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Sustainability and the Food Industry: A Bibliometric Analysis

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Abstract: The food industry has significantly expanded and become globalized due to the growth of the economies of many countries and an increasing world population. The industry is consequently facing major sustainability challenges. Food, which is critical to the existence of humanity and is affected by the world's ecosystems and human intervention, is a fundamental issue within academic research, especially in terms of sustainability. Using a bibliometric approach, this paper analyzed studies on sustainability in the food industry in the context of the most cited articles, trends in the number of articles, most influential journals, most influential authors, most productive and influential institutions and countries, and future research directions. The software tools Bibliometrix 3.1.4 R-package and VOSviewer 1.6.18.0 were used together to analyze the dataset, which was obtained from the Web of Science database. The results indicated that *Sustainability*, *Journal of Cleaner Production*, and *Frontiers in Sustainable Food Systems* are the most important journals in this field, with the greatest number of articles published. Analyses of the network and overlay visualization of keyword co-occurrences identified six different research clusters. Since climate change and food security issues are in alignment with each other, sustainable food chains and social aspects are an important cross-cutting area of research. The results showed that future research should be multi-disciplinary and involve adjacent fields, including agriculture, agroecology, and climate science. There is also a need for research in the field of economic and social sustainability in the food industry. Studying the research topics found in the thematic map analysis, such as the effect of a sustainable diet on the food chain and the relationships among the agri-food system, sustainable agriculture, sustainable food systems, and sustainability of the food chain, is recommended for future research.

Keywords: food industry; food supply chain; food system; sustainability; bibliometric

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1. Introduction

Food has been the most important requirement of humanity throughout the history of the world, and is a critical component of the world economy. The increase in the world population and globalization have led to the global distribution of food. The need for food and nutrition in modern times has led to the formation of a large food industry. This industry, which feeds a world population of approximately 7.8 billion, will operate to supply food to 9.7 billion individuals by 2050 [1]. With the increasing population and development of the economy and industry, discussions about the use of resources and food safety are also on the agenda. Food is influenced by the world's ecosystems and human intervention, and is a fundamental issue in academic research, especially in terms of sustainability.

All of the companies involved in producing food, from farm to fork, make up the food industry. The term food industry can also refer to the food supply chain. A large number of global and local companies are active in the food industry, where activities such as farming, food processing, packaging, transport, sales, and customer service take

place. A system capable of regulating the extent to which a multitude of companies within the food industry comply with environmental, social, and economic sustainability is of paramount importance for the entire world.

Sustainability in food production means "*that food is produced and consumed in a way that supports the well-being of generations*" [2]. The definition of sustainable development has been given as "*meeting the needs of the present without compromising the ability of future generations to meet their needs*" [3]. However, the current food industry, which has reached extremely large dimensions, has created unsustainable conditions. One example of this is the water usage in food production [2,4–6]. In addition, the food industry directly affects climate change, and agricultural activities are responsible for 17–32% of global greenhouse emissions [7]. One study [8] found a rate of 25%. The use of fertilizers and chemicals also threatens the soil and ecosystem health [9]. Distribution and storage are another source of pollution. Ref. [10] reported that 16% of the total energy used in the USA is consumed by the food industry. In addition, food safety and quality are being discussed globally [11]. Production and consumption in the food industry place a significant burden on the world's ecosystem. While ensuring sufficient food production and access for everyone remains a top priority for humanity, transitioning to more sustainable processes must now take precedence due to the long-term impact of the food industry. As a result, there has been an increase in the number of studies focusing on sustainability in the food industry [12].

The global food industry is at a turning point in its history. A growing body of academic research is focusing on sustainability due to the intersection of social, environmental, and economic factors [13,14]. Discussions of sustainable practices in the food industry have becoming increasingly common in recent years [15]. This increase in interest demands a thorough grasp of the research environment, prompting our use of bibliometric analysis to analyze and illustrate the complex network of scholarly contributions. To this end, our research explored the large corpus of literature on sustainability in the food industry, using rigorous bibliometric techniques to spot trends, pinpoint key themes, and discover the cooperative networks that define the theoretical boundaries of this evolving topic.

This investigation's main objective was to present a comprehensive and methodical summary of the body of knowledge pertaining to sustainability in the food industry. Through the examination of a corpus of 1608 documents from 1991 to 2023, our analysis provides a chronological view of the development of research in this field and illuminates the important sources, prolific writers, and subject concentrations that have influenced the discourse. Our objective was to enhance understanding of the complex interrelationships among the social, environmental, and economic aspects of the food industry's pursuit of sustainable practices through the application of bibliometrics. This will serve as a foundation for future research and policy endeavors.

2. Literature Review

2.1. The Concept of Sustainability in the Food Industry

Excluding the discussion of other sectors, the concept of sustainability in the food industry is highly controversial. According to [16], "sustainable food" is a very broad and vague concept for both consumers and policy makers. In this study, the concept of "sustainability" will be used in accordance with the principles of sustainable development. For this reason, it was necessary to examine the definitions of sustainable development in the work of the United Nations.

The concept of "sustainability" was first used in the 1970s to express concern about environmental impacts around the world. Following the establishment of the World Commission on Environment and Development in 1983, a report entitled *Our Common Future* was published in 1987, officially defining the concept of sustainability for the first time. This report is now commonly referred to as the "Brundtland report", in reference to the name of the first chair of the Commission.

The United Nations Environment Program published the report (UNEP) *Caring for the Earth: A Strategy for Sustainable Living* in 1991, and used this definition for sustainable

development: "*improving the quality of human life while living within the carrying capacity of supporting ecosystems*". As time progressed, the definition evolved and, in 1992, the United Nations Conference on Environment and Development (UNCED) added economic and socio-cultural dimensions to the definition. From this point forward, the three pillars of sustainability that are now commonly used gained increasing attention and became sanctioned in many areas [17,18].

2.2. Sustainability in the Food Industry from a Social Perspective

Sustainability in the food industry is a complex and urgent issue that goes beyond simple environmental concerns [19]. It necessitates a thorough investigation of the intricate interactions between the food industry, society, and the larger global community from a social perspective, from the 1990s onwards [20]. This perspective emphasizes the significant impact of the food business on societal well-being, as opposed to traditional concepts of sustainability, which frequently highlight environmental impacts [21,22]. The fact that food is not merely a commodity but a basic human necessity, and how it is produced, distributed, and consumed, has significant ramifications for social fairness, public health, and cultural identity, and this is central to this discussion [23].

Some societies enjoy comfortable lifestyles with high living standards. These societies have encountered food problems mainly in the context of obesity. In some parts of the world, overnutrition has resulted in a high adult obesity rate (13%), and under-five obesity rates have reached 5.6% [8]. In contrast, other parts of the world are struggling to survive due to malnutrition. This issue is an integral part of the current social dimension of the food industry. Furthermore, the more food that is produced by the agriculture industry, the greater the exposure and resulting impacts on humans, animals, and the wider environment. Specifically, extensive research is required to investigate the effects on national healthcare systems [24].

Equitable access to healthy, wholesome, and culturally appropriate food is essential for social sustainability in the food industry [25]. Disparities in food access have profound societal repercussions and disproportionately harm poor populations [26]. Food insecurity is a serious societal problem that emphasizes the need for accessible and inclusive food systems [27]. Additionally, the social aspect of sustainability includes labor standards in the food industry, such as fair pay, secure working conditions, and rights for employees [28]. Because of the industry's reliance on a worldwide labor force, which frequently works in low-wage and precarious jobs, fundamental issues of social justice and equity are raised [29]. It is essential to acknowledge and examine these social dimensions in order to fully address sustainability in the food industry [30]. The goal should be a more inclusive and equitable food system that benefits all members of society [31].

2.3. Environmental Sustainability and the Food Industry

Environmental sustainability pertains to the ecological integrity and carrying capacity of the natural environment, and how it can maintain productivity and resilience to ensure support for human life [32]. Recognizing the need for environmental sustainability in the future, we must explore the complex options to accomplish this objective in a way that balances social and economic sustainability [33,34]. In addition to highlighting the importance of environmental preservation, the discussion should cover the realistic tactics and trade-offs that can support an all-encompassing and sustainable strategy [35]. We can find solutions to advance comprehensive sustainability—where environmental objectives align with societal and economic well-being—by examining how environmental, social, and economic concerns are intertwined [36].

Food production, distribution, and consumption are closely linked to ecosystems and environmental resources [37]. Food consumption is increasing as the world's population grows, placing a tremendous strain on natural resources, including land, water, and energy [38]. The food industry can play a crucial role in reducing climate change, preserving

biodiversity, and creating a more sustainable and resilient future for our planet and its inhabitants by switching to ecologically friendly methods.

The adoption of circular economy ideas is a crucial component of environmental sustainability in the food industry [39]. A circular economy model prioritizes reuse, recycling, and regeneration when designing products and processes in order to reduce waste and maximize resource efficiency [40]. This translates, in the context of the food industry, into lowering food waste, reusing leftovers and by-products, and promoting recyclable or compostable packaging [41]. Sustainable sourcing methods can also greatly lessen the environmental impact of intensive agriculture practices while simultaneously fostering healthier ecosystems [42]. The food industry can help create a more sustainable future, where environmental protection and food production work together for the good of our planet and future generations, by adopting a circular economy approach.

2.4. Economic Sustainability and the Food Industry

Economic sustainability entails a production system that meets existing consumption levels without jeopardizing future requirements [12]. A critical component of the food industry is economic sustainability, which includes the need for long-term stability and profitability, while taking into account the wider economic impact [43]. Businesses in the food industry must strike a careful balance between maximizing profits and taking into account the interests of all stakeholders, from farmers and workers to customers and shareholders, in order to preserve their economic sustainability [44]. Fair pricing for producers, responsible investment in innovation and technology, and building value chains that can withstand market volatility are just a few examples of the sustainable economic practices used in this industry [45]. Economic sustainability also necessitates a dedication to moral business conduct that fosters openness, guards against abusive working conditions, and encourages ingredient sourcing from ethical sources [46]. Addressing the problem of food waste is one of the critical obstacles to achieving economic sustainability in the food industry. Essentially, economic sustainability in the food industry necessitates a comprehensive strategy that takes into account the financial effects of food production and distribution, supports ethical business conduct, and adopts novel approaches to reduce waste and boost profitability in a socially and environmentally responsible way.

3. Materials and Methods

Through bibliometric analysis, it is possible to obtain a systematic and holistic picture of the de facto structure in any field, to identify the clusters of research that drive the field, and to visualize the big picture of the important concepts in the field and the relationships between these concepts [47]. To achieve this, the R package Bibliometrix and VOSviewer software tools were used together in this study, as these tools have both advantages and disadvantages. One of the key advantages of the R package software is that other software programs often focus on implementing specific bibliometric analyses (data download, data conversion, data preprocessing, analysis, data reduction, networking, normalization, mapping, and visualization), while Bibliometrix performs the entire process. Bibliometrix also has a user-friendly interface [48–50]. VOSviewer's display capabilities are particularly useful for maps that contain at least a moderately large number of items (1608 studies, in the case of this study). In addition, VOSviewer has a powerful user graphical interface that allows easy inspection of the generated maps [49,51–54]. In this research, network analysis was completed using VOSviewer, while the other research processes were run by Bibliometrix. After choosing the software tools, the researchers carried out the analysis according to the bibliometric research steps using Biblioshiny, as illustrated in Figure 1 [55].

Author keywords are the most important indicators of the main purpose of a study [56]. The hypothesis of a study can often be inferred from them. Author keywords within the WOS were therefore used in gathering the dataset in this study. The most important data in bibliometric research sources are SCI, SSCI, and AHCI scientific citation indexes; these indexes can be accessed by the Web of Science Core Collection database [57]. Traditionally,

the WoS has been the primary source for scientific review due to its high quality and extensive coverage [58–60]. On the other hand, Scopus is a better choice for bibliometric analyses within the Arts and Humanities [61]. In this study, the researchers searched for the keywords stated below in WoS, using the following formula:

Author keywords:

((AK = (sustainable)) and AK = (food industry)) or ((AK = (sustainability)) and AK = (food industry)) or ((AK = (sustainable)) and AK = (food system)) or ((AK = (sustainability)) and AK = (food system)) or ((AK = (sustainable)) and AK = (food supply chain)) or ((AK = (sustainability)) and AK = (food supply chain))

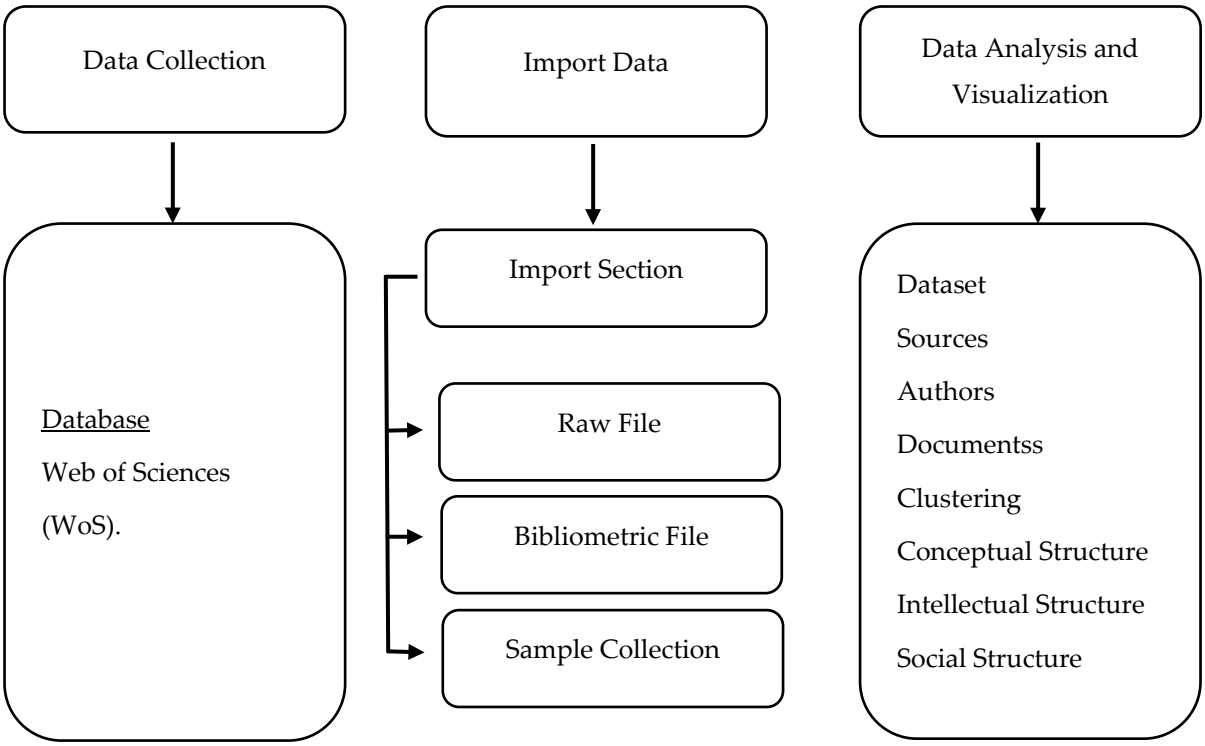

Figure 1. Bibliometric research steps using Biblioshiny 3.1.4 (figure adapted from [55]).

These terms may be used as synonyms for each other. The researchers did not apply any exclusion criteria to the dataset. As a result, 1608 studies were found on WoS and analyzed by the software packages stated above. This research aimed to carry out a bibliometric analysis that answered the following research questions:

1. How has the number of articles published on this topic evolved?
2. What are the field's most influential journals, articles, authors, and geographical regions?
3. What future lines of research exist in the field?

4. Results

Section 4 presents the bibliometric analysis, including the citation analysis, source analysis, author analysis, document analysis, structure analysis, network analysis, and co-citation analysis.

According to the table below, the timespan of the 1608 documents was between 1991 and 2023. The 1608 documents were published by 553 different sources, including journals, books, and more. The average years from publication was 3.66 and the average citations per documents was 21.15. A total of 83,032 references were used in the 1608 documents. Of the 1608 documents, 1152 were articles; the rest were book chapters, proceedings papers, and so forth. A total of 2657 Keywords Plus (IDs) were used in the documents, and 4684 Author's Keywords (DEs) were used. There were 5322 authors who appeared 6509 times, indicating that some of the authors contributed to more than one study. Of these,

179 authors appeared on single-authored documents, while 5143 authors were included on multi-authored documents. The documents per author value was 3.31, and the co-authors per document value was 4.05. Table 1 gives further details.

Table 1. Main information of the bibliometric analysis (own elaboration using Bibliometrix®).

Description	Results
ABOUT THE DATA	
Timespan	1991:2023
Sources (journals, books, etc.)	553
Documents	1608
Average years from publication	3.66
Average citations per document	21.15
Average citations per year per doc	4.075
References	83,032
DOCUMENT TYPES	
Article	1152
Article; book chapter	32
Article; data paper	1
Article; early access	42
Article; proceedings paper	19
Correction	1
Editorial material	42
Editorial material; book chapter	2
Meeting abstract	7
Proceedings paper	76
Review	221
Review; book chapter	3
Review; early access	10
DOCUMENT CONTENTS	
Keywords Plus (ID)	2657
Author's Keywords (DE)	4684
AUTHORS	
Authors	5322
Author appearances	6509
Authors of single-authored documents	179
Authors of multi-authored documents	5143
AUTHOR COLLABORATIONS	
Single-authored documents	190
Documents per author	0.302
Authors per document	3.31
Co-authors per document	4.05
Collaboration index	3.63

Table 2 displays information on the annual scientific production. The annual growth rate was 23.81%. According to the table, it is clear that the rate of scientific production started to increase after 2008 and reached 125 after 2018. After that, the number of articles continued to increase. A total of 258 articles had already been published in 2023 at the time of this study, although it was not yet the end of the year.

According to Table 3, over the years, there has been a continuous increase in the number of citations in the field. All of the 1608 documents (100%) had been cited by October 2023. The mean total citations per document was the highest (93.31%) in 2014, clearly signifying that the articles published in that year received a greater number of citations. As the year 2023 had not ended yet when this research was carried out, no citable year was included in this column.

Table 2. Annual trend in the number of publications in the field of sustainability research in the food industry (own elaboration using Bibliometrix®).

Year	Articles
2023	258
2022	307
2021	276
2020	174
2019	124
2018	125
2017	66
2016	59
2015	44
2014	38
2013	25
2012	16
2011	21
2010	21
2009	18
2008	12
2007	3
2006	1
2005	2
2004	3
2003	6
2002	2
2001	1
2000	2
1998	2
1997	1
1991	1

Table 3. Number of publications, average citations, and average annual citations (own elaboration using Bibliometrix®).

Year	Number of Publications	Mean Total Citations per Article	Mean Total Citations per Year	Citable Years
2023	258	1.631782946		0
2022	307	5.889250814	5.889250814	1
2021	276	13.67028986	6.835144928	2
2020	174	22.51149425	7.503831418	3
2019	124	24.61290323	6.153225806	4
2018	125	32.832	6.5664	5
2017	66	43.93939394	7.323232323	6
2016	59	42.30508475	6.043583535	7
2015	44	24.20454545	3.025568182	8
2014	38	93.31578947	10.36842105	9
2013	25	51.24	5.124	10
2012	16	50.6875	4.607954545	11
2011	21	56.85714286	4.738095238	12
2010	21	20.9047619	1.608058608	13
2009	18	77.94444444	5.567460317	14
2008	12	53.58333333	3.572222222	15
2007	3	58	3.625	16
2006	1	62	3.647058824	17
2005	2	130	7.222222222	18
2004	3	17.66666667	0.929824561	19
2003	6	49.16666667	2.458333333	20
2002	2	20	0.952380952	21

Table 3. *Cont.*

Year	Number of Publications	Mean Total Citations per Article	Mean Total Citations per Year	Citable Years
2001	1	12	0.545454545	22
2000	2	69	3	23
1999	0	0	0	0
1998	2	9	0.36	25
1997	1	48	1.846153846	26
1996	0	0	0	0
1995	0	0	0	0
1994	0	0	0	0
1993	0	0	0	0
1992	0	0	0	0
1991	1	59	1.84375	32

4.1. Source Analysis

The table below shows the first 10 most relevant sources of the subject. The journal *Sustainability* had the most publications, followed by the *Journal of Cleaner Production* and *Frontiers Sustainable Food Systems*. The other journals are given in Table 4.

Table 4. The top 10 leading journals based on the number of relevant publications (own elaboration using Bibliometrix®).

Sources	Articles
SUSTAINABILITY	231
JOURNAL OF CLEANER PRODUCTION	79
FRONTIERS IN SUSTAINABLE FOOD SYSTEMS	75
BRITISH FOOD JOURNAL	29
FOODS	26
AGROECOLOGY AND SUSTAINABLE FOOD SYSTEMS	22
JOURNAL OF AGRICULTURE FOOD SYSTEMS AND COMMUNITY DEVELOPMENT	22
SUSTAINABLE PRODUCTION AND CONSUMPTION	21
JOURNAL OF HUNGER & ENVIRONMENTAL NUTRITION	20
AGRICULTURE AND HUMAN VALUES	19

A bibliometric analysis approach known as the "most local cited sources" (from reference lists), as shown in the table below, can identify the sources that are most commonly cited within a specific research area or field of study. It is often carried out by examining the reference lists of scientific papers to identify the sources that authors in a certain discipline most commonly cite [62]. The *Journal of Cleaner Production* had 4048 citations to their articles. *Sustainability* had 2477 citations to their articles. *The International Journal of Production Economics* had 1455 citations to their articles. The others, which had less than 1000 citations, are given in Table 5.

Samuel C. Bradford first proposed Bradford's Law in 1934, after noticing a pattern in the distribution of scientific journals in the early 20th century. Bradford's Law is a theory that describes the distribution of information in a collection or dataset. According to the law, for any subject area there will be a core set of journals or information sources that are highly relevant and frequently cited, as shown in Figure 2, then a secondary set of sources that are less relevant but still useful, and finally a sizable set of sources that are rarely cited [62,63]. For this reason, *Sustainability* can be categorized as the most highly relevant and frequently cited journal among the core sources.

Table 5. The top 10 leading journals based on cited articles (own elaboration using Bibliometrix®).

Sources	Articles
Journal of Cleaner Production	4048
Sustainability (Basel)	2477
International Journal of Production Economics	1455
Food Policy	889
British Food Journal	848
Agriculture and Human Values	823
Resources, Conservation and Recycling	792
Journal of Rural Studies	759
International Journal of Production Research	706
Supply Chain Management	686

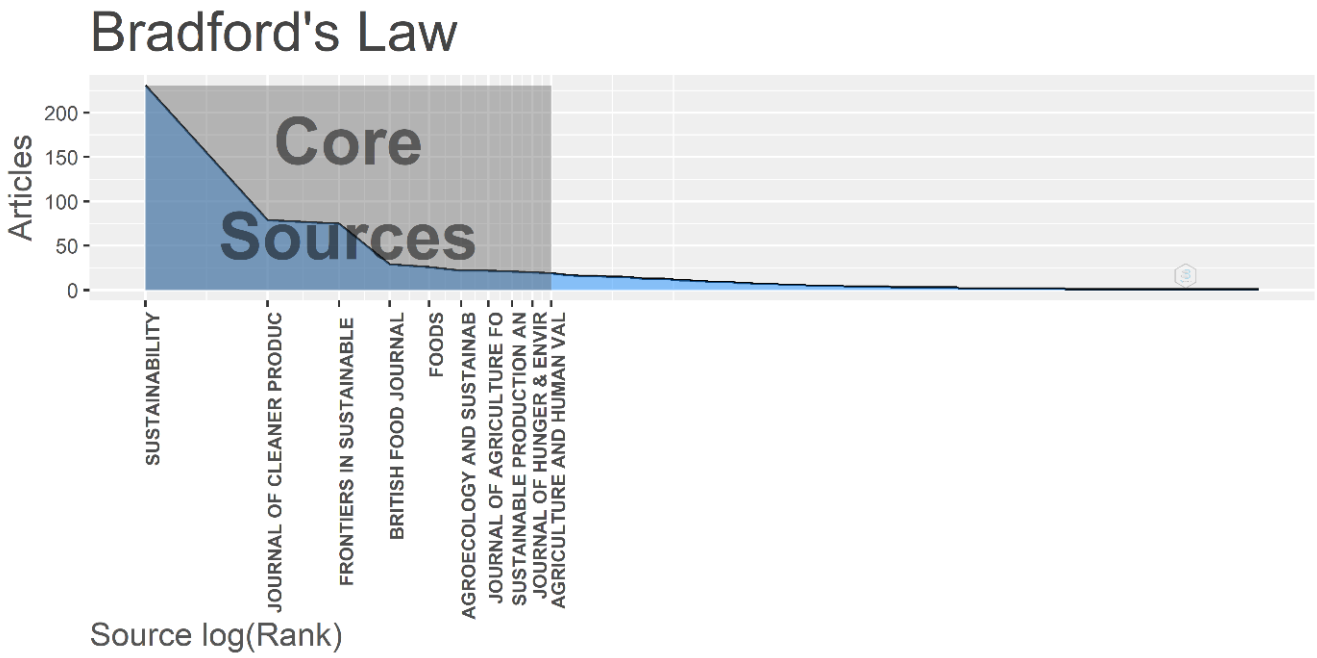

Figure 2. Results of Bradford's Law (own elaboration using Bibliometrix®).

4.2. Source Local Impact

A journal, book, conference proceeding series, etc. that published one or more documents that were part of our bibliographic collection was defined as a source in this analysis [64]. The h-index metric is frequently used to estimate a person's research output [65]. Leo Egghe proposed the author-level indicator known as the g-index as an alternative to the more traditional h-index in 2006. The quantity of citations is not averaged by the h-index. Instead, the h-index ignores the citation count of extremely highly cited publications and merely requires a minimum of n citations for the least-cited item in the set. As h increases, the number of publications that fulfill a certain standard of quality increases. As g increases, citations from higher-cited papers can be utilized to support lower-cited papers in reaching this standard [66,67]. The m-index is defined as h/n, where n is the number of years since the scientist's first work was published and h is the h-index [65].

When the h-index, TCs (total citations), and NP (number of publications) were considered, it was clear that *Sustainability* was the leading journal in the list. The other journals and their metrics can be seen in Table 6.

Table 6. Leading sources sorted according to the h-index (own elaboration using Bibliometrix®).

Element	h-Index	g-Index	m-Index	Total Citations	Number of Publications	Publication Year Start
SUSTAINABILITY	33	49	2.538461538	3505	199	2011
JOURNAL OF CLEANER PRODUCTION	31	53	3.1	3008	77	2014
FRONTIERS IN SUSTAINABLE FOOD SYSTEMS	11	20	1.833333333	469	40	2018
BRITISH FOOD JOURNAL	13	25	1	629	25	2011
FOODS	11	20	2.75	408	20	2020
AGROECOLOGY AND SUSTAINABLE FOOD SYSTEMS	7	19	0.636363636	485	19	2013
JOURNAL OF AGRICULTURE FOOD SYSTEMS AND COMMUNITY DEVELOPMENT	7	12	0.5	165	19	2010
AGRICULTURE AND HUMAN VALUES	8	18	0.470588235	662	18	2007
JOURNAL OF HUNGER & ENVIRONMENTAL NUTRITION	11	17	0.6875	322	18	2008
SUSTAINABLE PRODUCTION AND CONSUMPTION	9	16	1	259	18	2015

4.3. Author Analysis

In this chapter, authors were analyzed according to their performance and ranked by their number of articles. In the "most relevant authors" category, S.K. Mangla (n = 16) was the first author identified. Y. Kazancoğlu was the second (n = 13), followed by A. Kumar and R.D. Raut (n = 11) as the third authors in the list. The other authors, who had less than 10 articles, can be seen in Table 7.

Table 7. The top 10 most productive authors within the subject (own elaboration using Bibliometrix®).

Authors	Articles
Mangla, Sachin Kumar	16
Kazancoğlu, Yiğit	13
Kumar, Anil	11
Raut, Rakesh D.	11
El Bilali, Hamid	9
Luthra, Sunil	9
Carlsson, Liesel	8
Kumar, Sandeep	8
Anastasiadis, Foivos	7
Jagtap, Sandeep	7

In parallel with the "most local cited sources", the "most local cited authors" can contribute to defining the academic performance indicators of authors. S.K. Mangla was the lead author again, as in the most relevant authors metric. The number of publications of this author explains this: As this author has the most publications, it is not surprising that she has the most local citations. S. Seuring was the second author (n = 97), and J.G.A.J. Van Der Vorst the third author (n = 85). The other authors are listed below in Table 8.

Lotka's law, named after Alfred J. Lotka, describes the frequency of publication of authors in any given field [68]. Using Lotka's Law, it was determined that the exponent N and the percentage of authors who each contributed one article to the subject were 0.852 and 0.109, respectively. These variables point to an uneven distribution of output in the field, low productivity, and a high percentage of authors who contributed fewer than one paper [69]. Table 9 indicates that 98% of the authors had three or less publications within this subject.

Table 8. Most local cited authors (own elaboration using Bibliometrix®).

Author	Local Citations
Mangla, Sachin Kumar	114
Seuring, Stefan	97
Van der Vorst, Jack G.A.J.	85
Govindan, Kannan	82
Landert, Jan	73
Bourlakis, Michael	72
Luthra, Sunil	72
Sarkis, Joseph	68
Beske, Philip	67
Damian, Maye	66

Table 9. Distribution of authors according to the number of publications (own elaboration using Bibliometrix®).

Documents Written	N. of Authors	Proportion of Authors
1	4536	0.852
2	582	0.109
3	111	0.021
4	50	0.009
5	24	0.005
6	6	0.001
7	5	0.001
8	2	0
9	2	0
10	2	0

The findings regarding the corresponding authors of the studies are also shown in the Table 10 below. Here, data on whether the corresponding authors were from the same country (SCP) or a different country (MCP) are given [70]. It is noteworthy that in the majority of the studies, the corresponding authors were from the same country as the country where the article was submitted, while the number of those from different countries was low. In 56 of the 235 articles belonging to the USA, which ranked first, the corresponding authors worked in institutions in different countries. In these cases, the degree of international cooperation was notable. In 179 of the articles, the corresponding author worked at institutions within the same country. In the United Kingdom, the situation was split almost evenly. For 86 of 154 articles, the corresponding author was from the same country, while 68 were from different countries. In Italy, only 39 out of 153 studies included an author or authors from a different country. Other details regarding the countries in the top 10 are presented in Table 10 below.

Table 10. Corresponding author and country affiliation (own elaboration using Bibliometrix®).

Country	Articles	Freq	SCP	MCP	MCP_Ratio
USA	235	0.147335	179	56	0.238
UNITED KINGDOM	154	0.096552	86	68	0.442
ITALY	153	0.095925	114	39	0.255
AUSTRALIA	83	0.052038	54	29	0.349
CANADA	80	0.050157	57	23	0.287
CHINA	80	0.050157	39	41	0.512
INDIA	69	0.04326	45	24	0.348
GERMANY	58	0.036364	38	20	0.345
SPAIN	56	0.03511	40	16	0.286
NETHERLANDS	48	0.030094	33	15	0.312

4.4. Document Analysis

Reference publication year spectroscopy analysis can detect the historical roots of research fields [71,72]. Figure 3 shows the number of references (blue line) and the number of citations (red line). There was an upward tendency in both the number of references and the number of citations. When the figures were compared, the citations were less than expected considering the number of references. After the year 2020, there was a downward tendency in 2021 (−1545), 2022 (−5146), and 2023 (−6079). A major increase was observed during 2013–2020, when most of the publications were produced.

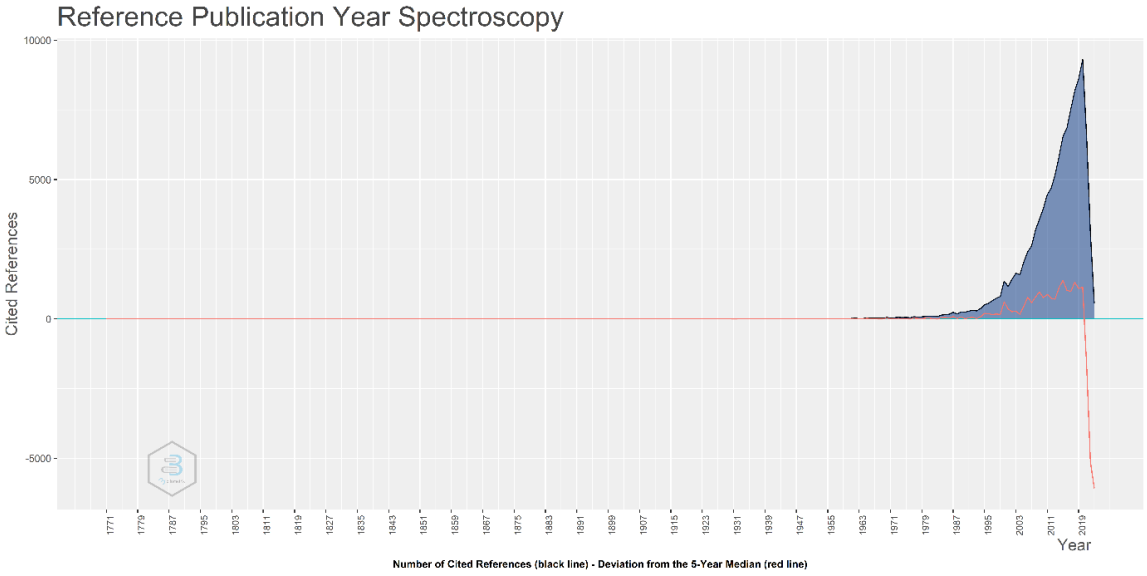

Figure 3. Reference publication year spectroscopy. The blue part shows the deviation from the 5-year-median in the publications in this subject over time. The red part shows the number of cited references (own elaboration using Bibliometrix®).

When the abstracts were set as a parameter for the most frequent words analysis, the word "food" ranked first, as shown in the figure below (n = 6283). "Sustainable" was ranked second (n = 2132), and "supply" was ranked third (1804), as seen in Figure 4 below.

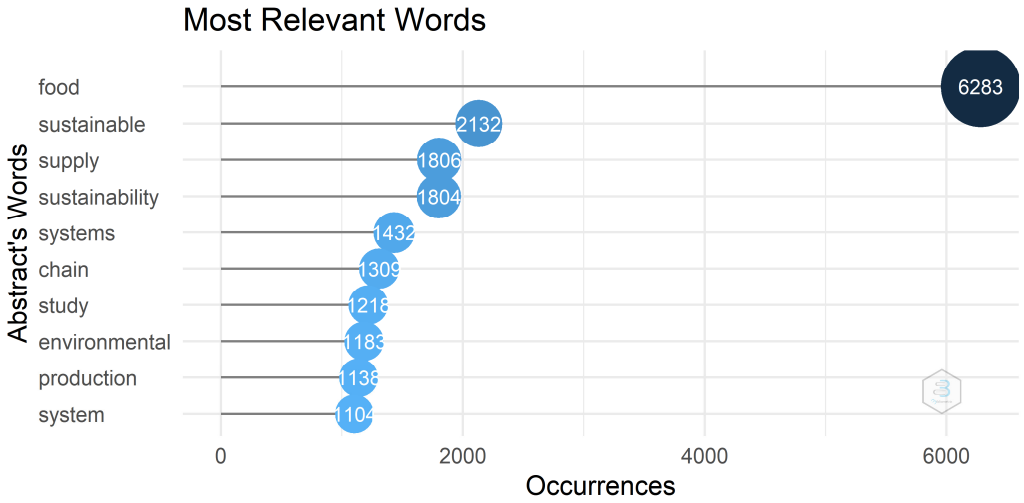

Figure 4. Most frequent words (own elaboration using Bibliometrix®).

Although different parameters (titles) were set for the word cloud, similar results were found. Figure 5 shows that the terms "food" (f = 1076), "sustainable" (f = 572), "supply" (f = 373), "systems" (f = 262), "sustainability" (f = 251), and "chain" (f = 244) occurred at

high frequency, suggesting consistency in the author keywords, abstracts, and titles of the studies.

Figure 5. Word cloud produced from titles (own elaboration using Bibliometrix®).

4.5. Conceptual Structure Analysis

The thematic map shown in Figure 6 had five clusters. When the author keywords were considered, the emerging themes were sustainable development, agri-food system, system dynamics and food system, sustainable, and sustainable diet. The motor (developed) themes were sustainability, food supply chain, and food industry. The sustainable agriculture, sustainable food system, and local food systems' cluster was located in the middle of two quadrants, and were niche themes and motor themes like the sustainable food systems, food security, and food systems cluster, which was located in the middle of the basic theme and motor theme quadrants.

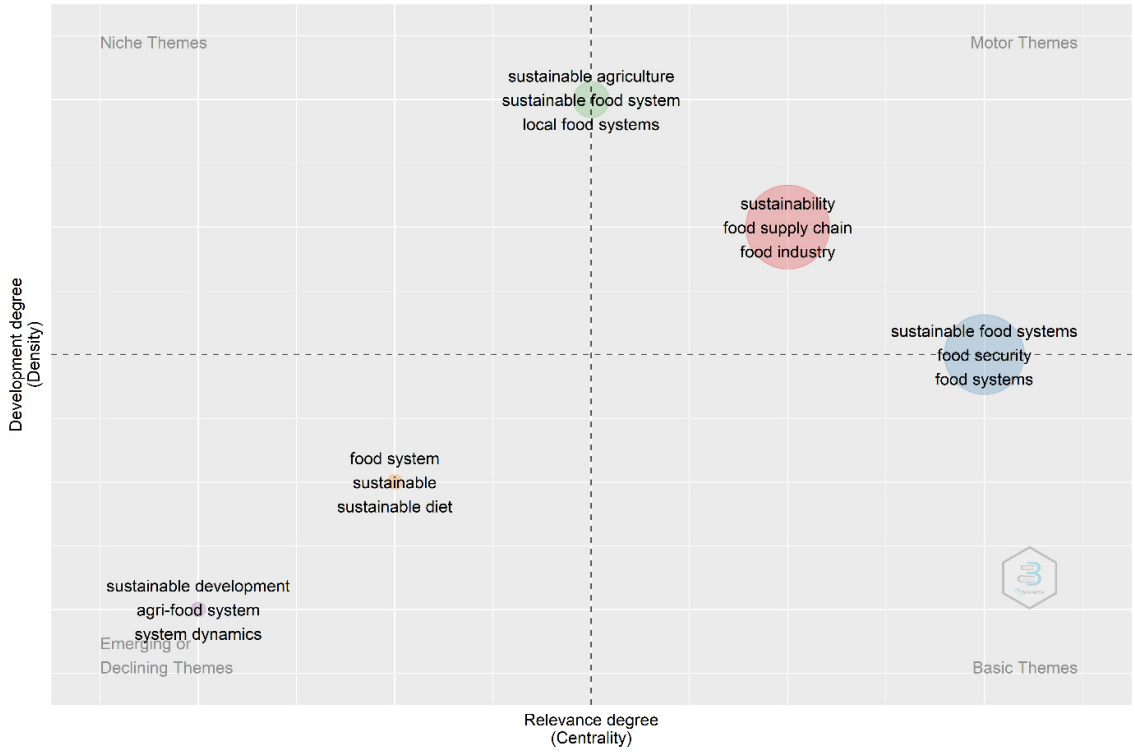

Figure 6. Thematic map of the research topics in the subject (own elaboration using Bibliometrix®).

4.6. Network Analysis

As stated above, VOSviewer was used for the network analysis due to its high graphic output. The co-occurrence network, co-citation network, and collaboration network analyses were run concurrently.

4.6.1. Co-Occurrence Network

The co-occurrence network analysis shows the relatedness of items, and is determined based on the number of documents in which they occur together [53]. For the co-occurrence network analysis, author keywords were chosen as a unit of analysis and the minimum number of occurrences of a keyword was five, which is the default number. Full counting was chosen to avoid missing any details. As a result, 218 keywords met the threshold from among the 4717 total keywords. The weight was set for the occurrences and the network map was generated. Table 11 shows the terms "sustainability" (occurrences = 396, total length strength = 890), "sustainable food system" (occurrences = 252, total length strength = 371), and "food security" (occurrences = 167, total length strength = 415) were clear. These terms were the first three terms in the ranking. Other terms (the first 20) and their occurrences, with total length strength, are shown in Table 11 below. This co-occurrence network analysis of author keywords shows that the topic is multidisciplinary and related to many terms, such as agriculture, agroecology, climate change, and so forth.

Table 11. Author keyword occurrences (own elaboration using VOSviewer®).

Keyword	Occurrences	Total Link Strength
Sustainability	396	890
Sustainable Food Systems	252	371
Food Security	167	415
Sustainable Development	153	264
Food Supply Chain	145	326
Food Systems	137	346
Food Industry	133	268
Sustainable Agriculture	99	229
Food Waste	74	171
Food System	74	154
Sustainable Food System	74	98
Sustainable Development Goals	73	164
Supply Chain	66	180
Climate Change	54	160
Sustainable Diets	50	126
Circular Economy	50	119
Agriculture	43	162
Local Food Systems	40	75
Agroecology	38	106
Supply Chain Management	37	106

4.6.2. Bibliographic Coupling Analysis

In bibliographic coupling analysis, the relatedness of items is determined based on the number of references they share [73]. For the bibliographic coupling analysis in this study, authors, organizations, and countries were chosen as units of analysis, and the maximum number of authors per document was 25, which is the default number. A full counting was undertaken, to avoid missing details. As a result, 29 authors met the threshold among the 5398 authors. For each of the 29 authors, the total strength of the bibliographic coupling links with other authors was calculated. The total link strength indicated the number of publications in which two keywords occurred together [74]. The authors with the greatest total link strength were selected. According to the generated map, Sachin Kumar Mangla (documents = 15, citations = 640, total length strength = 3508), Sunil Lunthra (documents = 9, citations = 434, total length strength = 2978), and Yiğit Kazancoğlu

(documents = 13, citations = 230, total length strength = 2760) were the top three authors in this category. The authors who are ranked after these three authors are shown in Figure 7 and Table 12.

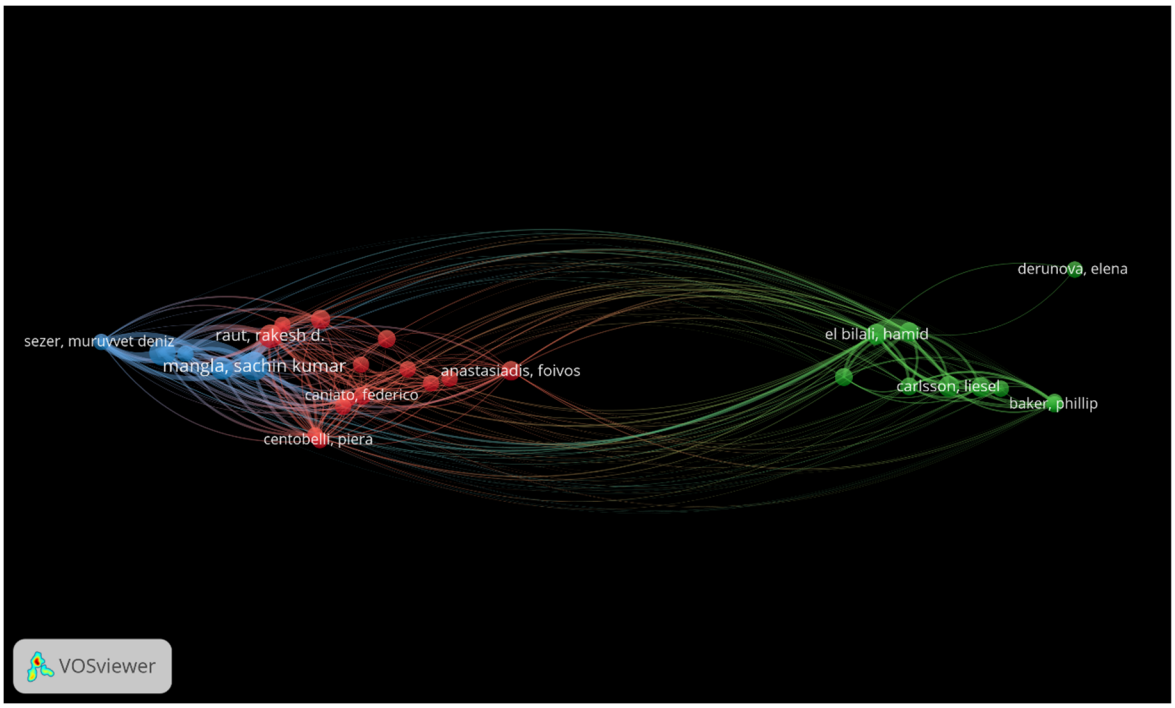

Figure 7. Bibliographic coupling analysis for authors (own elaboration using VOSviewer®).

Table 12. The top 10 authors in the bibliographic coupling analysis (own elaboration using VOSviewer®).

Authors	Documents	Citations	Total Link Strength
Mangla, Sachin Kumar	15	640	3508
Luthra, Sunil	9	434	2978
Kazancoğlu, Yiğit	13	230	2760
El Bilali, Hamid	8	264	2742
Raut, Rakesh D.	10	260	2615
Strassner, Carola	7	141	2472
Sezer, Mürüvvet Deniz	5	133	1592
Kumar, Anil	5	69	1578
Centobelli, Piera	5	156	1457
Cerchione, Roberto	5	156	1457

When two publications both cite a third publication, this is known as a bibliographic coupling [73]. In parallel with the author and sources analysis, Sachin Kumar Mangla was ranked first in this category. The other nine authors in the category are shown in Table 12.

Of the organizations, 158 met the threshold among a total of 2166. The minimum number of documents for an organization was 5 and the minimum number of citations by an organization was 0, which are the default numbers. For each of the 158 organizations, the total strength of the bibliographic coupling links with other organizations was calculated. The organizations with the greatest total link strength were selected. The map in Figure 8 was generated according to these parameters.

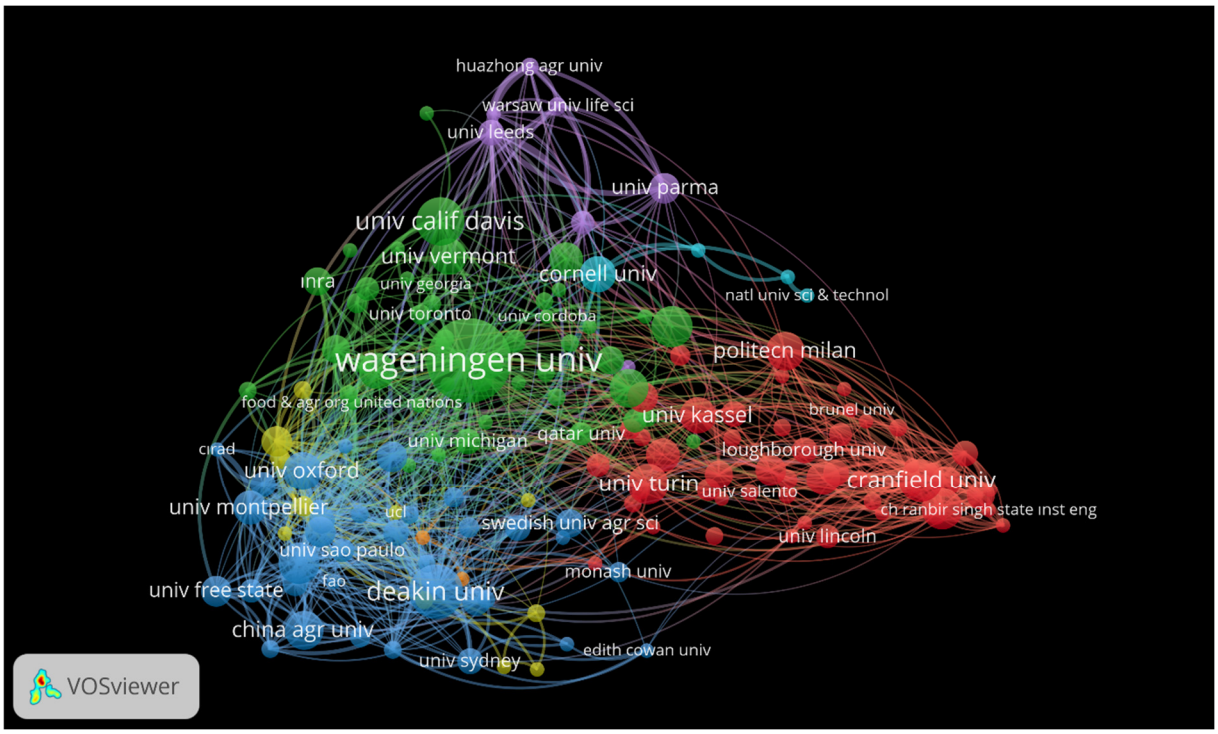

Figure 8. Bibliographic coupling analysis for organizations (own elaboration using VOSviewer®).

The map (Figure 8) showed that Deakin (in the blue cluster) and Wageningen (in the green cluster) were located in the center of the network. Oxford University, which is a well-known organization, was ranked third in the table and located in the blue cluster. Other organizations are given in Table 13 below.

Table 13. The top 10 organizations for bibliographic coupling analysis (own elaboration using VOSviewer®).

Organization	Documents	Citations	Total Link Strength
Deakin Uni	20	142	11,382
Wageningen Uni	33	1468	9947
Oxford Uni	14	895	9047
Wageningen Uni&Res	15	238	7754
Uni Leeds	9	165	7749
European Comiss	9	607	6840
Natl Inst Ind Engn Nıtıe	11	581	6542
Uni Montpellier	12	222	6243
Cranfield Uni	16	541	6102
City Uni London	11	526	5627

Of the assessed countries, 66 met the threshold from a total of 114. The minimum number of documents for a country was 5 and the minimum number of citations by a country was 0, which are the default numbers. For each of the 66 countries, the total strength of the bibliographic coupling links with other organizations was calculated. The organizations with the greatest total link strength were selected. The map (Figure 9) was generated according to these parameters.

The map indicated the three important categories in the center, which were the USA (green cluster), England (purple cluster), and Italy (blue cluster). The details of the countries included in the analysis are given in Table 14 below.

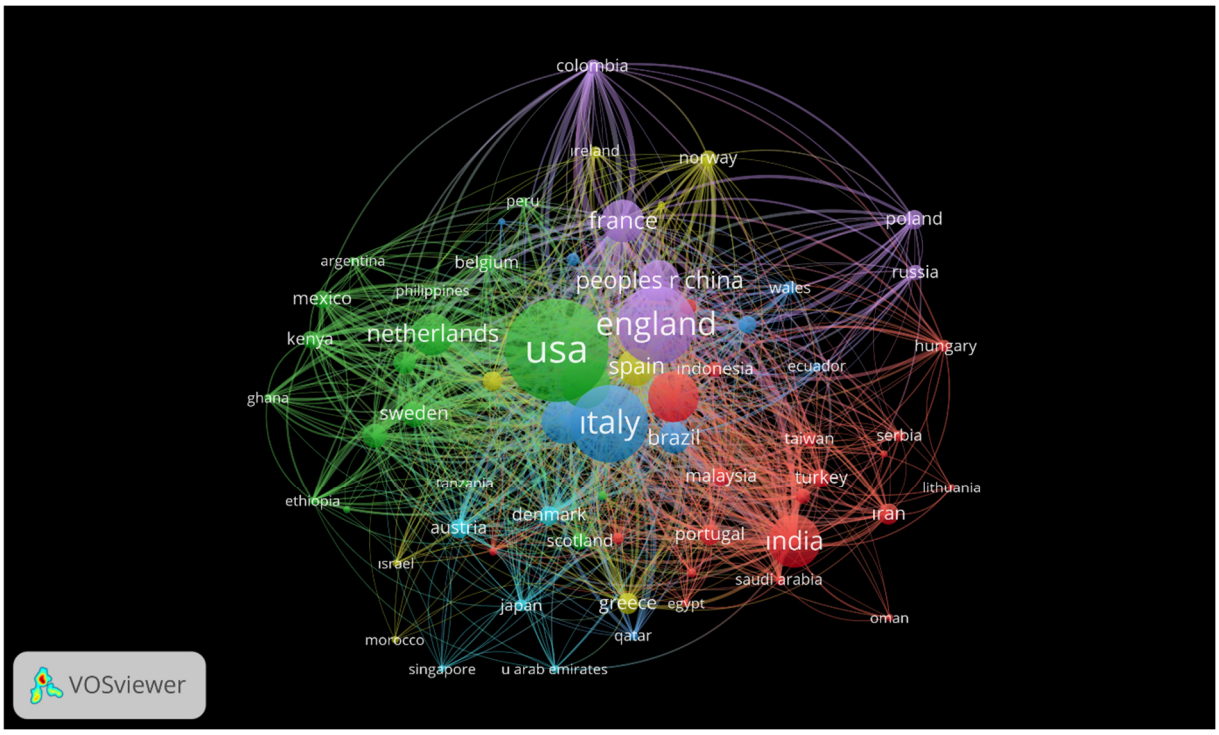

Figure 9. Bibliographic coupling analysis by country (own elaboration using VOSviewer®).

Table 14. The top 10 countries for bibliographic coupling analysis (own elaboration using VOSviewer®).

Country	Documents	Citations	Total Link Strength
England	213	6657	155,497
USA	315	8371	137,427
Italy	210	5883	124,180
France	93	3141	88,193
India	122	2699	81,295
Australia	117	2726	80,162
Netherlands	89	3010	65,207
Germany	102	2323	60,348
Canada	111	2013	59,951
People's R. China	87	1186	50,980

5. Conclusions

This study carried out comprehensive bibliometric research in the field of sustainability in the food industry. The concepts of the "food industry", "food system", and "food supply chain" can be used interchangeably, so we included all these words in the keyword analyses. "Sustainable" (an adjective) and "sustainability" (a noun) are concepts that can be utilized according to the topic and focus of the study. The authors used the aforementioned words in the query to mine the dataset.

Since 2018, the acceleration in the increase of the number of articles has been remarkable. In the last five years, sustainability in food industry research has become more popular. *Sustainability*, the *Journal of Cleaner Production*, and *Frontiers in Sustainable Food Systems* are the most important journals within this subject, with the greatest number of articles being published in these three journals.

These three journals are also the most cited journals. The *Journal of Cleaner Production*, *Sustainability*, and the *International Journal of Production Economics* also publish a large number of articles, so it is not surprising that these articles have been highly cited. Re-

searchers should explore these journals first, and may prefer to submit their manuscripts to these journals.

Another important indicator for researchers working in this field is the average number of citations. Articles from 2013 onwards received an average of five citations per year, but the average citation of 38 publications in 2014 was quite high. Some of the articles published this year have been pioneering studies.

Sustainability and the *Journal of Cleaner Production* had h-index scores of 33 and 31 in the WoS database for this subject. These two journals are the most influential journals in the field. It can be inferred that academics who produce research that is likely to obtain more citations prefer these journals.

The majority of the authors working on this subject were involved in three or fewer articles. The number of authors who work on this subject continuously and consistently is limited. This offers an opportunity for future researchers. Researchers who focus on this topic may see benefits to their careers, especially if they are consistent in producing studies addressing sustainability in the food industry.

In the analysis of the most frequent words, the words "food", "sustainable", and "supply" were in the first three positions. This confirmed that the choice of author keywords for the search of the WoS database was correct, as the results of this analysis were parallel to the keywords. In addition, we inferred from the analysis that the author keywords, abstracts, and titles of the studies were consistent. "Environment" is another word that appears quite often in abstracts. However, words reflecting the economic perspective of sustainability were not among the most frequently repeated abstract words. This showed that there is a need for studies that focus on economic sustainability issues.

"Food safety", "climate change", "biodiversity", "ecosystem", and "organic food" are keywords that are commonly used together. In other areas, "food waste", "agri-food industry", "food loss", "waste management", and "supply chain sustainability" are studied together. The relationship between climate change and food security was found to be a strong theme, and other common themes included food waste and supply chain sustainability.

The keywords "sustainable development goals", "sustainable transition", "sustainable food systems education", and "rural development" were often used together in the research papers. These subjects were generally a main topic of the research.

Articles with keywords such as "sustainable food system", "food governance", "social justice", "healthy diets", "public health", "nutrition", "agriculture", and "sustainable diets" reflected another theme. The three different keywords and research groups mentioned here may provide ideas for further research.

In the word cloud, after the most frequent words, the keywords "social", "environmental", "security", "agri-food", "chain", "impact", "development", "supply", "local", "management", "economy", "agriculture", and "waste" stood out. These keywords can also help us to understand relevant topics in the food industry area.

The results showed that around 85% of the total number of documents published were produced in the last decade. The research field is developing and growing. However, it is still not as mature as the research on the general food industry.

The overview of the most cited authors and papers revealed the intellectual structure of sustainability research in the food industry. This investigation provided valuable insight into the knowledge components of the field, and indicated that most cited research was from the areas of the supply chain, sustainable supply chain management, sustainable development, and food security.

Research in this area has been influenced by studies on the supply chain and oriented towards this field. However, there has also been research on sustainable diets and foods. Supply-side research is certainly important; however, studies focusing on the behavior of consumers, which can be used to guide societies and governments, will also be valuable in the future.

The most productive countries in terms of research were found to be the USA, China, and the UK. There was not enough evidence to draw exact conclusions from this result. However, the reasons for this finding may include the level of development of the countries, the budget allocated to research and development, the suitability of the research environment, and the availability of data sources. Future research is necessary to confirm the reasons for this finding. Factors and sources that need to be developed in other countries to create this research background may emerge.

In Africa, despite the amount of available agricultural land, there has been a lack of research into agricultural potential and sustainability. Due to the limited research in this area, which is home to some of the most remarkable agricultural lands on earth, more research attention needs to be given to the continent.

The emergence of new problems in the food industry tends to be closely tied to the development of the economy and society. Future studies should focus on the social aspects of sustainability in the food industry.

The modern era has led to digitalization in all kinds of businesses. The word cloud results showed that "industry 4.0", "digitalization", and "artificial intelligence" have been repeated keywords, although this was based on a small number of studies. Future research should focus on digitalization in the food/agri-food industry. Innovative technologies, such as AI, drones, blockchain, and big data, could contribute to sustainability in the food industry research area.

Climate change has received significant attention, but the term "resilience" in relation to climate change has not been widely used in research. This indicates a potential for future research on how the food industry can enhance its resilience to climate change.

Sustainability assessments in the food industry is also a notable topic in keyword analysis. This topic may offer important study opportunities for future researchers.

Finally, our thorough bibliometric analysis showed a diverse range of research projects devoted to food sector sustainability. From its modest popularization to an extensive and varied compilation of research in recent years, the observed trajectory of scholarly output highlights the growing global concern regarding sustainable practices within the food industry. Not only does the identification of prominent authors, important journals, and topic foci give an overview of the intellectual environment, but it also sheds light on the interdisciplinary nature and collaborative networks that define this research area. The topic clusters pertaining to social viewpoints, environmental sustainability, and economic considerations are highly interrelated, as our analysis indicated. This highlights the need for a comprehensive strategy in tackling the multifaceted issues confronting the food industry. In the future, our study will be a fundamental resource that scholars, decision-makers, and industry participants can utilize to navigate and participate in the continuing conversation about sustainable practices in the global food landscape.

No bibliometric review can provide a perfect description of the state of a specific field. The scope of the findings of this study was limited because the search approach used to build the corpus of literature on sustainability research in the food industry will have excluded some relevant studies. Future studies could consider extending the findings of this research by using alternative databases, such as Scopus, and including other types of publications, other than journal articles. Following this, a meta-analysis could be conducted on sustainability in the food industry research to derive a more comprehensive picture of the subject.

6. Implications

Our bibliometric analysis has ramifications that go beyond simply counting publications and citations. The frequency with which words like "sustainable", "food", and "supply" appeared in abstracts, titles, and author keywords highlighted how consistently and coherently academics in this field employ language. Within the scientific community, this linguistic convergence facilitates successful communication and collaboration by suggesting a shared understanding and emphasis on fundamental topics. Furthermore, the

list of eminent journals, prolific authors, and patterns of international collaboration will provide a road map for academics who want to contribute to or further the conversation around sustainability in the food industry. The multidisciplinary aspect of this topic was further highlighted by an understanding of the theme clusters and their co-occurrences, which could encourage researchers to investigate synergies with adjacent fields, including agriculture, agroecology, and environmental engineering. Our research will advance the knowledge on the topic from an academic perspective, while also providing industry leaders and policymakers with useful information for promoting sustainability in the global food supply chain. Studying the effect of sustainable diets on the food chain could be beneficial for the academic world. Additionally, studying the other findings from the thematic map of the research topics within the subject, which included the relationships among the agri-food system, sustainable agriculture, sustainable food system, and sustainability of the food chain, is recommended for future research, as these topics may shed light on the unstudied elements of the literature.

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