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Applying network analysis to explore the global scientific literature on food security

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ABSTRACT

Food security represents one of the most pressing challenges to humankind to be faced in the twenty-first century. Food security is a complex issue dealing with multiple research domains, among which human health and nutrition, environment, and policy. Several recent studies showed that biodiversity loss, soil erosion, and water scarcity are key problems exacerbating the issue of food security at local and global scale. The attention towards the issue of food security, highly recognized by international policy and scientific research, has considerably increased over the last decades. In this context, it is expected that the scientific literature on food security will continue increasing over the next years. The present study aims at exploring the global scientific literature on food security tracking its evolution and trends by applying social network analysis to bibliometric science. The bibliometric analysis performed over the timeframe 1990–2019 allowed the generation of maps based on network data displaying the relationships among scientific journals, researchers, and countries. Results showed that a number of 19,449 publications on food security were published from 193 countries in 3792 journals with 219 different subject categories. Mario Herrero resulted the most productive author with 50 documents, while USA resulted the first country publishing 5634 documents on food security. Among the journals, Food Security ranked first by total link strength, links, and number of documents, while Science showed the highest number of citations. The co-occurrence network map of keywords showed that, over the last decades, the main focus of food security research has shifted from socio-economic to environmental aspects. In conclusion, the integration of social network analysis and bibliometric science resulted a useful approach capable of capturing the multidimensional nature of food security by analyzing a large amount of literature data while identifying the main scientific patterns in this field of science.

1. Introduction

The impact of climate change on natural capital stocks is decreasing the capability of natural ecosystems to deliver ecosystem services vital for human well-being (FAO, 2019; Foley et al., 2011; Häyhä et al., 2015; Häyhä and Franzese, 2014; Nikodinoska et al., 2018; Ulgiati et al., 2011; Vihervaara et al., 2019). Among these services, food provision to an increasing world population represents one of the major challenges to be addressed in the twenty-first century, as also acknowledged by the Sustainable Development Goal n. 2 “Zero Hunger” of the Untied Nation 2030 Agenda for Sustainable Development (UN, 2018).

Biodiversity loss, soil erosion, and water scarcity are key problems exacerbating the issue of food security at local and global scale. Monocultures and high-chemical input agriculture aimed at harvest maximization are reducing biodiversity while increasing soil and water pollution (Foley et al., 2011; Godfray et al., 2010). In addition, the intensification of agriculture is favoring soil erosion with a negative feedback on food production (Franzese et al., 2009). It is important to remark that soil biodiversity contributes to soil processes and ecosystem functioning, from which food provision and human health largely depend (El Mujtar et al., 2019).

Sustainable agriculture, defined as farming that is environmentally sound, socially responsible, and economically profitable for farmers, is a key target contributing to long-term food provision while building resilience of agroecosystems to human pressure and climate risks (Garnett et al., 2013; Skaf et al., 2019; Willett et al., 2019). Climate change affects all four dimensions of food security, including food availability, accessibility, utilization, and food systems stability. People living in poor rural areas are likely to be the most affected by ecosystems changes induced by the over exploitation of natural resources and the effects of climate change (Lipper et al., 2014; Wheeler and von Braun, 2013).

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The share of undernourished people in the world has decreased from about 19% in 1990 to about 11% in 2017 (FAO, IFAD and WFP, 2015; FSIN, 2018). Yet, the number of people that still lack adequate access to food is unacceptable. In 2018, people across 53 countries experienced acute food insecurity, requiring an urgent humanitarian action (FSIN, 2018). FAO defined food insecurity as "a situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life" (FAO, 1996).

Several publications remarked the strong link between food security and nutrition (FAO et al., 2018; Prosekov and Ivanova, 2018; WFP, 2018). Globally, the number of undernourished people (i.e., people facing chronic food deprivation) has reached more than 820 million in 2018. Undernourishment and severe food insecurity are increasing in almost all the subregions of Africa and, to a lesser extent, in Latin America and Western Asia (FAO et al., 2019).

Moreover, the world population is expected to reach 9.8 billion in 2050 leading to an increase of food demand, worsening the current state of global food security (Huston, 2018; UN, 2017).

Food security is a complex issue whose comprehension requires a multicriteria approach based on different disciplines and perspectives including economy, politics, environment, agronomy, and society. Indeed, multidisciplinary research is required to explore different aspects related to food security, among which human pressures on natural resources, the effects of climate change on agro-ecosystems, poverty and distribution of wealth, food prices, human health, food aids, and international policies.

Considering the importance of the issue of food security and the international policy promoting scientific research on the topic, it is expected that the scientific literature on food security will continue increasing over the next years.

The use of bibliometric network analysis has proved to be a useful tool to quantitatively assess trends and patterns of scientific literature (Otte and Rousseau, 2002). Recent studies used bibliometric network analysis to explore the scientific literature on timely ecological topics such as natural capital, ecosystem services, and circular economy (Buonocore et al., 2018; Pauna et al., 2018, 2019; Türkeli et al., 2018).

Many studies provided a review of specific aspects of the food security issue, among which the relationships between sustainable agricultural systems and food security (Armanda et al., 2019; Farrukh et al., 2020; Poulsen et al., 2015), food and water pollution (Ren et al., 2019), and global food security scenarios (van Dijk and Meijerink, 2014). Yet, these studies did not explore the global scientific literature on food security and the relationships among different research areas that are important to face the food security issue adopting an interdisciplinary perspective.

The present study aims to explore the global scientific literature on the issue of food security tracking its evolution and trends by applying network analysis to bibliometric science. The bibliometric analysis allowed the generation of maps based on network data displaying the relationships among scientific journals, researchers, and countries. Specific keywords were used to explore the co-occurrence of different terms connected to the global research on food security.

2. Materials and methods

2.1. Bibliometric network analysis

The review of the global scientific literature on food security was conducted through a bibliometric network analysis, which combines bibliometrics and social network analysis to investigate specific field of science (Reuters, 2008; Zou et al., 2018). Social Network Analysis is the process of investigating social structures through the use of networks and graph theory (Otte and Rousseau, 2002). Social network analysis and maps based on network data allow for the application of systems thinking in bibliometric science. In particular, such analysis allows for the development of network maps and statistics based on the relationships among countries, journals, organizations, authors, and keywords related to the investigated topic (Chen et al., 2016).

The VOSviewer software (version 1.6.11) was used to perform the bibliometric analysis in this study. This software allows for the creation, visualization, and exploration of maps based on bibliometric network data. The output results are displayed in clusters to visualize the existing connections among the bibliometric data. Table 1 summarizes the main technical terms used by the software.

Co-authorship, co-occurrence, and citation analyses (Table 2) were conducted to create network maps showing: (1) the co-authorship among researchers and countries, (2) the co-occurrence of keywords, and (3) cited scientific journals. Each network map that resulted from the analyses contains nodes with size determined by "total link strength" (Table 1) or number of documents, and lines connecting the nodes with thickness based on "link strength" (Table 1).

The amount of clusters visualized in the network maps is determined by the resolution parameter. The higher is its value, the higher the level of details. This value can be set to visualize an appropriate number of clusters in the maps (Van Eck and Waltman, 2018). In this study, the resolution was set to 1.

2.2. Bibliographic data collection

The documents in this study were retrieved from the Web of Science search engine on August 2nd, 2019 using the keyword "food security" as search input. The timeframe was set to include all available

Table 1
Main terms in VOSviewer software (Van Eck and Waltman, 2018).

Term	Description
Items	Objects of interest (e.g., publications, researchers, keywords, authors).
Link	Connection or relation between two items (e.g., co-occurrence of keywords).
Link Strength	Attribute of each link, expressed by a positive numerical value. In the case of co-authorship links, the higher is the value, the higher the number of publications the two researchers have co-authored.
Network	Set of items connected by their links.
Cluster	Sets of items included in a map. One item can only belong to one cluster.
Weight attribute: Number of Links	The number of links of an item with other items.
Weight attribute: Total Link Strength	The cumulative strength of the links of an item with other items.

Table 2
Description of VOSviewer analyses used in this study (Van Eck and Waltman, 2014, 2018).

Type of Analysis	Description
Co-authorship	In co-authorship networks, researchers, research institution, or countries are linked to each other based on the number of publications they have authored jointly.
Co-occurrence	The number of co-occurrences of two keywords is the number of publications in which both keywords occur together in the title, abstract or keyword list.
Citation	In citation networks, two items are linked if at least one cites the other.

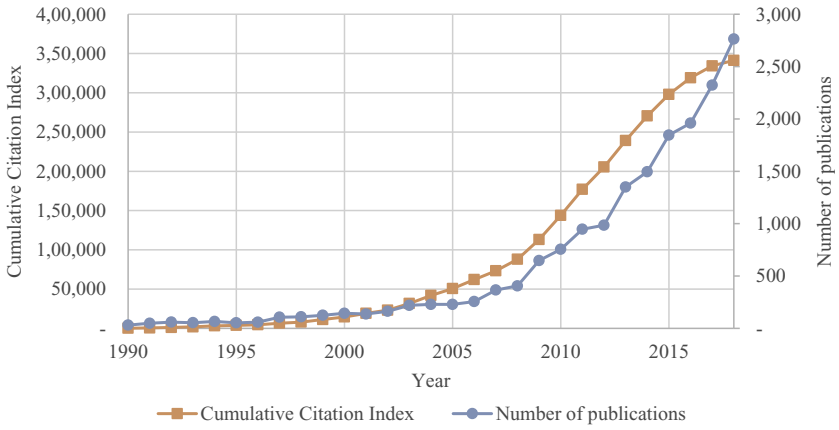

Fig. 1. Trend of citations and publications on food security.

Table 3
Top 5 most productive authors ranked by number of documents.

Author	Specialization	Total link strength	Link	Documents	Citations
Herrero, Mario	Environmental sciences, Agriculture multidisciplinary	157	77	50	1902
Perez-Escamilla, Rafael	Nutrition Dietetics, Public environmental occupational health	68	15	49	553
Lal, Rattan	Agronomy, Environmental sciences, Soil science	54	26	47	1076
Melgar-Quinonez, Hugo	Nutrition dietetics, Public environmental occupational health	37	11	37	328
D'Odorico Paolo	Environmental sciences, Meteorology atmospheric sciences	91	20	35	1050

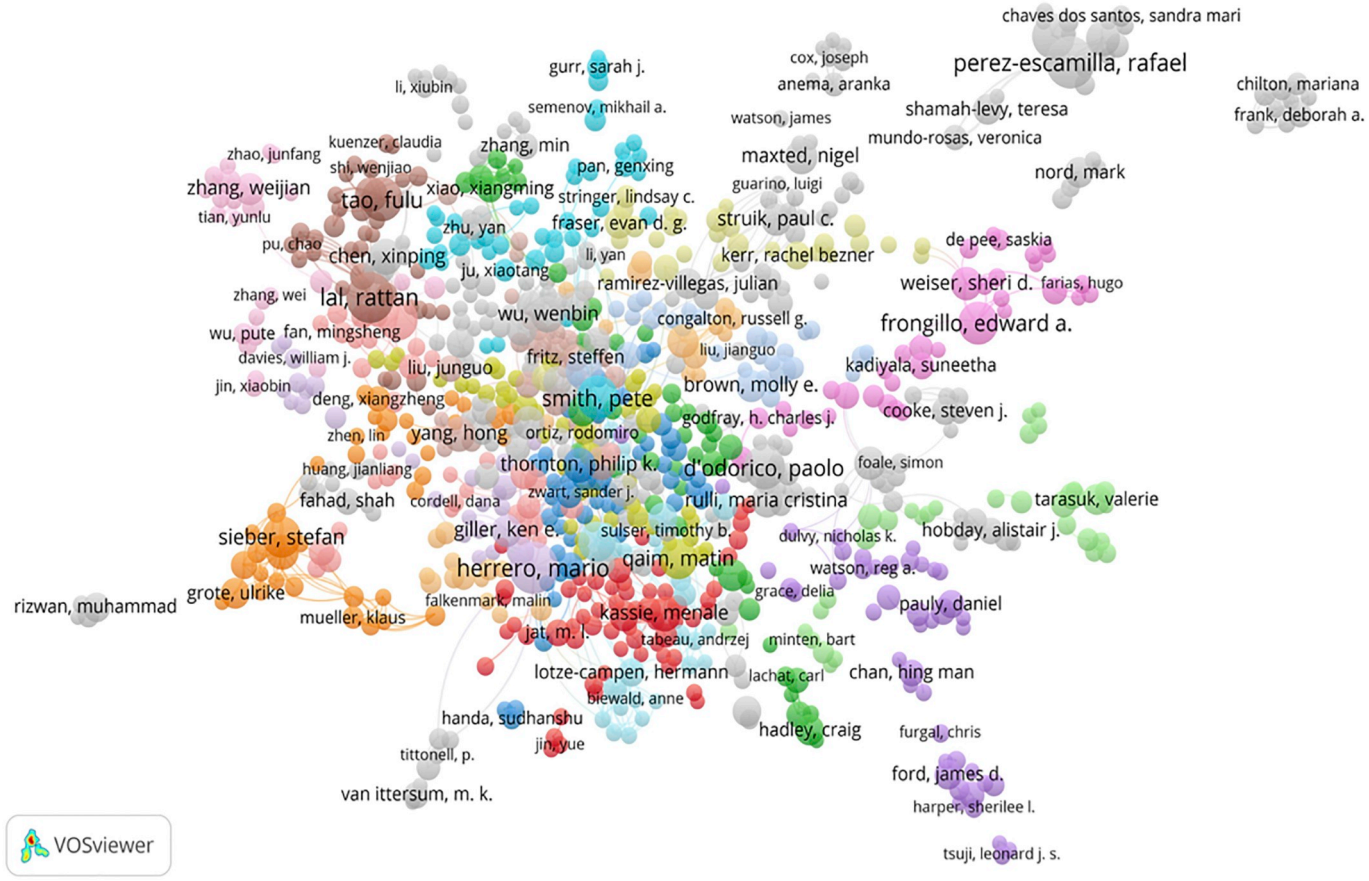

Fig. 2. Co-authorship network map of main authors based on number of documents.

publication years in the Web of Science Core Collection (WSCC) database, which is automatically set from 1990 to 2019. The total number of publications on the issue of food security was 19,449.

All data were saved as "Tab-delimited (Mac)" files, which contained "Full Record" and "Full Record and Cited References" content. The "Full Record" and "Full Record and Cited References" content were

Table 4
Top 5 countries ranked by total link strength.

Country	Total Link Strength	Links	Documents	Citations
USA	5901	137	5634	149,975
England	3704	123	2130	63,680
Australia	2691	113	1611	40.166
Germany	2450	115	1238	32,455
Peoples Republic of China	2115	91	2391	37,180

respectively used for co-authorship and co-occurrence analyses (e.g., network maps of authors, countries, and keywords) and citations analysis (e.g., network map of scientific journals).

2.3. Temporal trend analysis

In addition to the bibliometric network analysis, a trend analysis of the number of articles regarding food security was also performed. Being still in progress, the year 2019 was not considered in this analysis.

3. Results and discussion

3.1. Publications and citations trend analysis

The WSCC database search resulted in 19,449 publications on "food security" in the period from 1990 to August 2nd, 2019 (date in which the analysis was performed). Both the cumulative citation index and number of publications show an increasing trend in the investigated timeframe, more marked starting from 1996 (Fig. 1). In particular, over the last 10 years, the number of publications has increased by 7-fold with an average annual growth of 236 publications.

The food security issue was firtsly tackled in 1935 through the report entitled "Nutrition and Public health" conducted by the Health Division of the League of Nations (Simon, 2012). Yet, only after the publication of the FAO world food security declaration in 1996, the issue of food security was universally recognized as one of the most pressing challenges to humankind.

3.2. Authors network analysis

The total number of authors publishing on food security was 58,239, of which 160 (0.27%) published more than 10 documents, 1090 (1.87%) published between 5 and 10 documents, and 56,989 (97.85%) published less than 5 documents. Table 3 shows the five top authors publishing on food security ranked by total number of documents. Mario Herrero resulted the most productive author with 50 documents and 1902 citations. The co-authorship network map of main authors based on publications number is shown in Fig. 2. The authors included in the map are those who published at least five papers on food security.

3.3. Country network analysis

The co-authorship analysis of countries provided 193 results.

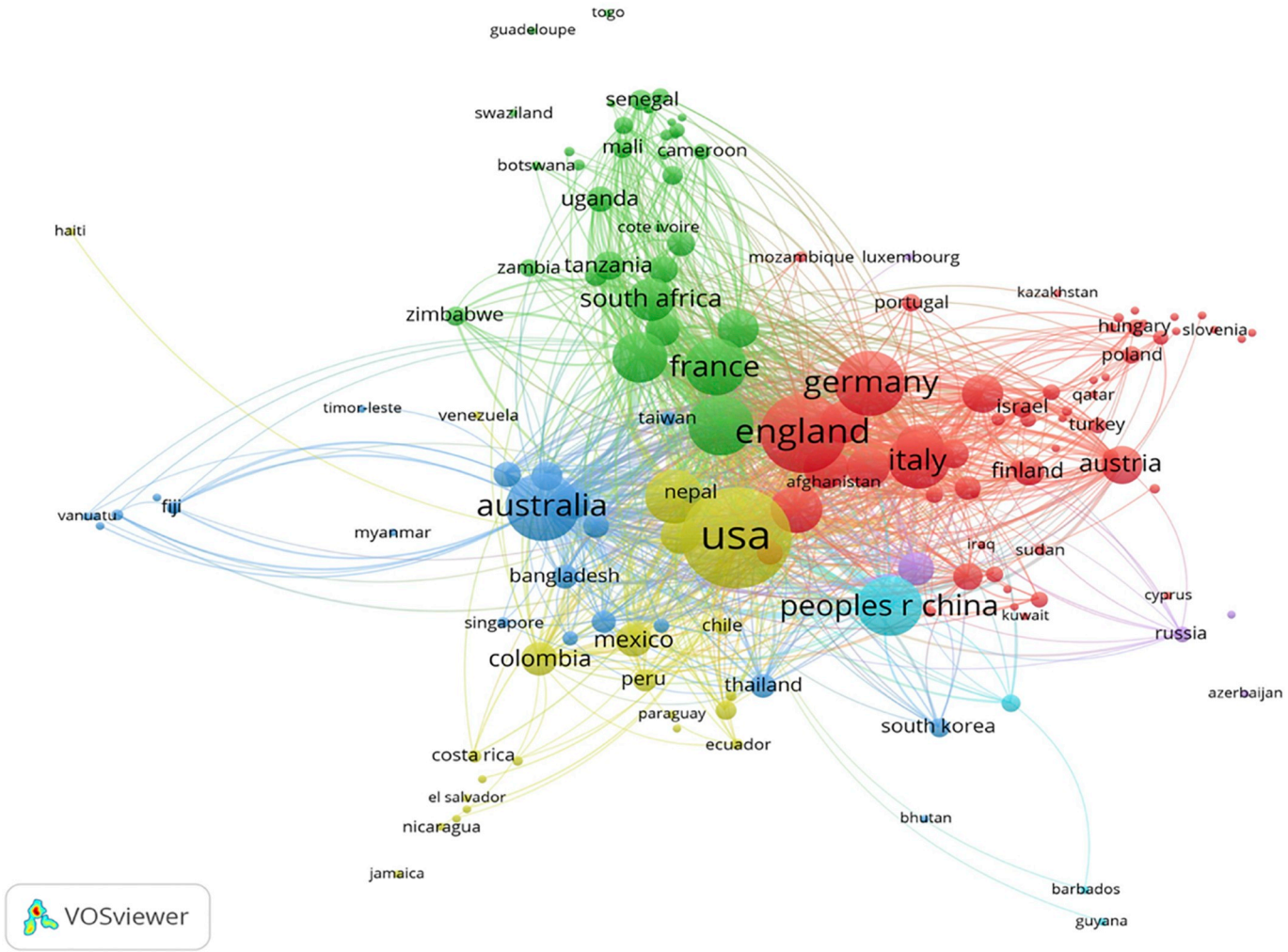

Fig. 3. Co-authorship network map of countries based on total link strength.

Table 5
Top 10 journals publishing on food security ranked by total link strength.

Journal	Total link strength	Links	Documents	Citations
Food security	3696	432	494	6169
Science	2778	402	64	15,602
Proceedings of the National Academy of Sciences	2732	355	105	12,834
Food Policy	2420	353	310	6631
The journal of nutrition	2247	184	97	5801
Sustainability	1933	314	337	1861
Global environmental change: Human and policy dimensions	1823	301	105	8023
Environmental research letters	1803	234	135	4260
Global food security: Agriculture, policy, economics, and environment	1689	307	169	2461
Public health nutrition	1566	187	171	2966

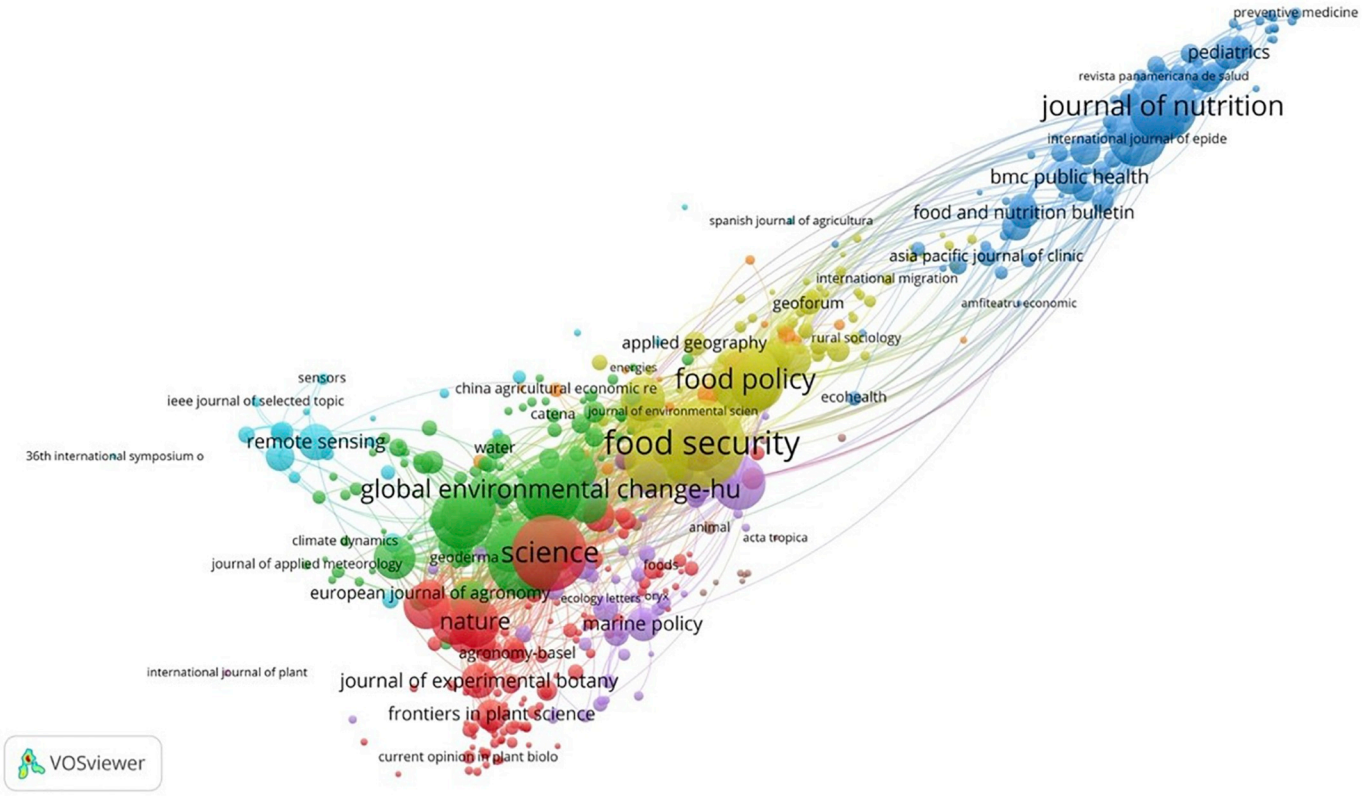

Fig. 4. Citations network map of journals based on total link strength.

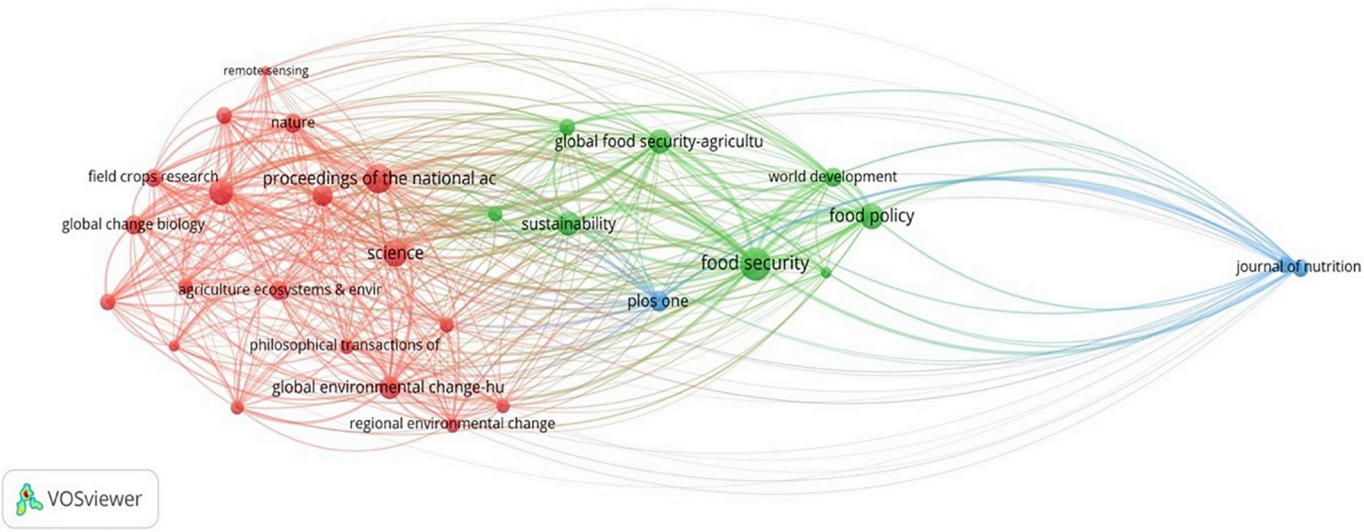

Fig. 5. Citations network map of the top 30 journals based on total link strength.

Table 6
Top 10 keywords ranked by total link strength.

Keywords	Co-occurrences	Total link strength	Link
Climate Change	2321	15,981	922
Agriculture	1605	10,713	888
Management	1252	8458	844
Health	876	5700	651
Adaptation	666	5415	676
Impacts	735	5405	749
Africa	820	5399	750
Security	707	5014	695
Systems	688	4943	758
Poverty	728	4867	648

Among these countries, USA resulted the first one with the higher value for all the investigated parameters (Table 4). In particular, both the number of documents and citations was more than double compared to the other countries. These results, in line with other bibliometric analyses performed on timely topics such as “natural capital” and “ecosystem services” (Buonocore et al., 2018; Pauna et al., 2018), are also due to the high investments performed by USA in research and developments.

Using a threshold of five documents per country, 148 countries were selected and displayed in the co-authorship network map (Fig. 3). This network map shows 6 main clusters in different colors grouping the countries characterized by a higher level of interaction. The size of the circles represents the weight of items based on total link strength. Only one country (Trinidad and Tobago) was not connected with other countries and it was excluded from the network map. The map in Fig. 3 shows a low level of interaction between most of the developed countries and the countries more affected by the food insecurity problem.

3.4. Journals network analysis

The citation analysis of journals generated 3792 results. Table 5 shows the ten top journals publishing on food security ranked by total link strength. Among these journals, Food Security ranked first by total link strength, links, and number of documents, while Science showed the highest number of citations (Table 5). Using a threshold of at least five articles per journal, a citation network map of journals was generated showing a number of 699 items (Fig. 4).

Fig. 5 shows a subset of 30 journals clustered in three groups dealing with three main aspects of food security: human health and nutrition, environment, and policy.

3.5. Keywords network analysis

The analysis of the keywords connected to food security generated a number of 47,850 results. Among them, only 4939 met the threshold of at least five co-occurrences. The top 10 keywords ranked by total link strength are shown in Table 6. The first keyword was “climate change” with 2321 co-occurrences.

The co-occurrence network map of keywords is shown in Fig. 6 in which the bigger is the size of the circle, the higher the co-occurrence of an item. Moreover, the shorter is the distance among items, the stronger their relation. Colors were used to identify the average year of publication of the keywords (i.e., the average of the publication years of all documents having a given keyword in their title or abstract).

It is noteworthy that, in the timeframe 1990–2000, the main focus of the research was placed on socio-economic aspects of food security (blue and dark-green color) such as health, gender, hunger, poverty, access to food, and nutrition. Instead, from 2000 to date, the network map shows a higher attention to environmental issues related to food

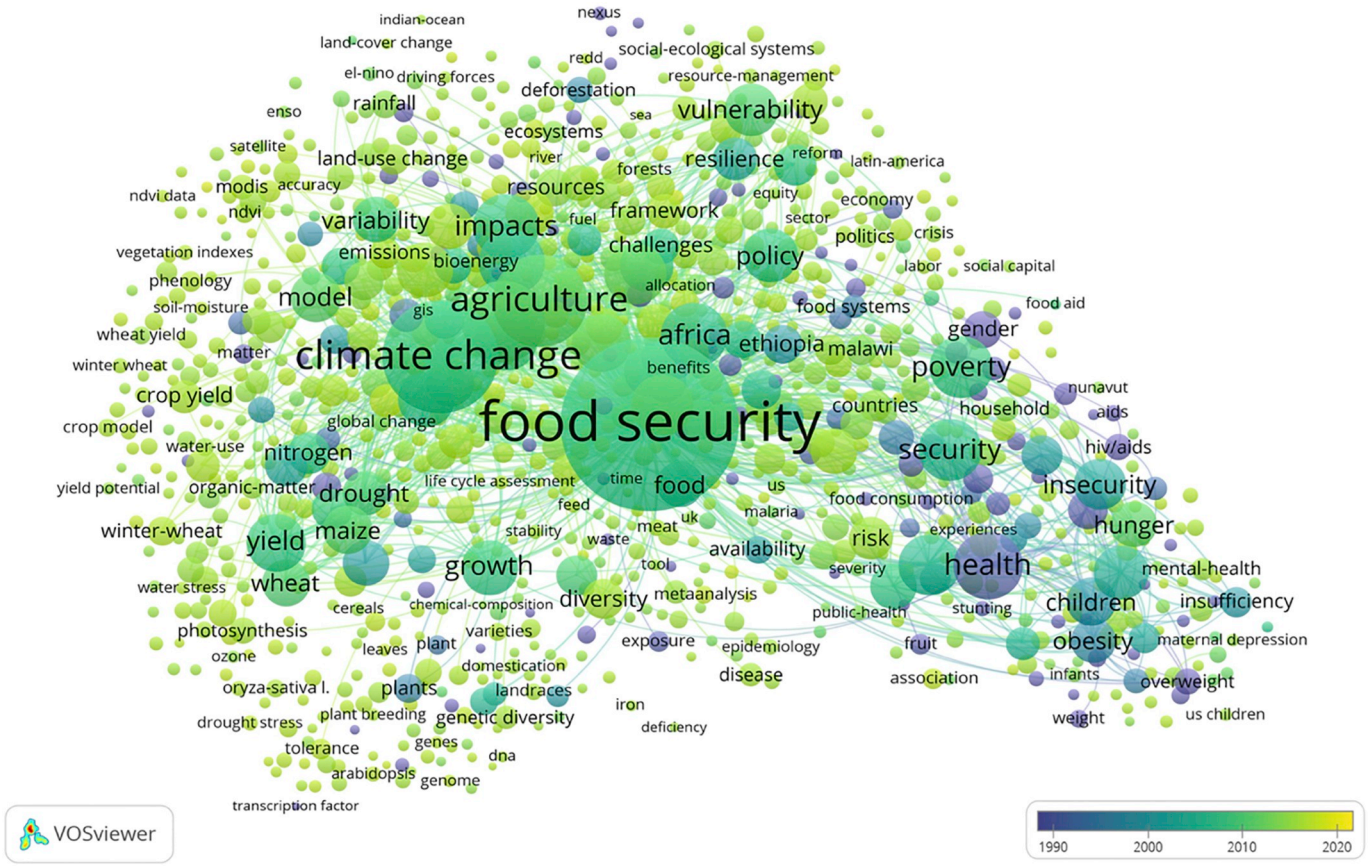

Fig. 6. Co-occurrence network map based on total link strength.

security such as climate change, emissions, agriculture, diversity, land use change, resources, and socio-ecological systems.

4. Conclusions

In this study, we explored the global scientific literature on food security. The bibliometric network analysis provided an overview on the main aspects characterizing the food security issue, allowing the investigation of the relationships occurring among authors, keywords, journals, and countries.

While the share of undernourished people in the world decreased in the last decades, the scientific literature on food security showed an exponential growth, confirming that international policy and academic research have recognized food security as one of the major challenges to face in the twenty-first century. The network maps highlight that food security is a complex issue dealing with multiple research domains, among which human health and nutrition, environment, and policy. Moreover, the network maps also suggest that a higher level of interaction between developed and developing countries would be desirable to tackle the food security issue at global scale.

The integration of social network analysis and bibliometric science resulted a useful approach capable of capturing the multidimensional nature of food security by analyzing a large amount of literature data while identifying the main scientific patterns in this field of science. Future studies should explore the nexus among different aspects related to food security, also considering the impact of climate change on reaching food security targets at national and global scale.

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