Bibliometric analysis of peer-reviewed literature on food security in the context of climate change from 1980 to 2019

Waleed M. Sweileh*

Abstract

Background: Climate change poses a threat to global food security. Assessing research activity on food security in the presence of climate change is important for policymakers and funding sponsors to make future decisions. The current study aimed to give an overview of research activity on food security in the context of food security.

Methodology: A bibliometric methodology was implemented using the Scopus database for the period from 1980 to 2019. The search strategy utilized the title/abstract search of keywords related to food security and climate change with certain constraints. Bibliometric indicators, frequent author keywords, research themes, and international research collaboration were presented.

Results: The search query retrieved 5960 documents. The last decade of the study period witnessed an increasing trend in both the number of publications and the number of cumulative citations. The top five author keywords were climate change, food security, drought, adaptation, agriculture, and water scarcity. Mapping the retrieved documents showed four general research themes: water security, crop yield, food availability, and health. The Sustainability journal ranked first in terms of productivity while documents published in the Global Change Biology journal received the highest number of citations per document. At the country level, the USA ranked first in terms of numbers, India ranked first in terms of research productivity per GDP/capita, and the UK ranked first in terms of the number of citations per document. France and the Netherlands had the highest percentage of documents with international authors while India and China had the least. At the regional level, the European region had the highest contribution and the Eastern Mediterranean region had the least contribution. Half of the top-cited documents in the field were review articles and appeared in prestigious journals. At the institutional level, the active list included three Chinese and two American institutions.

Conclusion: Food security under the umbrella of climate change is an emerging global challenge. Research on new technologies to mitigate the impact of climate change on food security is a top priority. Research contribution and collaboration from world regions with limited resources should be encouraged.

Keywords: Food security, Climate change, Bibliometric analysis, Scopus

Background

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as “a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer” [1]. Climate change...
is associated with greenhouse gases such as carbon dioxide, methane, chlorofluorocarbons and nitrous oxide [2]. Greenhouse gases are released into the atmosphere by natural and anthropogenic mechanisms and pose serious risks to human health and survival on planet earth [3]. One of the most dangerous consequences of climate change is food shortage due to the damaging effects of climate change on food security.

The IPCC report published on 2014 demonstrated that, on average, global mean crop yields of rice, maize and wheat are projected to decrease between 3 and 10% per degree of warming above historical levels. Climate change will contribute to global food insecurity by reducing crop yield, increasing expenses due to drought, and therefore increasing food prices and the number of people with poor nutrition [4, 5].

The increasing number of the world population worsens the food security challenge. It is estimated that the world population is projected to reach eight billion by 2024–2030 [6]. Meeting the needs of the world population under climate change effects is a serious challenge [7]. Climate and food challenges are well presented in the Sustainable Development Goals (SDGs). For example, the second goal in the SDGs is "Zero Hunger". The SDGs aim to end all forms of hunger and malnutrition by 2030, making sure all people—especially children and the more vulnerable—have access to sufficient and nutritious food all year round [8]. The Food and Agricultural Organization of the United Nations (FAO) estimated that the food production will have to increase by at least 60% in the next decades to meet the growing global food demand [9].

The term food security originated in the mid-1970s, almost 50 years ago [10, 11]. The widely accepted definition of "food security" is the one negotiated in the World Food Summit in 1996. “Food security, at the individual, household, national, regional and global levels [is achieved] when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” [12]. In 2009, the World Summit on Food Security stated that the "four pillars of food security are availability, access, utilization, and stability" [13]. Availability is the amount of food that is physically present regardless of the source. Access refers to economic and sociocultural reasons that might limit access of people to available food. Utilization refers to the idea that available and accessible food is nutritious, safe, and of good quality. The fourth dimension which is stability refers to the idea that availability, access, and utilization do not to occur only at a single moment in time, but need to be present all the time and with sustainability [14].

The evolution of the food security concept was discussed in an article published in the Global Food Security journal in 2013 by Jennifer Coates [10]. The concept of food security has witnessed several shifts with time [10, 15]. Examples on the changes in food security concept was a shift in the definition from food availability to food access and utilization. With time, the concept of food security has witnessed a stronger link with economic and social development. Furthermore, a shift from 'food first' to a more inclusive 'livelihood' perspective and a shift from the world and the nation towards households and individuals have been witnessed in the last few decades. Other changes included the tendency to consider the subjective perceptions of food security or insecurity, market mechanisms and incentives, nutrition and food safety, and a growing consideration of local food habits, the right to food, 'food sovereignty' and smallholder production.

Climate change will have serious negative effects on the four pillars of food security: food availability, food accessibility, food utilization and food system stability. The negative effects of climate change are particularly significant for millions of people living in specific rural locations where agriculture is the backbone of their living. Research on climate change and food security is of national and global importance because it gives policymakers baseline information on the current situation and what needs to be done in the future to adapt and mitigate the situation. Climate change and food security are topics of hot debate due to their direct effects on human health. The contribution of scientists in both developing and developed countries to the discussion about climate change and food security is needed because climate change is expected to have different effects on different world regions. For example, in Africa, the main risks of climate change will be water and food scarcity in addition to increased spread of infectious diseases such as malaria [16]. In Europe, climate change will cause more coastal floods and higher frequency of wildfires [17, 18]. Therefore, it is important to investigate and assess research themes and research pattern on climate change and food security at the global and regional levels.

Assessment of scientific productivity has been carried out for food security as a single topic and also has been carried out for climate change as a single topic [19, 20]. However, no published studies analyzed scientific literature on food security in the context of climate change. Therefore, the current study was undertaken to assess and analyze scientific literature on climate change and food security. The approach commonly utilized to assess and analyze science is called bibliometrics, which is different from systematic or scoping reviews. The main goal in the bibliometric analysis is to analyze growth of
research, main research themes, top-cited documents in the field, national and regional contribution, scientific impact, and key players in the field. Bibliometric analysis has been used to assess the research activity in different medical subjects and topics [21, 22]. However, bibliometric studies should always abide by certain principles to ensure best practice in metrics-based research assessment. Such principles were names the Leiden Manifesto after the name of the conference in which they were formulated [23]. The Leiden Manifesto came as an endorsement to the Declaration on Research Assessment (DORA), which aimed to improve how the outputs of scholarly research are evaluated. The author of the current manuscript did his utmost to ensure that current study was comprehensive, accurate, relevant, valid, and supported by evidence.

Literature review on bibliometric studies on climate change and food security

Bibliometric analysis of publications on climate change has been published [20, 24–31]. Similarly, bibliometric analysis of publications on food security has been published [32–37]. None of the published bibliometric studies analyzed literature discussing the impact of climate change or the presence of climate change on food security. However, for comparative purposes, few bibliometric studies on food security were discussed. A recently published bibliometric study on food security was carried using Web of Science and analyzed documents on food security in general [38] without specifying the keywords used to retrieve the relevant documents. Results of the study showed that 19,449 publications on food security were published from 193 countries in 3792 journals with Mario Herrero being the most productive author, while the USA ranked first in productivity. Among the journals, Food Security ranked first by total link strength, links, and the number of documents. The co-occurrence network map of keywords showed that, over the last decades, the focus of food security research has shifted from socio-economic to environmental aspects. A second recently published study on the impact of climate change and infectious diseases was published and analyzed the research themes of the impact of climate change on human health with an emphasis on infectious diseases [30]. A third recently published scientometric study discussed the impacts of climate change on water quality by reviewing 2998 related articles extracted from the Science Citation Index-Expanded (SCI-E) database from 1998 to 2018. The results of the study revealed that the impacts of climate change on water quality mainly included the aggravation of eutrophication, changes in the flow, hydrological and thermal conditions, and the destruction of ecosystems and biodiversity [29].

Methodology

Database used

For an ideal bibliometric study, different databases need to be used to retrieve the relevant documents to ensure the comprehensiveness of the analysis. However, the use of multiple databases is applicable only when the volume of literature on the investigated topic is limited. In the current study, a single database was used because of the large volume of literature on the investigated topic. Literature review showed that Scopus database is superior to both PubMed and Web of Science in terms of size and functions available for analysis and sorting of data [39–43]. Therefore, in the current study, Scopus was used to achieve the required objective. The advanced search function in Scopus was used because it allows for building long and complex search queries. In bibliometric studies, usually one database is used because bibliometric indicators and literature mapping are difficult to perform on documents retrieved from different databases. Scopus is 100% inclusive of PubMed and has double the number of indexed journals than Web of Science. Therefore, Scopus is considered almost comprehensive of publications in PubMed and Web of Science.

Search strategy

To be able to build a search query that can retrieve the maximum related number of documents with minimum false-positive results, the author did an extensive literature review on the topic, especially review articles and systematic reviews to find out all potential keywords that could be used [44–50]. The simplest approach was to use the title/abstract search methodology for keywords related to "climate change" and "food security". However, applying such an approach will retrieve a high proportion of irrelevant documents. Therefore, to sharpen the title/abstract approach, a certain constraint was implemented that included the presence of certain "terms" related to food security or climate change in addition to the title/abstract strategy.

Search query

The overall search query consisted of specific phrases related to climate change and specific phrases related to food security entered in the title/abstract search followed by certain terms as a constraint to minimize irrelevant documents.

1. Phrases or expressions related to "food security" were: title-abs ("inadequate food" or "household dietary diversity" or "household food expenditure" or "food consumption" or "food use" or "water security" or "clean water" or "safe water" or "crop failure" or...
"crop vulnerability" or "food security" or "food insecurity" or "food utilization" or "food access" or "food abundance" or "food scarcity" or "food limitation" or "food poverty" or "food insufficiency" or "food system stability" or "nutrition security" or "food availability" or "stability of food system" or "food crisis" or "food challenge" or "food shortage" or "stable food supply" or "water scarcity" or "water security").

Validation of the search strategy

The overall search query was finalized after several trials and fine-tuning process. The following criteria were considered in the development of the search query. First, the retrieved top 100 cited documents should be free of false-positive results and within the scope of the study. Second, the top ten active authors in the search strategy should have a similar number of results as present in their Scopus profile. Third, the top 20 active journals are related to the field of the study. This approach was adopted from the previously published bibliometric study [51]. For the first criterion, the top 100 cited articles were sent as an endnote file to two independent researchers in the field of life sciences and were asked to confirm that the articles were within the scope of the study. Whenever a false-positive result was found, the search query was fine-tuned to sharpen the query. In the second criterion, the number of articles retrieved for active authors and the number of articles for the same authors found in their Scopus profile were compared using Pearson correlation test. For example, the overall search query showed that the following researchers were among the top active authors: Herrero, M.; Thornton, P.K; Tao, F. and their research output based on the search query was 29, 25, and 19 documents, respectively. The same authors have produced 30, 25, and 20 documents based on their Scopus personal profile. This approach was carried out for 10 different authors and the correlation between the retrieved and the actual number of publications was significant ($p < 0.01$) and the correlation coefficient was above 95% suggestive of high validity of the search query. The top active author mentioned by Skaf et al. was the same in our study. In Skaf et al., Herrero, M. ranked first and produced 50 documents on food security in general. In the current study, Herrero, M. also ranked first with 29 documents on food security in the context of climate change. For the third criterion, a quick scanning of the top active journals indicated that all were related to food security or climate change or both as indicated in their subject scope in Science Journal Ranking. The retrieved documents using the developed search query might not be 100% inclusive of literature on food security in the context of climate change, but the retrieved documents are considered an accurate representation of the study question being addressed.

Data export and bibliometric indicators

The validated search query was run using the advance search function in Scopus. The retrieved data from Scopus were exported to Microsoft Excel. The exported data included: annual number of publications, types of documents, languages, subject areas, names of countries.
involved in publishing the retrieved documents, authors, journals, author keywords, funding sponsors, institutions, and citations. The exported data were analyzed to produce the bibliometric indicators, which included the followings: (1) annual growth of publications; (2) most frequent author keywords in the retrieved documents; (3) top ten active countries, institutions, and journals; (4) citation analysis and top-cited documents, and (5) international research collaboration. In the citation analysis, we used the mean number of citations per document and Hirsh-index (h-index) which are used as a measure of scientific impact [52].

Network visualization maps
The retrieved literature was mapped to visualize research themes. For research themes, the terms in titles/abstracts of the retrieved documents with a minimum occurrence of 10 were mapped using the free on-line program, VOSviewer [53]. In the map, related terms exist in close proximity and have the same color. Terms having the largest node size are the ones with the highest frequency. Each cluster of terms with the same color represents a research topic or a research theme. Therefore, the number of clusters represents the number of research themes in the retrieved documents. These research themes are overlapping.

International research collaboration
For each active country, the number and percentage of documents that included international authors were investigated. These multiple country publications (MCP) represent the extent of inter-country (international) research collaboration. Documents with no international authors were termed single country publications (SCP). The SCP represent the extent of intra-country collaboration.

Geographic distribution of the retrieved articles
In the current study, the World Health Organization classification of world regions included the region of Americas, the African region, the European region, the Western Pacific region, the South-East Asian region, and the Eastern Mediterranean region.

Citation analysis
The scientific impact of active journals and countries was evaluated using the number of citations per document.

Data presentation
All results were presented as tables except for annual growth, research collaboration, and research themes. The annual growth was presented as a linear graph using Statistical Package for Social Sciences (SPSS, version 25, USA). Research collaboration and research themes were presented as network visualization maps using VOSviewer program [53].

Results
Volume and annual growth
The research query retrieved 5960 documents. The retrieved documents were mainly research articles (n=5017; 84.2%) and review articles (n=752; 12.6%). The remaining documents were editorials, conference papers, notes, and letters. Eighteen different languages were encountered in the retrieved documents. The main language was English (n=5750; 96.5%) followed by Chinese, French, and Spanish. In total, 26,386 authors participated in publishing the retrieved documents, an average of 4.4 authors per document. The annual number of publications showed a steep increase after 2007 and more than half (n=3455; 58.0%) of the retrieved publications were published in the last 5 years of the study period (2015–2019) (Fig. 1). During the study period from 2009 to 2019, the last decade, both the cumulative number of citations and the number of publications showed a parallel increasing trend (Fig. 2). The number of publications increased by fivefolds while the cumulative number of citations increased by more than tenfolds.

Subject areas
The retrieved documents belonged to different subject areas emphasizing the multidisciplinary nature of food security and climate change. The subject area of environmental sciences (n=3036; 50.9%) ranked first followed by the subject areas of agricultural and biological sciences (n=2333; 39.1%), social sciences (n=1597; 26.8%), “Earth and Planetary Sciences” (n=884; 16.5%), and biochemistry/“genetics/molecular biology” (n=533; 8.9%), (Table 1).

Top frequent author keywords
Figure 3 is a network visualization map of the top 50 author keywords. In the map, the keyword "climate change" has the largest node size (n=1408 occurrences). The second largest node size was "food security" (n=747) followed by drought (n=316), adaptation (n=311), agriculture (n=264), and water scarcity (n=194). The map of the most frequent author keywords included the names of the following countries/regions: Africa, sub-Saharan Africa, Ethiopia, Bangladesh, China, and India. The map also included keywords such as health, nutrition, livelihood, and poverty. Of the types of food that appeared on the map were rice, maize and wheat.
Research themes
Figure 4 is a network visualization map of terms in titles/abstracts of the retrieved documents with minimum occurrences of 10 times. The map included 2020 terms distributed into four different clusters (colors). Closely related terms have the same color and represent a separate research topic/theme. The map shows four different clusters representing four general research themes. The largest theme (blue cluster = 826 terms) focused on crop yield of various types of food such as rice, wheat, and grains. The second research theme (green cluster = 587 terms) discussed water security/scarcity/supply and precipitation. The third research theme (red cluster = 461 terms) focused on health/poverty/household dimension of food security. The fourth research theme (yellow cluster = 146 terms) focused on food availability.

Top ten prolific journals
The retrieved documents appeared in 1831 different journals. Table 2 shows the top ten prolific journals. The Sustainability journal ranked first with 98 (1.6%) documents followed by the Climatic Change journal (n = 94; 1.6%) and the Science of the Total Environment journal (n = 91; 1.5%). Documents published in the Global Change Biology journal received the highest number of citations per document (62.2).

Top ten prolific countries
Authors from 170 different countries participated in publishing the retrieved documents. The top ten prolific countries published 5566 (93.4%) documents. The USA ranked first (n = 1562; 26.2%) followed by the UK (n = 724; 12.1%) and China (n = 623; 10.5%). The top ten prolific countries did not include countries from Latin America or Africa or the Eastern Mediterranean region or Eastern Europe (Table 3). Documents published from the UK received the highest number of citations per document followed by those from the Netherlands and Italy. When the research productivity was standardized by GDP (nominal) per capita, India ranked first followed by China and the USA.
International research collaboration

Figure 5 is a stacked bar chart presentation of the extent of international research collaboration for each of the top ten active countries. France had the highest percentage of MCP followed by the Netherlands and Germany while India and China had the least percentage of MCP.

Geographical distribution of the retrieved documents

Table 4 shows the geographical distribution of the retrieved documents. The European region ($n=2377; 39.9\%$) had the highest contribution followed by the region of the Americas ($n=2103; 35.1\$$. The Eastern Mediterranean region had the least contribution ($n=348; 5.8\%$). Figure 6 shows the annual growth of publications from each WHO world region. The growth pattern was similar in all regions. However, for the region of the Americas and the European region, the growth pattern was the steepest. The growth pattern in the Eastern Mediterranean region showed the slowest growth pattern.
Top ten cited documents
The retrieved documents received 164,062, an average of 27.5 citations per document and an h-index of 163. The document that received the highest citations \( n = 4655 \) was a review article published in 2010 in the Science journal and discussed food security in the face of increasing number of world population and the factors that worsen the threat including climate change [54]. The top-cited documents appeared in leading scientific journals [54–63]. Half of the top ten cited documents were review articles (Table 5) and half appeared in the Science journal.

Top ten active institutions
Table 6 shows the top ten active institutions. The Chinese Academy of Sciences ranked first \( n = 190; 3.2\% \) followed by Wageningen University & Research \( n = 161; 2.7\% \). The list of top ten active institutions included three Chinese and two American institutions.

Discussion
The current study aimed to give an overview of research activity on food security in the context of climate change, which is one of the top important subjects for governments, international non-governmental agencies, policymakers, food and agricultural experts, food technologists, and climate experts. The current study showed a noticeable growth in the number of publications in the last decade with considerable international research collaboration. The increase in the number of publications is due to several reasons. The IPCC fourth report issued in 2007 called for all countries to take adaptive measures to face climate changes [64]. This coincides with the steep rise in the number of publications. Several warning signals appeared in the 1980s and 1990s on the hazardous impact of climate change on livelihood. The first major international conference on the greenhouse effect at Villach, Austria, warned that greenhouse gases will cause a rise of global mean temperature which is greater than any in man’s history [65]. In 1992, Climate Change Convention, agrees to reduce emissions from industrialized countries
to stop global warming [66]. In 1997, the Kyoto Protocol calls for cutting emissions from industrialized nations [67]. However, due to political and economic reasons in industrialized nations, the Kyoto protocol did not come into force until 2005. All these warning messages were translated into policies set by the

![Network visualization map of most frequent terms in titles/abstracts of the retrieved documents. Terms with the same color represent a separate cluster (research theme)](image)

**Fig. 4** Network visualization map of most frequent terms in titles/abstracts of the retrieved documents. Terms with the same color represent a separate cluster (research theme)

| Rank | Journal                             | Frequency | %  | Total citations | Citations per document |
|------|-------------------------------------|-----------|----|-----------------|------------------------|
| 1    | Sustainability Switzerland          | 98        | 1.6| 763             | 7.8                    |
| 2    | Climatic Change                     | 94        | 1.6| 4648            | 49.4                   |
| 3    | Science of the Total Environment    | 91        | 1.5| 1598            | 17.6                   |
| 4    | Plos One                            | 77        | 1.3| 1349            | 17.5                   |
| 5    | Water Switzerland                   | 77        | 1.3| 546             | 7.1                    |
| 6    | Regional Environmental Change       | 73        | 1.2| 2105            | 28.8                   |
| 7    | Agricultural Water Management       | 71        | 1.2| 2253            | 31.7                   |
| 8    | Environmental Research Letters      | 68        | 1.1| 2314            | 34.0                   |
| 9    | Food Security                       | 66        | 1.1| 1816            | 27.5                   |
| 10   | Global Change Biology               | 61        | 1.0| 3797            | 62.2                   |

*In ranking system, journals with equal productivity were given the same rank*
Millennium Development Goals (MDGs) and SDGs. The steep growth in the number of publications emphasizes the fact that policymakers at the national and international levels are fully aware and are implementing measures in the area of climate change and food security by supporting research from both academic
and non-academic centers to face the challenges of the twenty-first century.

The current study showed that the retrieved documents belonged to diverse subject areas, but mainly environmental and agricultural sciences. The contribution of various subject areas to the retrieved literature emphasizes the complex nature of the topic and the role of various sectors in discussing the impact of climate change on food security. Climate change directly affects agriculture through changes in temperature, drought, heat waves, floods and concentration of ozone and atmospheric carbon dioxide [68, 69]. Both agriculture and climate change are inter-related. Agriculture can worsen climate change by producing greenhouse gases such as methane and CO₂ [70]. The global impact of climate change on agriculture is manifested in the reduction of quantity and quality of crops, changes in agricultural practices, changes in soil properties, and changes in plant properties such as the development of drought- or flood- or heat- or salt-resistant rice [71]. A study assessed the projected impacts of climate change on the yield of eight major crops in Africa and South Asia showed that the projected mean change in yield of all crops is 8% by the 2050s in both regions. Across Africa, mean yield changes of 17%
(wheat), 5% (maize), 15% (sorghum) and 10% (millet) and across South Asia of 16% (maize) and 11% (sorghum) were estimated [72]. The IPCC report published in 2014 stated that the world might reach "a threshold of global warming beyond which current agricultural practices can no longer support large human civilizations." by the middle of the twenty-first century.

The current study showed that adaptation, mitigation, and crop model prediction were among the top 50 frequent author keywords in the retrieved literature. Several methods of adaptation and mitigation to climate change have been developed and included the development of genetically resistant crop varieties and the development of efficient irrigation systems [73, 74]. In developed countries, innovative agriculture and development of new technologies and the use of cleaner energy have been suggested and implemented to adapt to climate change and to decrease the contribution of agriculture to greenhouse gases [75].

The current study showed that China and Chinese institutions were major key players in this area. Approximately 20% of the world population lives in China, which has less than 7% of the world’s arable land. China observed a ground average temperature increase of 0.24 °C/decade from 1951 to 2017, exceeding the global rate and the annual mean concentration of atmospheric carbon dioxide, methane and nitrous oxide were slightly higher than the global mean concentration in 2016 [76]. Climate change poses a huge challenge to food production in China. Climate change will not only threaten China’s food production, but also the global food market of rice, wheat and corn which are produced in large quantities in China [77]. The current study showed that India had higher research output than China when research productivity was normalized by income and population size. India is highly populated and despite its economic growth it failed to achieve the target set in MDG regarding the reduction of hunger [78]. The problem of food security in India will be worsened by climate change because of water scarcity and droughts [79, 80]. The current study also showed that publications from the UK had the highest

| Rank | Title                                                                                     | Document type | Source title                        | Cited by | Year |
|------|-------------------------------------------------------------------------------------------|---------------|-------------------------------------|----------|------|
| 1    | Food security: The challenge of feeding 9 billion people                                  | Review        | Science                             | 4655     | 2010 |
| 2    | Climate trends and global crop production since 1980                                     | Article       | Science                             | 1617     | 2011 |
| 3    | Impact of regional climate change on human health                                        | Review        | Nature                              | 1533     | 2005 |
| 4    | Prioritizing climate change adaptation needs for food security in 2030                    | Article       | Science                             | 1506     | 2008 |
| 5    | Climate change will affect the Asian water towers                                         | Article       | Science                             | 1486     | 2010 |
| 6    | How plants cope with water stress in the field: Photosynthesis and growth                 | Article       | Annals of Botany                    | 1146     | 2002 |
| 7    | Managing the health effects of climate change. Lancet and University College London Institute for Global Health Commission | Review       | The Lancet                          | 1130     | 2009 |
| 8    | Sustainable biochar to mitigate global climate change                                     | Article       | Nature Communications               | 1006     | 2010 |
| 9    | Climate change impacts on global food security                                            | Review        | Science                             | 905      | 2013 |
| 10   | Global food security under climate change                                                 | Review        | PNAS                                | 883      | 2007 |

Table 6 Top ten active institutions

| Rank | Institution                                      | Frequency N=5960 | %   | Country  |
|------|--------------------------------------------------|------------------|-----|----------|
| 1    | Chinese Academy of Sciences                      | 190              | 3.2 | China    |
| 2    | Wageningen University & Research                 | 161              | 2.7 | Netherlands |
| 3    | International Food Policy Research Institute     | 84               | 1.4 | USA      |
| 4    | Beijing Normal University                        | 71               | 1.2 | China    |
| 5    | University of Oxford                             | 70               | 1.2 | UK       |
| 6    | Commonwealth Scientific and Industrial Research Organization | 67               | 1.1 | Australia |
| 7    | International Livestock Research Institute Nairobi | 66               | 1.1 | Kenya    |
| 8    | China Agricultural University                    | 64               | 1.1 | China    |
| 9    | International Institute for Applied Systems Analysis, Laxenburg | 62               | 1.0 | Austria  |
| 10   | University of California, Davis                  | 61               | 1.0 | USA      |
number of citations per document. One possible explanation for this is the finding that the *Global Change Biology* journal, which received the highest number of citations in this field, is based in the UK. Interestingly, both China and India had the least international research collaboration, which explains the findings that documents from these countries had the least number of citations per document. In contrast, countries such as the UK, Italy, France, and the USA had a relatively high percentage of international research collaboration and therefore had a higher number of citations per document. Although the top list of active countries did not include countries from the African or the Eastern Mediterranean regions, the contribution of these two regions was reasonable given the limited funding, limited scientific expertise in climate change and food security, as well as the unstable political situation in many countries in these two regions.

The current study showed that documents received a relatively high number of citations per document and high *h*-index. This is indicative of the importance of the topic and the high level of interest of researchers in this field. This is not surprisingly given that the topic is not limited to a geographical area. Both food security and climate change are global problems and have direct effects on human health, wellbeing, and livelihood. The number of citations is also a function of the number of authors per document and the extent of international research collaboration and both were high for the investigated topic [81]. The contribution of all world regions to the topic was also a motivating factor for collaboration and an increased number of citations. The finding that half of the top-cited documents were review articles and published in highly prestigious journals with high impact factors also played a positive role in the number of citations received by the retrieved documents. However, the fact that these prestigious journals were based in Europe might have created publication bias toward these countries [47].

The current study was the first bibliometric analysis of climate change and food security. Searching Scopus database showed at least 30 bibliometric studies on climate change and a few on food security [28, 31, 82, 83]. However, none was on food security under the umbrella of climate change. Therefore, the current study is the first to discuss this topic from a bibliometric point of view. The current study had a few limitations. The author used all potential and possible keywords to maximize validity. However, missing some data remains a possibility. The use of Scopus as a source for relevant documents is another potential limitation. Scopus is indeed the largest database but there are many peer-reviewed journals in Asia, Africa, Latin America, and Eastern Europe that are not indexed in Scopus. Therefore, documents published in unindexed journals were missed. This might under-estimate the productivity of certain countries, world regions, authors, and institutions. The third limitation is the type of keywords used in the search query. The author did his best to be comprehensive and to use all keywords mentioned in the literature that are relevant to climate change and food security. However, missing some terms remains a possibility. The final limitation is the use of single database to retrieve all relevant documents [84]. This is common to almost all bibliometric studies.

**Conclusion**

In the current study, an overview of research activity on food security in the context of climate change was presented hoping to create a beneficial contribution to the field. The retrieved literature was characterized by rapid growth, high citations, and involvement of leading journals. China and India were actively involved in research in this area while the UK, the Netherlands produced publications with the highest impact in the field. International research collaboration in this field was relatively high indicative of the importance of the topic. All world regions were involved in publishing documents in this area with the African region ranking fourth exceeding both the Eastern Mediterranean and the South-East Asian regions. The current study showed that water security, health, crop production, and food availability were the main research themes on food security under the umbrella of climate change. New technologies and innovative solutions to adapt and mitigate climate change need to be investigated to avoid food insecurity, especially in world regions with limited resources.

**Abbreviations**

WHO: World Health Organization; Q1: First quartile; IPCC: Intergovernmental Panel on Climate Change; UNFCCC: United Nations Framework Convention on Climate Change.

**Acknowledgements**

The authors would like to thank An-Najah National University for giving us the opportunity to access most recent information sources.

**Author contributions**

WS started the idea, designed the methodology; did the data analysis, graphics, and data interpretation; wrote and submitted the manuscript. The author read and approved the final manuscript.

**Funding**

None.

**Availability of data and materials**

All data presented in this manuscript are available on Scopus database using the search query listed in the "Methodology" section.
References

1. Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC. Climate change 2014: impacts, adaptation, and vulnerability: summaries, frequently asked questions, and cross-chapter boxes: A Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change: Intergovernmental Panel on Climate Change, 2014.

2. Manabe S. Role of greenhouse gas in climate change. Tellus A Dyn Meteorol Oceanogr. 2019;71(1):1–13.

3. Horton R, Beaglieholle R, Bonita R, Raelburn J, McKee M, Wall S. From public to planetary health: a manifesto. Lancet. 2014;383(9920):847.

4. Hertel TW. Food security under climate change. Nat Clim Change. 2016:10–3.

5. Chatzopoulos T, Dominguez IP, Zampieri M, Toreti A. Climate extremes and agricultural commodity markets: a global economic analysis of regionally simulated events: Weather Clim Extremes. 2019;27:100193.

6. United Nations (UN). World population prospects 2019 https://population.un.org/wpp/. Accessed 29 June 2020.

7. Hinrichsen D, Robey B. Population and the environment: the global transition in Europe—review of projections for the future. Mitig Adapt Strateg Glob Change. 2010;15(7):641–56.

8. Girvan E. Governance by global goals: the evolvement of Sustainable Development Goal 2-End Hunger, achieve food security and improved health to planetary health: a manifesto. Lancet. 2014;383(9920):847.

9. Gitz V, Meybeck A, Lipper L, Young CD, Braatz S. Climate change and food security: risks and responses. Food and Agriculture Organization of the United Nations (FAO) Report; 2016. p. 110.

10. Coates J. Build it back better: deconstructing food security for improved measurement and action. Glob Food Security. 2013;2(3):188–94.

11. Maxwell S, Smith M. Household food security: a conceptual review. Household Food Security Concepts Indic Meas. 1992;1:1–72.

12. World Food Summit. Rome Declaration on World Food Security. In: World Food Summit: 1996; Rome; 1996.

13. Food and Agriculture Organization of the United Nations (FAO): declaration of the world summit on food security. 2009.

14. Aborisaide B, Bach C. Assessing the pillars of sustainable food security. Eur J Sci Technol. 2014;3(4):117–25.

15. Hector Maletta: From hunger to food security, a conceptual history. 2014.

16. Müller C, Cramer W, Hare WL, Lotze-Campen H. Climate change risks for African agriculture. Proc Natl Acad Sci. 2011;108(11):4313–5.

17. Ciscar J-C, Iglesias A, Feyen L, Szabó L, Van Regemorter D, Amelung B, Nardini M, Ebi KL, Estrada YO, Genova RC. Climate change 2014: impacts, adaptation, and vulnerability: summaries, frequently asked questions, and cross-chapter boxes: A Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change: Intergovernmental Panel on Climate Change, 2014.

18. Kundzewicz ZW, Luterbacher J, Mearns L. Climate change and food security: risks and responses. Food and Agriculture Organization of the United Nations (FAO) Report; 2016. p. 110.

19. Renn O, Schutz T, Scholz R. Climate change and human health: an emphasis on infectious diseases. Glob Health. 2020;16(1):1–7.

20. Zyoud SH, Fuchs-Hanusch D. Mapping of climate change research in the Arab world: a bibliometric analysis. Environ Sci Pollut Res. 2020;27(3):3523–40.

21. Alves DC, Monte-Vele-CVB. Cientificometric analysis of freshwater fisheries in Brazil: repeating past errors? Rev Fish Biol Fish. 2013;23(1):113–26.

22. Ziyoud SH, Smale S, Waring WS, Sweileh WM, Al-Jabi SW. Global research trends in microbiome-gut-brain axis during 2009–2018: a bibliometric and visualized study. BMC Gastroenterol. 2019;19(1):158.

23. Hicks D, Wouters P, Wathman L, De Rijcke S, Rafols I. Bibliometrics: the Leiden Manifesto for research metrics. Nature. 2015;520(7548):429–31.

24. Wang B, Pan SY, Ye RX, Wang K, Wei YM. An overview of climate change vulnerability: a bibliometric analysis based on Web of Science database. Nat Hazards. 2014;74(3):1649–66.

25. Di Matteo G, Nardi P, Grego S, Guidi C. Bibliometric analysis of climate change vulnerability assessment research. Environ Syst Decis. 2018;38(4):508–16.

26. Wang Z, Zhao Y, Wang B. A bibliometric analysis of climate change adaptation based on massive review literature data. J Clean Prod. 2018;199:1072–82.

27. Wu F, Geng Y, Tian X, Zhong S, Wu W, Yu S, Xiao S. Responding climate change: a bibliometric review on urban environmental governance. J Clean Prod. 2018;204:344–54.

28. Huang L, Chen X, Zhou M. Climate change and carbon sink: a bibliometric analysis. Environ Sci Pollut Res. 2020;27(8):8740–58.

29. Li X, Li Y, Li G. A scientometric review of the research on the impacts of climate change on water quality during 1998–2018. Environ Sci Pollut Res. 2020;27(13):14322–41.

30. Sweileh WM. Bibliometric analysis of peer-reviewed literature on climate change and human health with an emphasis on infectious diseases. Glob Health. 2020;16(1):1–7.

31. Zyoud SH, Fuchs-Hanusch D. Mapping of climate change research in the Arab world: a bibliometric analysis. Environ Sci Pollut Res. 2020;27(3):3523–40.

32. Alves DC, Monte-Vele-CVB. Cientificometric analysis of freshwater fisheries in Brazil: repeating past errors? Rev Fish Biol Fish. 2013;23(1):113–26.

33. Monasterolo I, Pasquillino R, Janetos AC, Jones A. Sustainable and inclusive food systems through the lenses of a complex system thinking approach—a bibliometric review. Agriculture. 2016;3(4):44.

34. Suebsombut P, Sekhari A, Sureepong P, Ueasangkomsate P, Bouras A: The using of bibliometric analysis to classify trends and future directions on ‘smart farm’. In: 2nd joint international conference on digital arts, media and technology. 2017; digital economy for sustainable growth, ICDAMT 2017: 2017; 2017. p. 136–41.

35. Diaconeasa MC, Zaharia A: What hides under the sustainable agriculture umbrella? A bibliometric analysis. In: Proceedings of the 32nd international business information management association conference, IBIMA 2018—vision 2020: sustainable economic development and application of innovation management from regional expansion to global growth. 2018; 2018. p. 6590–88.

36. Zhang M, Gao M, Yue S, Zheng T, Gao Z, Ma X, Wang Q. Global trends and future prospects of food waste research: a bibliometric analysis. Environ Sci Pollut Res. 2018;25(25):24600–10.

37. Giraldo P, Benavente E, Manzano-Aguilagor F, Gimenez E. Worldwide research trends on wheat and barley: a bibliometric comparative analysis. Agronomy. 2019;9(7):352.

38. Alves DC, Monte-Vele-CVB. Cientificometric analysis of freshwater fisheries in Brazil: repeating past errors? Rev Fish Biol Fish. 2013;23(1):113–26.

39. Falagas ME, Pitsouni EI, Malaretzis GA, Pappas G. Comparison of PubMed, Scopus, Web of Science, and Google Scholar: strengths and weaknesses. FASEB J. 2008;22(2):338–42.

40. De Groot SL, Raszewska R. Coverage of Google Scholar, Scopus, and Web of Science: a case study of the h-index in nursing. Nurs Outlook. 2012;60(6):391–400.

41. Suebsombut P, Sekhari A, Sureepong P, Ueasangkomsate P, Bouras A: The using of bibliometric analysis to classify trends and future directions on ‘smart farm’. In: 2nd joint international conference on digital arts, media and technology. 2017; digital economy for sustainable growth, ICDAMT 2017: 2017; 2017. p. 136–41.

42. Skaf L, Buonocore E, Dumontet S, Capone R, Franzez P. Applying network analysis to explore the global scientific literature on food security. Ecol Inform. 2020;56:101062.

43. De Groot SL, Raszewska R. Coverage of Google Scholar, Scopus, and Web of Science: a case study of the h-index in nursing. Nurs Outlook. 2012;60(6):391–400.

44. Falagas ME, Pitsouni EI, Malaretzis GA, Pappas G. Comparison of PubMed, Scopus, Web of Science, and Google Scholar: strengths and weaknesses. FASEB J. 2008;22(2):338–42.

45. Harzing AW, Alakangas S. The current state of the art in bibliometric research: a systematic review of the literature. Cities. 2019;94:129–42.
45. Berrang-Ford L, Pearce T, Ford JD. Systematic review approaches for climate change adaptation research. Reg Environ Change. 2015;15(3):755–69.

46. Hatab AA, Cavaino MER, Lagerkvist CJ. Urbanization, livestock systems and food security in developing countries: a systematic review of the literature. Food Security. 2019;11(2):279–99.

47. Santerno FG, Lamonaca E. The effects of non-tariff measures on agri-food trade: a review and meta-analysis of empirical evidence. J Agric Econ. 2019;70(3):595–617.

48. Santerno FG, Lamonaca E. Evaluation of geographical label in consumers’ decision-making process: a systematic review and meta-analysis. Food Res Int. 2020;131:108995.

49. Santerno FG, Lamonaca E, Conto F, Nardone G, Stasi A. Drivers of grain price volatility: a cursory critical review. Agric Econ. 2018;64(8):347–56.

50. Santerno FG, Shabnam N. The income-elasticity of calories, macro- and micro-nutrients: what is the literature telling us? Food Res Int. 2015;76(P4):922–7.

51. Sweileh WM, Wickramage K, Pottie K, Hui C, Roberts B, Savalha AF, Zyoud SH. Bibliometric analysis of global migration health research in peer-reviewed literature (2000–2016). BMC Public Health. 2018;18(1):777.

52. Hirsch JE. An index to quantify an individual’s scientific research output. Proc Natl Acad Sci USA. 2005;102(46):16569–722.

53. van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics. 2010;84(2):523–38.

54. Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, Pretty J, Robinson S, Thomas SM, Toulmin C. Food security: the challenge of feeding 9 billion people. Science. 2010;327(5967):812–8.

55. Chaves MM, Pereira JS, Maroco J, Rodrigues ML, Ricardo CPP, Osório ML, Carvalho I, Faria T, Pinheiro C. How plants cope with water stress in the field. Photosynthesis and growth. Ann Bot. 2002;89(7):907–16.

56. Costello A, Abbas M, Allen A, Ball S, Bell S, Bellamy R, Friel S, Groce N, Johnson A, Kett M, et al. Managing the health effects of climate change. Lancet and University College London Institute for Global Health Commission. Lancet. 2009;373(9676):1693–733.

57. Immerzeel WW, Van Beek LPH, Bierkens MFP. Climate change will affect the Asian water towers. Science. 2010;328(5984):1382–5.

58. Lobell DB, Burke MB, Tebaldi C, Mastrandrea MD, Falcon WP, Naylor RL. Climate trends and global crop yields: a meta-analysis. Proc Natl Acad Sci USA. 2007;104(50):19703–8.

59. Wheeler T, Von Braun J. Climate change impacts on global food security. Environ Sci Policy. 2005;10(4):37–46.

60. Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. Nature. 2004;438(7066):310–7.

61. Schmidhuber J, Tubiello FN. Global food security under climate change. Proc Natl Acad Sci USA. 2007;104(50):19703–8.

62. Schmidhuber J, Tubiello FN. Global food security under climate change. Proc Natl Acad Sci USA. 2007;104(50):19703–8.

63. Wheeler T, Von Braun J. Climate change impacts on global food security. Environ Sci Policy. 2005;10(4):37–46.

64. Vermeulen SJ, Ajayi O, Angelsen A, Campbell BM, Chalimour DJ, Hansen JW, Ingram J, Jarvis A, Kristjanson P. Options for support to agriculture and food security under climate change. Environ Sci Policy. 2012;15(1):136–44.

65. World Meteorological Organization. Report of the international conference on the assessment of the role of carbon dioxide and of other greenhouse gases in climate variations and associated impacts. Austria: Villach; 1985.

66. Dodds F. Earth Summit 2002: a new deal. London: Routledge; 2014.

67. Breidenich C, Magraw D, Rowley A, Rubin JW. The Kyoto protocol to the United Nations framework convention on climate change. Am J Int Law. 1998;92(2):315–31.

68. Shakhor U, Saboor A, Ali I, Mohsin A. Impact of climate change on agriculture: empirical evidence from arid region. Pak J Agric Sci. 2011;48(4):327–33.

69. Mendelsohn R. The impact of climate change on agriculture in Asia. J Integr Agric. 2014;13(4):660–5.

70. Duxbury JM. The significance of agricultural sources of greenhouse gases. Fertil Res. 1994;38(2):151–63.

71. Eitzinger J, Utset A, Trinka M. Adaptation of methods and technologies in agriculture under climate change conditions. In: International climate protection. Berlin: Springer; 2019. p. 73–82.

72. Knox J, Hess T, Daccache A, Wheeler T. Climate change impacts on crop productivity in Africa and South Asia. Environ Res Lett. 2012;7(3):034032.

73. The Kyoto protocol to the United Nations framework convention on climate change. Am J Int Law. 1998;92(2):315–31.

74. Asfaw S, Di Battista F, Lipper L. Agricultural technology adoption under climate change in the Sahel: Micro-evidence from Niger. J Afr Econ. 2016;25(5):637–69.

75. Lin E, Jiang K, Hu X, Zuo J, Li M, Ju H. Climate change mitigation and adaptation: technology and policy options. In: Climate and environmental change in China: 1951–2012. Berlin: Springer; 2016. p. 107–27.

76. Yingchun H, Jing D. “China Climate Change Blue Book”: annual average temperature rises significantly. https://env.people.com.cn/n1/2018/0403/c1010-29905684.html. Accessed 29 June 2020.

77. Zhang J. Mitigating climate threat to China’s food security. https://www.chinadaily.com.cn/opinion/2017-07/28/content_30275360.htm. Accessed 29 June 2020.

78. Chakrabarty M. Climate Change and Food Security in India. New Delhi: Observer Research Foundation (ORF); 2016.

79. Goldin T. India’s drought below ground. Nat Geosci. 2016;9(2):98–98.

80. Rana M, Guleria V. Water scarcity in India: a threat to sustainable management of water. ESSENCE Int J Env Rehab Conserv. 2018;IX(1):35–44.

81. Tahamtan I, Afshar AS, Ahammadzadeh K. Factors affecting number of consumers’ decision-making process: a systematic review and meta-analysis. Econ. 2019;70(3):595–617.

82. Saravanan G, Rajan VR, Prasad S, Muthusankar G. Climate change research for climate change adaptation research. Reg Environ Change. 2015;15(5):755–69.

83. Stanhill G. The growth of climate change science: a scientometric study. Lib Philos Pract. 2014;0_1.

84. Dias C, Mendes L. Protected designation of origin (PDO), protected geographical indication (PGI) and traditional speciality guaranteed (TSG): a bibliometric analysis. Food Res Int. 2020;131:108995.