information and help analyze and investigate the development of the field in question (Yue et al., 2020). Bibliographic coupling is the opposite of co-citation. While author co-citation analysis is relevant to authors, bibliographic coupling is relevant to authors, institutions and countries (Mas-Tur et al., 2021). Shortly, a bibliographic coupling link is established between two items that share a common cited reference. A co-citation link refers to a connection between two items that are jointly referenced in a single document (van Eck and Waltman, 2023: p.27).

Figure 5. Network visualization of co-citation analysis of the cited authors

A minimum of 20 citations from the authors were required for the analysis. Among the 14,129 cited authors, 69 met the specified criteria. The total strength of co-citation links for each of the 69 authors was calculated, and those with the highest total link strength were subsequently chosen. According to the network (Fig. 5), Gössling, S. was the first author with 449 citations and 8221 total link strength. Becken, S. was second with 296 citations and 6807 total link strength and Scott, D. was the third with 195 citations and 5624 total link strength and Sun Y.Y. was the fourth with 185 citations and 3700 total link strength.
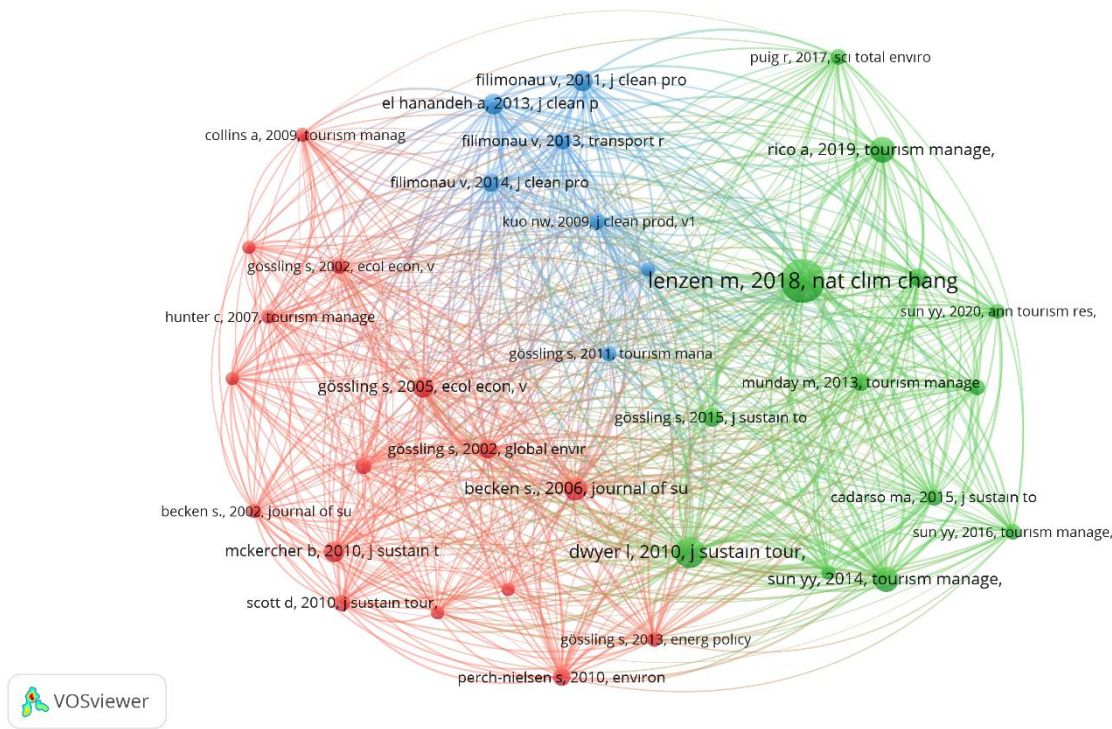
Figure 6. Network Visualization of Co-Citation Analysis of the Cited References

By analyzing, minimum number of citations of a cited reference was determined as 20. And of the 20372 cited references, 36 met the threshold. For each of the 36 cited references, the total strength of the co-citation links with other cited references was calculated. According to the findings (Fig. 6) of the co-citation analysis, Lenzen et al. (2018) was the most cited references with 138 citations and 35 links with other references. Dwyer et al. (2010) was the second with 77 citations and 35 links. And then, Rico et al. (2019) (56 citations), Sun (2014) (53 citations) and Becken (2006) (49 citations) were in the ranking respectively. The first four mentioned sources were in the same group (cluster 2) while the last one was in cluster 1.
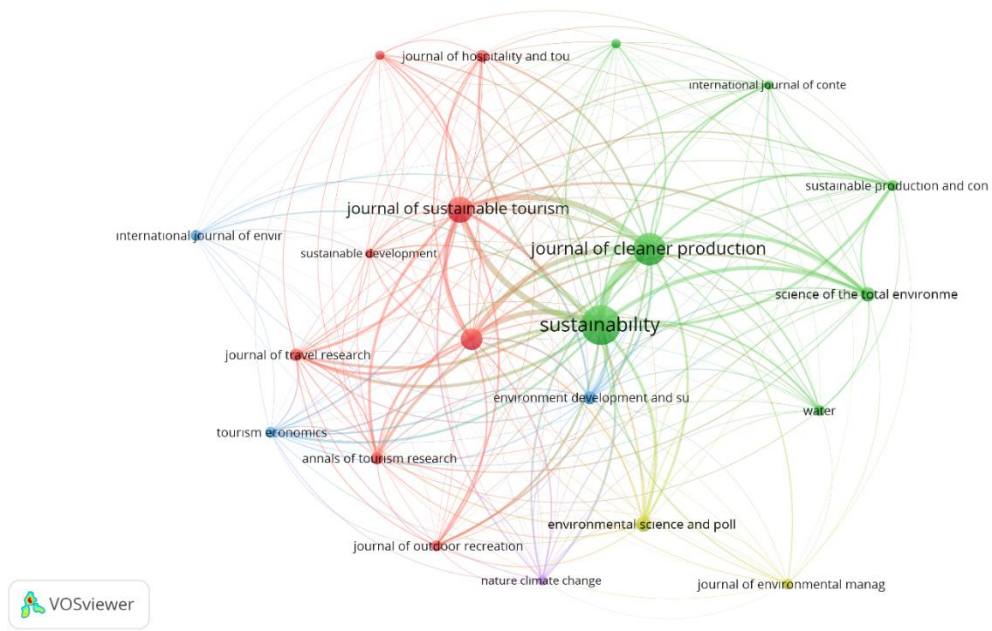
Figure 7. Network Visualization of Bibliographic Coupling Analysis of Sources

Minimum number of documents of a source was determined as 3 and of the 179 sources, 22 journals met the thresholds (Fig. 7). Journal of Sustainability had the strongest total link (7082), second was Journal of Cleaner Production (5915) and third was Journal of Sustainable Tourism (4485).
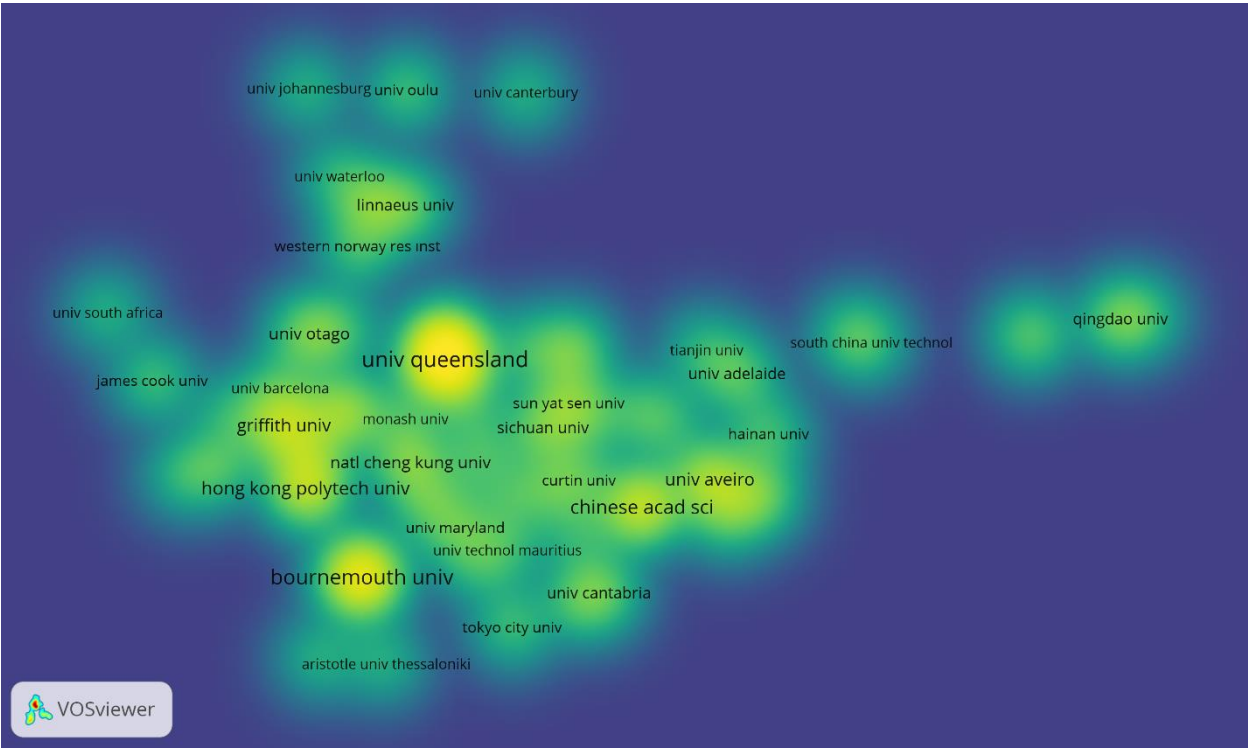
Figure 8. Density Visualization of Bibliographic Coupling Analysis of the Institutions

While analyzing, minimum number of documents and citations of an organization were determined as 3. Of the 677 institutions, 58 met the thresholds. The total strength of bibliographic coupling links for each of the 58 organizations was determined, and the highest total link strength was identified. According to the findings (Fig. 8), University of Queensland had the greatest total link strength (8370) with 1311 citations and 19 documents. Respectively, Bournemouth University was second with 8370 total link strength, 770 citations and 16 documents, and Chinese Academy was the third with 4216 total link strength, 146 citations and 11 documents.
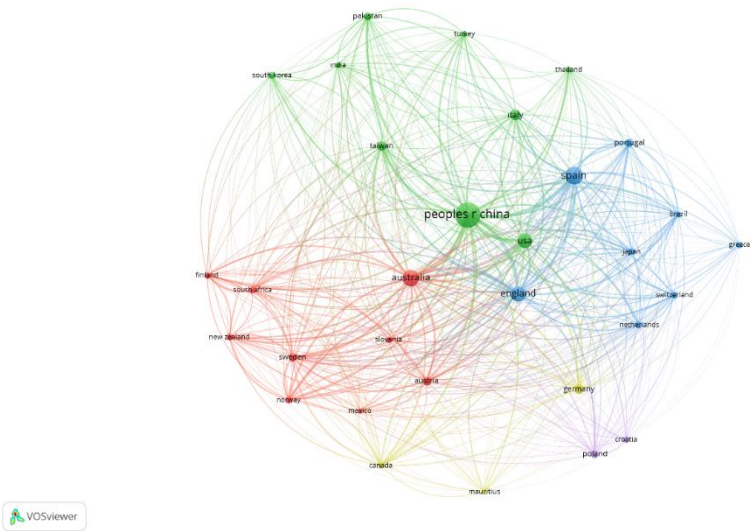
Figure 9. Network visualization of bibliographic coupling analysis of the countries

By analyzing, minimum number of documents of a country was determined as 5 and minimum number of citations of a country was determined as 3. Of the 76 countries, 31 met the thresholds. Republic of China had the strongest total links (30732) with 108 publications and 1936 citations. Respectively Australia (22300) with 47 publications and 2206 citations and UK (18098) with 41 publications 1212 citations were followed (Fig. 9).

Conclusion and Discussion

This study employed a bibliometric approach to identify trends and other key indicators in carbon footprint studies in tourism. Data was extracted from WOS Core Collection and was analyzed by VOSviewer. As stated in other studies (Yue et al., 2020) the number of CF publishments on tourism has shown an upward trend in recent years, especially after 2018. Moreover, Cao et al. (2023) demonstrated that CF studies on "climate change" and "energy use" started to be published in 2008 and was on a constant increase.

The most cited article (Lenzen et al., 2018) with 770 citations was published in 2018 and followed by Dwyer et al. (2010) & McKercher et al. (2010) with 204 and with 197 citations respectively. Lenzen et al. (2018) also had the most citation links with other studies according to the co-citation analysis of the cited references. Similarly, Chen et al. (2023) also demonstrated the largest number of similar co-citations represented by articles as Sun (2014), Lenzen et al. (2018) and Rico et al. (2019) in the field of tourism carbon footprint research.

In terms of publication sources, 162 of 393 studies were published in the Top 10 journals. Sustainability, Journal of Cleaner Production and Journal of Sustainable Tourism have the highest number of studies on carbon footprint in tourism. Moreover, according to the findings of bibliographic coupling analysis of sources, the mentioned journals also had the strongest total links in the same ranking. In terms of publishing affiliations, University of Queensland, Bournemouth University and Chinese Academy of Sciences have the highest numbers of published papers on CF in tourism. Wu et al. (2022) stated also the most influential institution in the carbon footprint researches in China was Chinese Academy of Sciences.

Of the top 10 publishing institutions, two were from Australia, China and UK. Moreover, according to the findings of bibliographic coupling analysis of institutions, University of Queensland had also the greatest total link strength followed by Bournemouth University and Chinese Academy respectively. On the other hand, in terms of bibliographic coupling of the countries, Republic of China had the most connections with other countries and respectively Australia, UK, Spain and USA were in the ranking.

Similarly, according to Raza et al. (2021), China and the USA were the countries with the largest share of the global carbon footprint and made the highest research contribution in the area of carbon footprint studies. Cao et al. (2023) also demonstrated that China and USA had an irreplaceable role in terms of regional publications and citations. Yue et al. (2020) also highlighted USA, China and UK as three important research forces that had the largest number of CF studies from the Web of Science database. Zhang et al. (2022), conducted a bibliometric analysis on the topic of carbon neutrality to reveal the research progress and describe the evolution of research hotspots. Zhang et al. (2022) also conducted a bibliometric analysis to examine research progress on carbon neutrality and trace the development of key research areas. According to the findings, the numbers of publications were dominated by China, followed by the USA and the UK. Furthermore, Khanra et al. (2021) stated that studies conducted in Australia, the

United States, and the United Kingdom have garnered significant attention in ecotourism literature. This method primarily focuses on a publication's level of popularity without considering its significance within a specific research area.

According to the country of the affiliations and most cited authors, Australia emerged as the most dominant country. Moreover, Sun, Y.Y. was the most cited author in CF Studies on tourism with 1254 citations in 15 documents. Of the top 15 most cited authors, the first five authors were from Australia (from The University of Queensland and The University of Sydney). Sun, Y.Y. also had the most authorship links and the total strength of the co-authorship links with other researchers. And second author was the Gössling, S. Moreover, according to the co-citation analysis of the cited authors, Gössling, S. also was the first author with 449 citations and 8221 total link strength. And other cited authors respectively were Becken, S., Scott, D., and Sun Y.Y.

According to the findings of co-occurance analysis of the keywords, carbon footprint was the most stated keywords and other keywords respectively were tourism, climate change, sustainability and sustainable tourism. Moreover, Wu et al. (2022) conducted a comparative bibliometric analysis of Chinese and foreign articles on the carbon footprint researches and they stated life cycle assessment, greenhouse gas emission and climate change as the themes closely related to carbon footprint. On the other part, Yue et al. (2020) generated a keyword co-occurrence network and they identified four hotspots through keyword clustering in CF research, including CF calculation methods and research scales, energy, policies, and agriculture. According to Ali and colleagues (2024), the most frequently searched keyword in publications about environmental degradation was "ecological footprint," with carbon emissions and carbon footprint ranking second.

Theoretical and Practical Implications

From theoretical and practical perspectives, this study has some implications. Bibliometric analysis of the literature on carbon footprint in tourism provides valuable information to this research field. Increasing the number of studies on carbon footprint and analyses of researches contributes to increasing the importance and awareness of sustainable tourism. Moreover, the researchers employed bibliographic coupling and co-citation analyses to pinpoint crucial matters in carbon footprint research within the tourism sector and then directed their findings toward postgraduate and doctoral students and faculty members who focus on this area (Harish and Rao, 2024).

Also the findings of the study enable easy viewing of emerging trends in carbon footprint studies in tourism. Thus, the findings of the study may contribute to the formation of original and new ideas in the emergence of original articles, projects and doctoral dissertations. Therefore, bibliometric researches have a valuable contribution in identifying new research topics. Finally, these studies can contribute to reducing the carbon footprint and developing preventive measures.

Limitations and Future Directions

This study has some limitations that should be mentioned. Firstly, the publications were extracted from the Web of Science Core Collection database for bibliometric analysis. Other databases can also be used for a more comprehensive approach in future studies. Secondly, among the footprint types, only carbon footprint was considered in the research. As other approaches, water and ecological footprints can also be considered as research topics. Finally, while searching, only the keywords of "carbon footprint" and "tourism" were used aligned with the purpose

of study. The scope of the research can be expanded with more keywords.

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