Theoretical and Applied Climatology (2022) 150:347–362
https://doi.org/10.1007/s00704-022-04169-3

ORIGINAL PAPER

Bibliometric analysis of rice and climate change publications based on Web of Science

Bao-Zhong Yuan[1] · **Jie Sun**[2]

Received: 12 August 2021 / Accepted: 3 August 2022 / Published online: 10 August 2022

Abstract

To clarify the current situation, hotspots, and development trends in the field of rice and climate change topic research, a massive literature dataset were analyzed from the Web of Science database by bibliometric method. The research theme was chosen given the continuous increase of studies related to climatic changes and their consequences to rice. Based on the Web of Science core database, this study analyzed 4170 papers in the field of rice and climate change topic research from 1990 to July 2022, which include 86 highly cited papers and 3 hot papers. Papers were mainly written in English (4157, 99.688%), from 16,363 authors, 4017 organizations, and 129 countries/territories, published in 841 journals and seven book series. The top five Journals are *Science of the Total Environment* (136, 3.261%), *Sustainability* (89, 2.134%), *Agronomy Basel* (81, 1.942%), *Agricultural and Forest Meteorology* (77, 1.847%), and *Climatic Change* (74, 1.775%), each published more than 74 papers. Top five countries and regions of People's Republic of China, the USA, India, Australia, and Japan were the major article contributors, each published more than 360 papers. Top five organizations of Chinese Acad Sci, Nanjing Agr Univ, Univ Chinese Acad Sci, Chinese Acad Agr Sci, and Int Rice Res Inst (IRRI) were popular based on contribution of articles more than 133 papers each. Among the all authors, top five authors were Tao Fulu, Pan Genxing, Zhang Zhao, Hasegawa Toshihiro, and Iizumi Toshichika, each published more than thirty papers. All keywords were separated into eight clusters for different research topics. Visualizations offer exploratory information on the current state in a scientific field or discipline as well as indicate possible developments in the future. The results will help researchers clarify the current situation in rice and climate change adaptation science but also provide guidance for future research. This work is also useful for student identifying graduate schools and researchers selecting journals.

1 Introduction

In recent years, climate change has had a more significant impact on earth's ecosystem and its human socio-economic system. In response to climate change, countries all over the world have enacted various policy measures to reduce greenhouse gas emissions to reduce the further rise in global average temperatures and reduce the risks and losses of climate change. Climate change adversely impacts our agriculture and will force agricultural production to adapt to the altered environmental conditions. Increase in climatic variations and extreme weather events in the recent past have exerted significant effect on crop productivity over different regions on earth. The consequences of climate change are drastically impacting field crop production; it is an immense prerequisite to attribute resilience through crop improvement. Rice (*Oryza sativa* L.) is the staple food for half the world's population. Climate change has been an increasingly significant factor behind fluctuations in the yield and quality of rice (Murphy et al. 2013; Morita et al. 2016; Zafar et al. 2018; Kingra et al. 2019; Schneider and Asch, 2020; Senguttuvel et al. 2020). In the recent years, increased interests in climate change research by scholars have been witnessed. These interests are accompanied by spectacular rise in the amount of scientific output in this topic of research.

Bibliometric analysis, as an important quantitative analysis tool, can effectively describe the overall trend of the development of a subject or field, and it has been widely used in various fields. In recent years, the bibliometric method is more and more frequently used in climate change

✉ Bao-Zhong Yuan
yuanbz@mail.hzau.edu.cn; yuanbzsj@163.com

[1] College of Plant Science and Technology, Huazhong Agricultural University, Wuhan City, Hubei Province, People's Republic of China 430070

[2] Library of Huazhong Agricultural University, Wuhan City, Hubei Province, People's Republic of China 430070

research. Li et al. (2011) used it to evaluate the academic output, trends, features, and research methods in climate change literature from 1992 to 2009 and proposed a key innovative clustering analysis method. Wang et al. (2014) explored the development trend of the literature in the cognate area of climate change vulnerability through quantitative analysis, pointing out that health problems in the socio-economic system, food safety problems in agriculture, and water resources management problem were the most frequently discussed in the field of vulnerability research at present. Based on Science Citation Index—Expanded (SCI–E) and Social Science Citation Index (SSCI) database, Wei et al. (2015) reviewed research hotspots and model methods used in the field of climate policy modelling with a bibliometric method. A bibliometric analysis of climate change adaptation was completed based on massive research literature data (Wang et al. 2018). There are others bibliometric analysis publications, such as peer-reviewed literature on climate change and human health with an emphasis on infectious diseases (Sweileh 2020), scientific production on coastal communities' social vulnerability to climate change (Lima & Bonetti, 2020), bioenergy research under climate change (Zhang et al. 2021), carbon capture technologies for climate change mitigation (Omoregbe et al. 2020), climate change and carbon sink (Huang et al. 2020), disaster and climate change resilience (Rana, 2020), soil and water conservation in the Loess Tableland-Gully Region of China (Wang et al. 2019), advances in water use efficiency in agriculture, and sustainable water use in agriculture (Velasco-Muñoz et al. 2018a, 2018b).

Bibliometric analysis technique has been adopted related with agronomy or crop research such as perennial staple crops (Kane et al. 2016), Japanese rice (Morooka et al. 2014), rice physiology and management in China (Peng, 2017), global rice research during 1985–2014 (Liu et al. 2017), genetically modified maize (Santillán-Fernández et al. 2021), transgenic maize (Li et al. 2018), fiber crops (Bartol and Mackiewicz-Talarczyk, 2015), climate change in agriculture (Aleixandre-Benavent et al. 2017), plant defense against biotic stresses as improvement for sustainable agriculture (Gimenez et al. 2018), soil nutrient research between 1992 and 2020 (Pan et al. 2021), planthopper (Hu and Cao, 2018), etc. Sun and Yuan have analyzed rice with fertilizer based on Citespace (Sun and Yuan, 2019), rice with irrigation (Sun and Yuan, 2020a), the top papers in world rice research (Sun and Yuan, 2020b), Library and Information Science (Sun and Yuan, 2020c), water Resources (Sun and Yuan, 2020d), Agronomy category (Sun and Yuan, 2021), green and sustainable science and technology (Yuan and Sun, 2019), scientific research on maize or corn (Yuan and Sun, 2020a, 2020b), muskmelon (Yuan et al. 2021), strawberry (*Fragaria* × *ananassa* Duch.) research publications from Horticulture category (Yuan and Sun, 2021a), and cotton research from Plant Sciences category based on Web of Science (Yuan and Sun, 2021b). However, no bibliometric research papers were published on climate change and rice topic research.

The purpose of this paper was to use bibliometric methods to analyze the publications of rice and "climate change" topic research through publication year, category, author, affiliations, country, journals, all keywords and other key features, according to the Clarivate Analytics Web of Science (WoS) core database. Co-authorship network visualization of author, organizations and countries, and co-occurrence network visualization of all keywords were done by VOSviewer.

2 Materials and methods

2.1 Web of science

Clarivate Analytics WoS is the world's leading scientific citation search and analytical information platform, and one of the world's largest and most comprehensive academic information resources covering more than 12,000 core academic journals. The publication counts from the WoS Core Collection were derived from the following databases: The Science Citation Index—Expanded (SCIE), 1900–present; Social Science Citation Index (SSCI), 1900–present; Conference Proceeding Citation Index-Science (CPCI-S), 2015–present; Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SSH), 2015–present; Current Chemical Reactions (CCR-EXPANDED), 1985–present; and Index Chemicus (IC), 1993–present.

2.2 Data collection

This study surveyed papers in WoS Core Collection (1900–present), and the data collection was completed on the single day on July 9, 2022, to avoid the bias. We used the keywords as "rice" and "climate change" in the topic (TS). The query as following: TS= "rice" and "climate change."

Then, the results were refined by document types of Article or Review article. So, there are 4170 papers on "rice" and "climate change" topic research from WoS core collection. The records were downloaded and saved as plain text format by selecting the export format "full records and cited references," and then imported into VOSviewer (version 1.6.18, 2022, Leiden University, Leiden, Netherlands) for further citation analysis. The impact factors (IF 2021 and IF 5 year) were taken from the Journal Citation Report (JCR 2021) published in June 2022, which had the latest data available (Clarivate, Journal Citation Reports ™ 2021, 2022a). The Journal Citation Reports™ includes journals from the SCIE and SSCI.

2.3 VOSviewer

Visualizations (network and overlay) using program VOSviewer are conducted on WoS data in order to determine co-occurrence and clusters of connected publications, country input and author collaboration (co-authorship), as well as clusters of interrelated research topics (text data). VOSviewer (1.6.18 version, 2022) is a free bibliometric visualizer with an intuitive and user-friendly interface. It was chosen because it can work with large sets of data and offer a range of analysis and investigation options, creating intuitive images that aid in evaluating data (Van Eck and Waltman, 2010). In this work, we used VOSviewer to show the international collaboration between the authors, organizations, countries, and the research trends through all keywords. VOSviewer (version 1.6.18; van Eck and Waltman, 2022) were used to conduct bibliometric analysis, network analysis, and cluster analysis. In this paper, default parameter values of the VOSviewer are usually used in the analysis. Items are represented by a label and a circle. The size of circles reflects the weight of an item. Some items are not displayed in avoidance of overlapping. The colors in network visualization (text maps) represent clusters of similar items as calculated by the program. Distance between the items indicates the strength of relationships.

3 Results and discussion

3.1 Document type and language of publication

Based on Clarivate Analytics WoS Index, there were a total of 4170 papers of the "rice" and "climate change" topic research during 1990–2022. All the publications were identified in SCIE (3958, 94.916%), SSCI (815, 19.544%), CPCI-S (75, 1.799%), Arts and Humanities Citation Index (26, 0.624%), Book Citation Index–Science (23, 0.552%), and CPCI-SSH (3, 0.072%). The document types of all papers were articles (3726, 89.353%) and reviews (444, 10.647%), and also including proceedings papers (78, 1.871%), early access (57, 1.367%), book chapter (23, 0.552%), and data paper (7, 0.168%).

Among the 4170 papers, there are 88 top papers of 86 highly cited papers and 3 hot papers based on Clarivate Analytics Essential Science Indicators (ESI) database covering over a 10-year 2-month period: January 1, 2012–February 28, 2022 (Clarivate, 2022a, b. Essential Science Indicators Help). All of the papers were almost published in English (4157, 99.688%), and then others were Portuguese (4, 0.096%), Spanish (4, 0.096%), French (3, 0.072%), German (1, 0.024%), and Japanese (1, 0.024%). The English was dominating language from the WoS, and scholars tend to publish their articles in English as they want them to be widely accepted. Moreover, most of the published documents were in the form of original research articles written in English language (Khan, et al. 2020).

3.2 Publication output

The number of published academic papers is an important indicator to measure the development trend of certain scientific research. Figure 1 shows the publications of "rice" and "climate change" topic research between 1990 and 2022. The highest publication value was 671 in 2021. In general, the quantity of rice and climate change topic research publications presents a fast growth tendency after 2008. There are 62, 213, 2322, and 1573 papers during the period of 1990–1999, 2000–2009, 2010–2019, and 2020–2022,

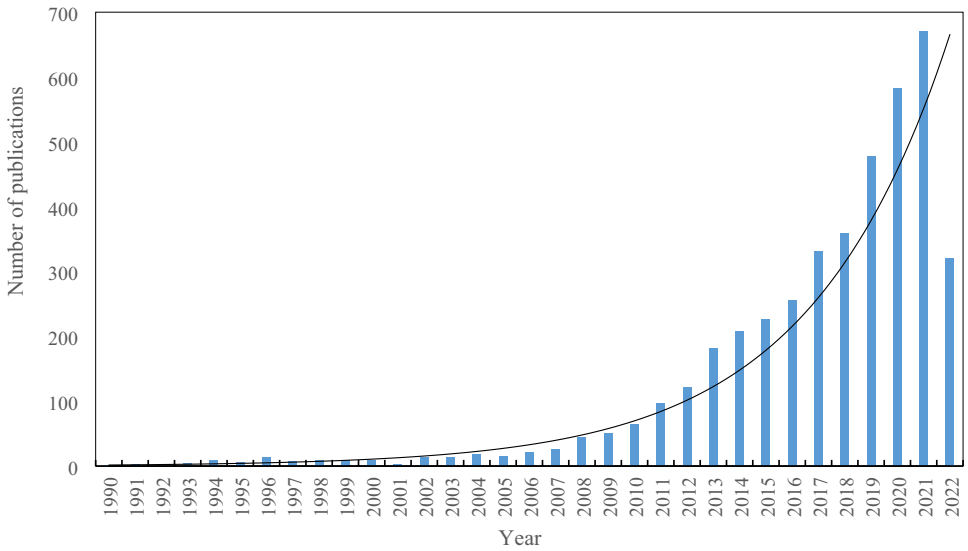

Fig. 1 Trends in the quantity of published papers of rice and climate change research from 1990 to 2022

respectively. These trends reflect the increasing attention devoted to this area during the past decade. Publications were exponential growth during period from 1990 to 2022 (R^2=0.948).

The number of citations to a paper is considered a good quantitative measure of a paper's impact. The quality of publications was measured by the number of citations and *h*-index. The *h*-index was initially proposed as a measure of a researcher's scientific output based on counting the number of publications (N) by that researcher cited N or more times (Hirsch, 2005). For the total 4170 papers, the *h*-index is 139, the total number of citations was 117,016 over the period, and the average citation per item is 28.06. Based on WoS core database, the first paper on the rice and climate change topic titled of "Potential rice yields in future weather conditions in different parts of Asia" written by Jansen DM was published in 1990 in the *Netherlands Journal of Agricultural Science* (38(4):661-680).

3.3 Web of Science categories and research areas

There are total 117 WoS subject categories and 79 research areas for rice and climate change topic research. Table 1 showed the top 20 WoS categories and research areas for rice and climate change topic research during 1990-2022. Among these, the top five categories include Environmental Sciences (1335 papers, 32.014% of 4170 papers), Agronomy (703, 16.859%), Meteorology Atmospheric Sciences (548, 13.141%), Plant Sciences (538, 12.902%), and Agriculture Multidisciplinary (341, 8.177%). The top five research areas include Environmental Sciences Ecology (1582 papers, 37.938% of 4170 papers), Agriculture (1261, 30.24%), Meteorology Atmospheric Sciences (548, 13.141%), Plant Sciences (538, 12.902%), and Science Technology Other Topics (481, 11.535%). Journals or papers may be classified into two or more categories in the WoS, showing the multidisciplinary character of this research field (Elango & Ho, 2018). Documents are also mapped to one or several research areas in WoS. In WoS, publications are mapped to WoS categories which are more detailed than research areas (Stopar et al. 2021).

3.4 Core journals

All the 4170 publications were published in 841 journals and seven book series. The seven book series titles are Advances in Agronomy (18), Annual Review of Phytopathology (2), Advances in Biochemical Engineering Biotechnology (1), Advances in Ecological Research (1), Advances in Parasitology (1), Biotechnology Genetic Engineering Reviews (1), and World Review of Nutrition and Dietetics (1). The top 20 core journals were displayed in the Table 2 with total articles

Table 1 Top 20 WoS categories and research areas for rice and climate change topic research after 1990

Rank	WoS categories			Research areas		
	Categories	No. papers	% total papers	Areas	No. papers	% total papers
1	Environmental Sciences	1,335	32.014	Environmental Sciences Ecology	1,582	37.938
2	Agronomy	703	16.859	Agriculture	1,261	30.24
3	Meteorology Atmospheric Sciences	548	13.141	Meteorology Atmospheric Sciences	548	13.141
4	Plant Sciences	538	12.902	Plant Sciences	538	12.902
5	Agriculture Multidisciplinary	341	8.177	Science Technology Other Topics	481	11.535
6	Environmental Studies	324	7.77	Water Resources	291	6.978
7	Ecology	294	7.05	Geology	261	6.259
8	Water Resources	291	6.978	Engineering	224	5.372
9	Geosciences Multidisciplinary	257	6.163	Food Science Technology	130	3.118
10	Green Sustainable Science Technology	243	5.827	Biodiversity Conservation	114	2.734
11	Multidisciplinary Sciences	237	5.683	Business Economics	114	2.734
12	Soil Science	190	4.556	Forestry	81	1.942
13	Engineering Environmental	139	3.333	Energy Fuels	76	1.823
14	Food Science Technology	130	3.118	Physical Geography	75	1.799
15	Biodiversity Conservation	114	2.734	Remote Sensing	75	1.799
16	Economics	112	2.686	Biochemistry Molecular Biology	69	1.655
17	Forestry	81	1.942	Chemistry	67	1.607
18	Energy Fuels	76	1.823	Biotechnology Applied Microbiology	62	1.487
19	Geography Physical	75	1.799	Imaging Science Photographic Technology	58	1.391
20	Remote Sensing	75	1.799	Genetics Heredity	51	1.223

Table 2 Top 20 core Journals on rice and climate change topic research indexed in the WoS from 1990

Rank	Journal	TP	Ratio	IF 2021	IF 5year	QC	Citations	Avg. citations
1	*Science of the Total Environment*	136	3.261	10.753	10.237	Q1	2,754	20.3
2	*Sustainability*	89	2.134	3.889	4.089	Q2	696	7.8
3	*Agronomy Basel*	81	1.942	3.949	4.117	Q1	378	4.7
4	*Agricultural and Forest Meteorology*	77	1.847	6.424	7.021	Q1	3,958	51.4
5	*Climatic Change*	74	1.775	5.174	6.058	Q1	4,143	56.0
6	*Frontiers in Plant Science*	70	1.679	6.627	7.255	Q1	1,759	25.1
7	*Global Change Biology*	70	1.679	13.211	13.111	Q1	5,782	82.6
8	*Agriculture Ecosystems Environment*	66	1.583	6.576	7.088	Q1	3,095	46.9
9	*Field Crops Research*	64	1.535	6.145	7.234	Q1	2,582	40.3
10	*Journal of Cleaner Production*	62	1.487	11.072	11.016	Q1	1,473	23.8
11	*Agricultural Water Management*	58	1.391	6.611	6.574	Q1	1,367	23.6
12	*Environmental Science and Pollution Research*	57	1.367	5.19	5.053	Q2	535	9.4
13	*Scientific Reports*	54	1.295	4.996	5.516	Q2	1,010	18.7
14	*Environmental Research Letters*	53	1.271	6.947	8.414	Q1	1,899	35.8
15	*PloS One*	53	1.271	3.752	4.069	Q2	1,528	28.8
16	*Agricultural Systems*	49	1.175	6.765	7.131	Q1	1,779	36.3
17	*Paddy and Water Environment*	47	1.127	1.554	1.924	Q3	486	10.3
18	*European Journal of Agronomy*	43	1.031	5.722	6.384	Q1	1,798	41.8
19	*Theoretical and Applied Climatology*	40	0.959	3.409	3.518	Q3	359	9.0
20	*Remote Sensing*	33	0.791	5.349	5.786	Q1	410	12.4

Note: *TP* total publications; *Ratio* ratio of 4170 (%); *IF 2021* journal impact factor in 2021; *IF5 year* journal impact factor of 5 years; *QC* quartile in category

each more than 33 papers, Journal impact factor as IF 2021 and IF 5 year, Quartile rank in Category, total citations, and average citations per paper.

The top 5 journals, top 10 journals, top 15 journals, and top 20 journals published about 10.959%, 18.922% 25.517%, and 30.600% of the total papers, respectively. The top five Journals are *Science of the Total Environment* (136, 3.261%), *Sustainability* (89, 2.134%), *Agronomy Basel* (81, 1.942%), *Agricultural and Forest Meteorology* (77, 1.847%), and *Climatic Change* (74, 1.775%), each published more than 74 papers. Based on results of Table 2, among top 20 journals, fourteen journals were in Quartile 1, four journals were in Quartile 2, and two journals were in Quartile 3. White-Gibson et al (2019) have also demonstrated the importance of publishing articles in the English language in a high IF journals. Journals in the Q1 rank are considered to have the highest impact. Based on the average citations per papers, the journals with more than 40 times were *Global Change Biology, Climatic Change, Agricultural and Forest Meteorology, Agriculture Ecosystems Environment, European Journal of Agronomy*, and *Field Crops Research*.

Journal co-citation analysis refers to the phenomenon that occurs when two journals are cited by the same document. Co-citation of journals reflects correlations between various journals and disciplines. The intellectual base of a research field can also be obtained through journal citation analysis. According to the publication data in the citation of 841 journals, there were 186 journals that met the thresholds of five publications, of which 186 journals were connected to each other. The network of citation in the field of rice and climate change topic research based on WoS has shown twelve clusters with different colors in Figure 2; the size of circles reflects a total number of journal publication records. Journals in the same color cluster usually suggested that they published the similar content papers and had close relations with each other. The first cluster (red) had thirty-eight journals and centered as *Sustainability and Climatic Change*, the second cluster (green) had thirty-five journals and centered as *Frontiers in Plant Science* and *PloS One*, the third cluster (blue) had thirty-three journals and centered as *Science of the Total Environment* and *Global Change Biology*, the fourth cluster (yellow) had twenty journals and centered as *Journal of Cleaner Production* and *Agricultural Water Management*, the fifth cluster (violet) had fifteen journals and centered as *Agricultural and Forest Meteorology* and *European Journal of Agronomy*, the sixth cluster (light blue) had thirteen journals and centered as *Environmental Research Letters*, the seventh cluster (orange) had thirteen journals and centered as *Remote Sensing*, the eighth cluster (brown) had seven journals and centered as *Field Crops Research*, the ninth cluster (pink) had six journals and centered as *Agronomy-Basel*, the tenth cluster had only three journal

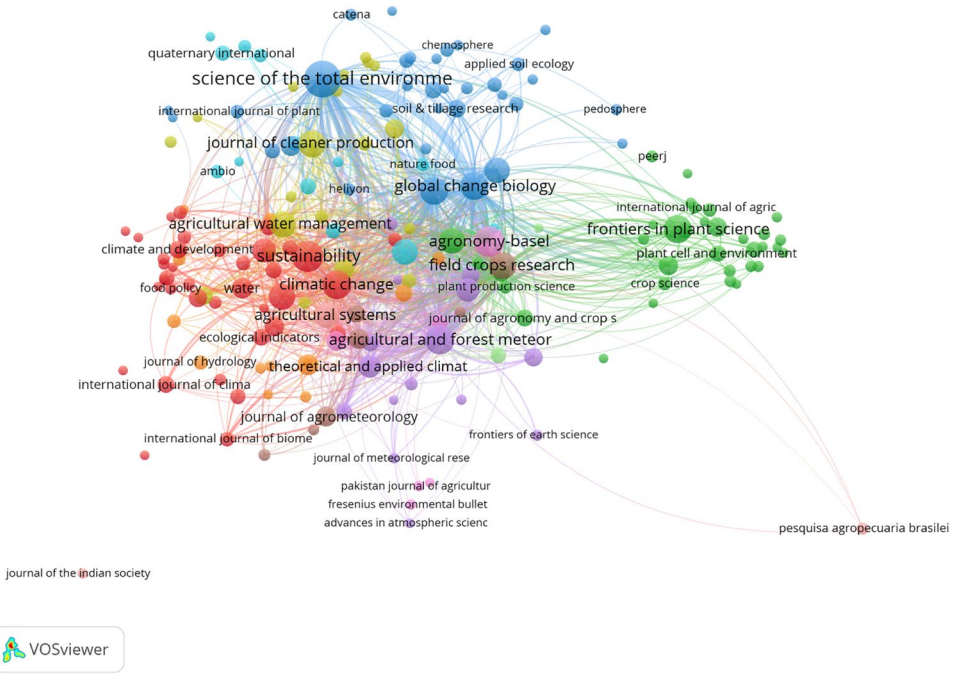

Fig. 2 Network visualization maps of citation journals with minimum of 5 publications in the field of rice and climate change topic research based on WoS with 186 circles and 12 clusters from 1990 to 2022

and centered as *Agricultural Systems*, the eleventh cluster had two journals both *Journal of the Science of Food and Agriculture* and *Global and Planetary Change*, and centered as *Agronomy-Basel*, and the twelfth cluster had only one journal of *Biomass Conversion and Biorefinery.*

3.5 Authors co-authorship analysis

Authors and their social relationships are the core elements of a research field, as well as an important embodiment of the research power of the field. Those researchers with high academic productivity usually dominate the development tendencies of research field. A total of 16,363 authors have 4170 publications, and among these, 409 authors met the thresholds of five publications, but only 354 authors were connected with each other. The network map has a large number of participants as well as a wide range of collaborations. The network map of authorship in the field of rice and climate change topic research based on WoS represented in Figure 3, the size of circles reflects a total number of records. Authors in the same cluster usually suggested that they studied in a similar field or worked at same institute or had close cooperation with each other.

Table 3 provides the top twenty-one author information published articles in the field of rice and climate change topic research from 1990 to 2022 along with citation, average citations, organization-enhanced and countries, and published more than eighteen papers. Among the all authors, top five authors were Tao Fulu, Pan Genxing, Zhang Zhao, Hasegawa Toshihiro, and Iizumi Toshichika, each published more than thirty papers.

The organization of the author is the latest institute based on the latest publications. Among the twenty-one authors, there were thirteen authors from China, the organizations were Chinese Acad Sci, Nanjing Agr Univ, Beijing Normal Univ, and Chinese Acad Agr Sci; three authors are from DNDC Applicat Res & Training, Ohio State Univ, and Univ Florida of USA; two authors are from Natl Agr & Food Res Org NARO of Japan; one author is from Int Maize & Wheat Improvement Ctr CIMMYT of India; one author is from Univ Aberdeen of Scotland; one author is from Leibniz Assoc, Potsdam Inst Climate Impact Res PIK of Germany. The five authors with the higher average citations per paper were Smith Pete, Mueller Christoph, Pan Genxing, Li Tao, and Zhu Yan, and the average citations per paper was more than 60.20 times.

3.6 Countries/regions co-authorship analysis

There were 129 countries or regions that contributed 4170 papers in the field of rice and climate change topic research from 1990 to 2022. Table 4 represents the list of the top 20 countries or regions that published more than 70 papers, and also shows the cluster, total link strength, citations, and average citations. Among the top 20 countries or regions, People's Republic of China, the USA, India, Australia, and Japan were the five major article contributors, each published more than 360 papers. In case of average citations, Canada, the USA, the Philippines, Germany, and the Netherlands showed the higher citations per paper more than 47.5 times. The strength of international research collaboration was presented as Total Link Strength (TLS) which is

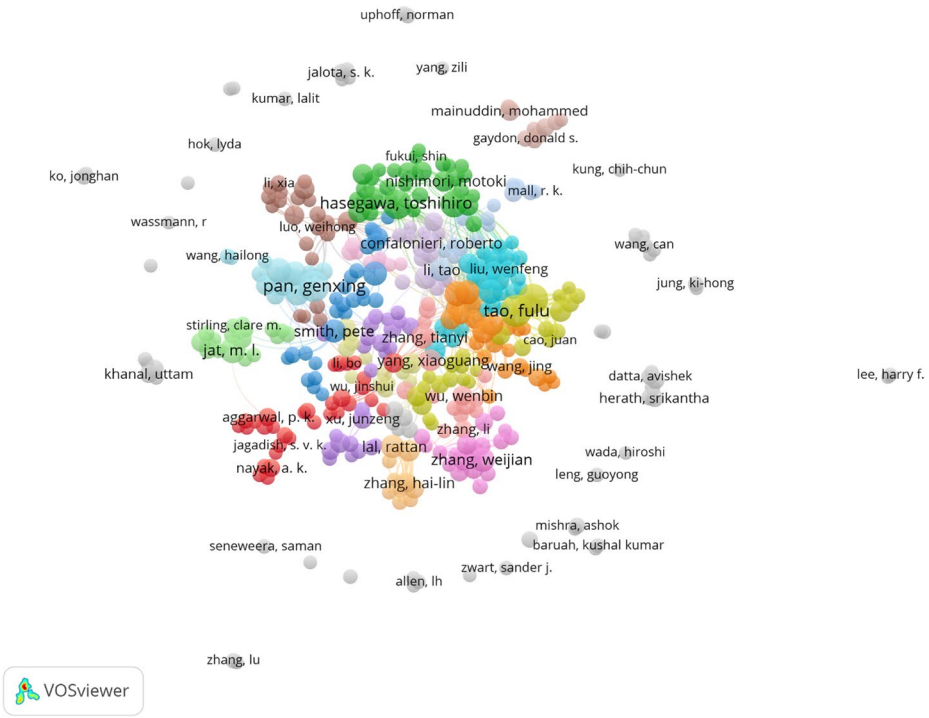

Fig. 3 Network visualization map of top authors in rice and climate change topic research from 1990 to 2022. Network visualization map of authors with minimum productivity of five publications in the studied field and exist within a collaborative research group

Table 3 The top 21 most prolific authors published papers in the field of rice and climate change topic research from 1990 to 2022

Rank	Author	Papers	Citations	Average citations	Organizations	Country
1	Tao, Fulu	49	2,650	54.08	Chinese Acad Sci	China
2	Pan, Genxing	43	3,680	85.58	Nanjing Agr Univ	China
3	Zhang, Zhao	41	2,274	55.46	Beijing Normal Univ	China
4	Hasegawa, Toshihiro	39	958	24.56	Natl Agr & Food Res Org NARO	Japan
5	Iizumi, Toshichika	30	1,221	40.70	Natl Agr & Food Res Org NARO	Japan
6	Jat, M. L.	28	785	28.04	Int Maize & Wheat Improvement Ctr CIMMYT	India
7	Li, Lianqing	25	1,398	55.92	Nanjing Agr Univ	China
8	Zhu, Yan	25	1,505	60.20	Nanjing Agr Univ	China
9	Tang, Liang	23	754	32.78	Nanjing Agr Univ	China
10	Zhang, Weijian	23	751	32.65	Chinese Acad Agr Sci	China
11	Liu, Xiaoyu	22	776	35.27	Nanjing Agr Univ	China
12	Mueller, Christoph	22	2,353	106.95	Leibniz Assoc, Potsdam Inst Climate Impact Res PIK	Germany
13	Zhang, Xuhui	22	1,006	45.73	Nanjing Agr Univ	China
14	Zhu, Jianguo	22	400	18.18	Chinese Acad Sci	China
15	Smith, Pete	21	2,454	116.86	Univ Aberdeen	Scotland
16	Lal, Rattan	20	723	36.15	Ohio State Univ	USA
17	Li, Tao	20	1,268	63.40	DNDC Applicat Res & Training	USA
18	Zhang, Tianyi	20	577	28.85	Chinese Acad Sci	China
19	Liu, Leilei	19	473	24.89	Nanjing Agr Univ	China
20	Cao, Weixing	18	411	22.83	Nanjing Agr Univ	China
21	Hoogenboom, Gerrit	18	704	39.11	Univ Florida	USA

automatically given by VOSviewer upon mapping research activity of selected countries. The TLS is proportional to the extent of international research collaboration where higher TLS value indicates greater collaboration.

We developed the co-authorship network map using VOSviewer (Figure 4). There are 76 countries or regions that met the requirement threshold as five. The size of circles in Figure 4 reflects a total number of records and the distance

Table 4 Top 20 countries or regions published papers in the field of rice and climate change topic research from 1990 to 2022

Rank	Countries/regions	Records	Cluster	Total link strength	Citations	Average citations
1	Peoples R China	1347	3	1,217	35,131	26.1
2	USA	897	6	1,390	45,681	50.9
3	India	640	2	548	15,479	24.2
4	Australia	383	4	748	14,949	39.0
5	Japan	360	4	379	9,197	25.5
6	England	298	1	673	12,827	43.0
7	Germany	270	5	703	12,844	47.6
8	Philippines	193	5	410	9,214	47.7
9	Bangladesh	180	4	307	2,805	15.6
10	South Korea	163	3	150	2,355	14.4
11	Netherlands	152	4	367	7,217	47.5
12	Italy	146	1	309	5,379	36.8
13	Pakistan	139	3	195	3,195	23.0
14	France	135	2	414	5,176	38.3
15	Vietnam	129	4	200	2,144	16.6
16	Canada	124	5	248	8,579	69.2
17	Thailand	113	4	195	3,313	29.3
18	Spain	96	1	218	3,903	40.7
19	Brazil	70	1	147	1,097	15.7
20	Malaysia	70	4	91	1,158	16.5

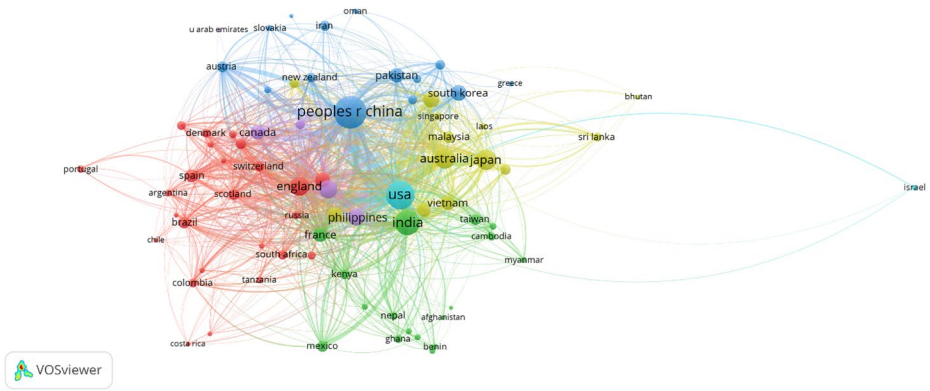

Fig 4 The country co-authorship network of rice and climate change research related publications from 1990 to 2022. The country co-authorship network map with 76 circles and 6 clusters; the bigger circles represented the more influential countries in this field. The distance and thickness of links represented the degree of cooperation among countries. Clusters are shown by different colors

between the countries indicate the strength of relationships. The VOSviewer divided these circles into six clusters. The different color groups represent the different clusters formed by sets of countries. Distance between the countries indicates the strength of relationships. Importance of countries/regions is represented by their centrality in the network. Bigger circles represent more publications by a country. Thicker lines indicate more and closer cooperation between countries

According to the number of publications from high to low among each cluster in Figure 4, the first cluster (red color) consisted of twenty-five countries or regions including England, Spain, Italy, Brazil, Scotland, Sweden, Switzerland, South Africa, Colombia, Denmark, Norway, Nigeria, Portugal, Ireland, Russia, Tanzania, Argentina, Poland, Hungary, Uganda, Peru, Costa Rica, Morocco, Uruguay, and Chile. The second cluster (green) consisted of seventeen countries or regions including France, India, Taiwan, Mexico, Kenya, Nepal, Cambodia, Ghana, Wales, Benin, Ethiopia, Cote d'Ivoire, Senegal, Myanmar, Madagascar, Afghanistan, and Mali. The third cluster (blue) consisted of fourteen countries including People's Republic of China, Pakistan, South Korea, Austria, Iran, New Zealand, Saudi Arabia, Egypt, Turkey, Czech Republic, Slovakia, Oman, Greece, and North Ireland. The fourth cluster (yellow) consisted of thirteen countries and regions including the Netherlands, Australia, Thailand, Japan, Vietnam, Malaysia, Bangladesh, Indonesia, Finland, Sri Lanka, Singapore, Laos, and Bhutan. The fifth cluster (violet) consisted of five countries and regions

including Canada, the Philippines, Germany, Belgium, and United Arab Emirates. The sixth cluster (shallow blue) is including two countries of the USA and Israel. Taiwan, as a region of China, shows the stronger research ability in the field of rice and climate change topic research. More cooperation could bring more advanced achievements in scientific research. Nowadays, increasing concept of international exchanges have promoted academic communications (Tang et al. 2018).

Comparison of the growth trends of the top five countries is displayed in Figure 5. China, the first on the list ranked by total papers, has published 1347 (32.3%) articles with the fastest growing trend after 2012 year. This could be due to a series of positive policies motivated the rapid development of research in China. China is one of the most attractive countries in terms of scientific performance today. It has experienced a sustained and remarkable increase in scientific production and became the global second largest producer of scientific publications since 2006, particularly taking a world-leading position in special fields (Fu et al. 2011). The past decades have witnessed a rapid rise of China in economic development, with a GDP averaging about a 10% annual growth rate since 2000, and China overtook Japan as the second largest economy in 2010 (Liu et al. 2015). Now, the GDP of China is the second after the USA in the world.

3.7 Organizations co-authorship analysis

The analysis of research institution will give us the information that which organizations stand on the frontier of this research. According to the publication data, it was revealed that a total of 4017 organizations have 4170 publications. Table 5 represents the top 20 organizations and institutions ranked by the number of total publications (more than 43 papers), the total link strength, citations, average citations, and country. These 21 organizations were mainly based in China (ten organizations), the USA (three organizations), Japan (three organizations), the Philippines (one organization), Mexico (one organization), Australia (one organization), the Netherlands (one organization), and India (one organization). Furthermore, top five organizations of Chinese Acad Sci, Nanjing Agr Univ, Univ Chinese Acad Sci, Chinese Acad Agr Sci, and Int Rice Res Inst (IRRI) were popular based on contribution of articles more than 133 papers each. Similarly in case of citation, the top five organizations of Univ Calif Davis, Natl Inst Agroenvironm Sci, Kansas State Univ, Int Rice Res Inst (IRRI), and Wageningen Univ showed the higher average citations more than 55.5 times per paper.

Among the 4017 organizations, there were 497 organizations that met the minimum thresholds of five, and 495 organizations were connected to each other (Figure 6). The VOSviewer software divided these 495 institutes into thirteen clusters with different colors. Geographical localization is an important factor for partnership and joint venture.

3.8 All keywords co-occurrence analysis

For a specific scientific field study, keyword plays a large role as it can reflect the root contents of articles and compilation of keywords can reveal the pattern and trends of specific academic research (Badaluddin et al. 2021). To analyze the co-occurrence of the keywords, author keywords, keywords plus, and all keywords as unit were chosen and analyzed.

For the author keywords by full counting method for co-occurrence analysis, there were a total of 9175 author keywords, and 511 keywords met the threshold level of more than five times and were separated into fourteen clusters in

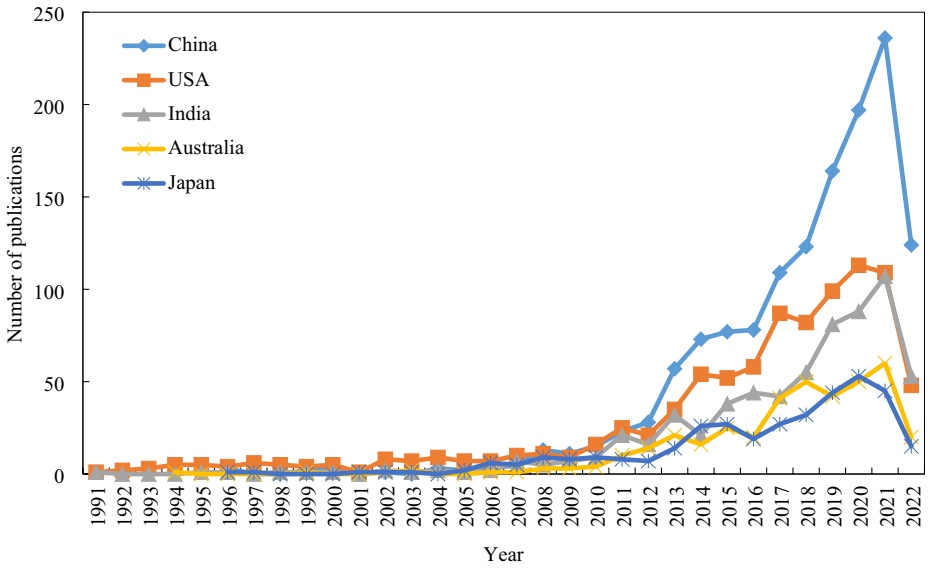

Fig. 5 Comparison the publications growth trends of the top five productive countries during 1991–2022

Table 5 Top 21 organizations publishing papers in the field of rice and climate change topic research from 1990 to 2022

Rank	Organizations	Records	Total link strength	Citations	Average citations	Country
1	Chinese Acad Sci	417	806	13,561	32.5	China
2	Nanjing Agr Univ	164	335	7,553	46.1	China
3	Univ Chinese Acad Sci	160	313	2,486	15.5	China
4	Chinese Acad Agr Sci	140	346	5,189	37.1	China
5	Int Rice Res Inst (IRRI)	133	340	7,793	58.6	Philippines
6	China Agr Univ	107	245	2,125	19.9	China
7	Beijing Normal Univ	98	237	2,749	28.1	China
8	Huazhong Agr Univ	67	117	2,745	41.0	China
9	Univ Florida	66	271	3,135	47.5	USA
10	Nanjing Univ Informat Sci & Technol	63	116	738	11.7	China
11	Natl Agr & Food Res Org (NARO)	57	181	1,246	21.9	Japan
12	Int Maize & Wheat Improvement Ctr Cimmyt (CIMMYT)	54	106	1,991	36.9	Mexico
13	Univ Queensland	53	93	1,240	23.4	Australia
14	Univ Tokyo	52	125	1,630	31.3	Japan
15	Northwest A&F Univ	49	102	524	10.7	China
16	Natl Inst Agroenvironm Sci	48	121	3,122	65.0	Japan
17	Wageningen Univ	47	144	2,608	55.5	Netherlands
18	Indian Agr Res Inst	45	63	1,792	39.8	India
19	Hohai Univ	43	43	666	15.5	China
20	Kansas State Univ	43	107	2,734	63.6	USA
21	Univ Calif Davis	43	86	3,522	81.9	USA

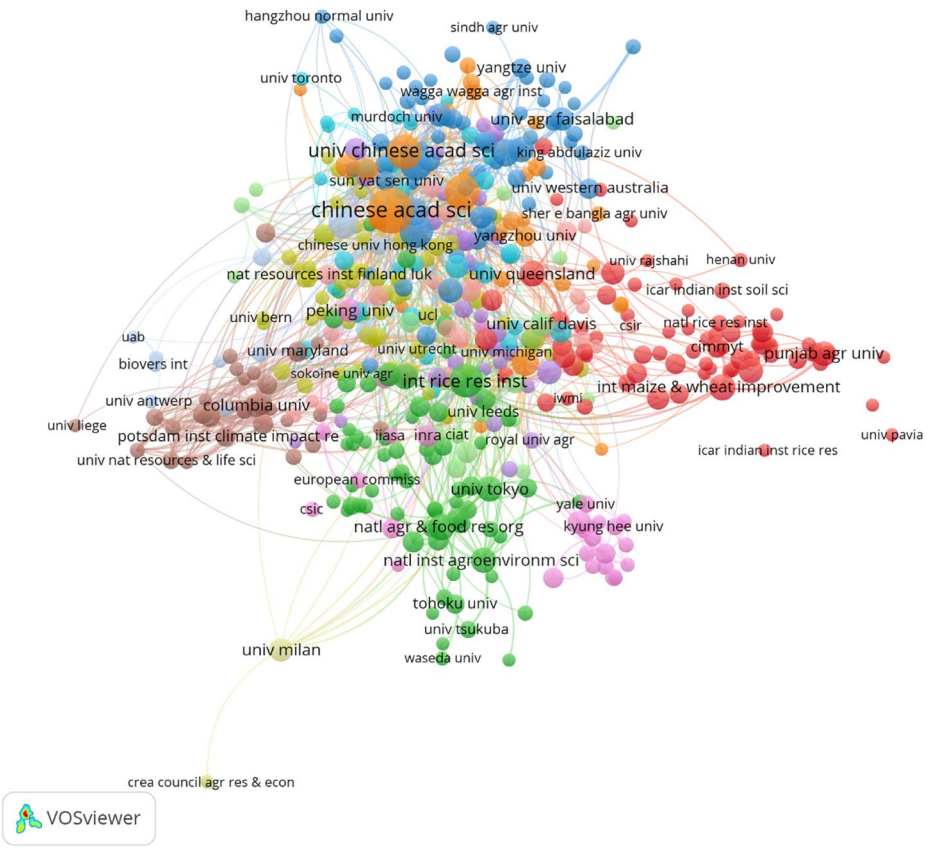

Fig. 6 The organizations co-authorship network map of rice and climate change topic research related publications from 1990 to 2022. The institutions co-authorship network map with 495 nodes and 13 clusters; the bigger nodes represented the more influential institution in this field. The distance and thickness of links represented the degree of cooperation among organizations.

network visualization. The top twenty co-occurrence author keywords were climate change, rice, agriculture, food security, adaptation, China, yield, drought, wheat, global warming, *Oryza Sativa*, irrigation, temperature, Bangladesh, rice production, heat stress, rice yield, methane, biochar, and crop model; each keywords co-occurred more than 58 times.

For the keywords plus by full counting method for co-occurrence analysis, there were a total of 7471 keywords plus, and 1060 keywords met the threshold level of more than five times and were separated into nine clusters in network visualization. The top twenty co-occurrence keywords plus were climate-change, rice, temperature, yield, impacts, growth, management, impact, agriculture, model, responses, variability, wheat, productivity, adaptation, food security, trends, soil, carbon-dioxide, and China; each keywords plus co-occurred more than 177 times.

For the all keywords by full counting method for co-occurrence analysis, there were a total of 15,029 all keywords, and 1494, 1249, 1053, and 920 all keywords met the threshold level of five, six, seven, and eight times. There are eight main clusters for 920; all keywords met the threshold level of eight times in network visualization map (Figure 7). Figure 7 shows the network map that links the all keywords to the entire sample of the articles analyzed. There are eight main clusters that represent different viewpoints on rice and climate change topic research. Each node in the figure represents a keyword. The larger the node, the higher the frequency of keyword occurrence; the more lines, the higher the frequency of keyword co-occurrence; additionally, the thickness of the connecting line is proportional to the closeness of the connection. The size of the node is proportional to the frequency of occurrence of the keyword, and the thickness of the line represents the intensity of co-occurrence between individual keywords (Leal et al. 2022). The top twenty co-occurrence all keywords were climate-change, climate change, rice, yield, temperature, agriculture, impacts, growth, food security, adaptation, impact, management, wheat, model, China, responses, productivity, variability, elevated CO_2, and maize; each all keywords occurred more than 206 times.

The same data in Figure 7 were then arranged by a period of rice and climate change topic research as overlay map (Figure 8). Blue color indicates earlier research topics, whereas yellow and green colors indicate the more recent topics of interest. The blue colored topics do not indicate no longer research work on that topics; it usually indicates that, on average, this topic was intensely investigated earlier and now more attention has shifted towards other topics. Perhaps, these terms are now so general, therefore no longer extensively used as keywords. Yellow and green circles present those research fronts. For example, the keywords of carbon-dioxide in Figure 8 can be observed with blue

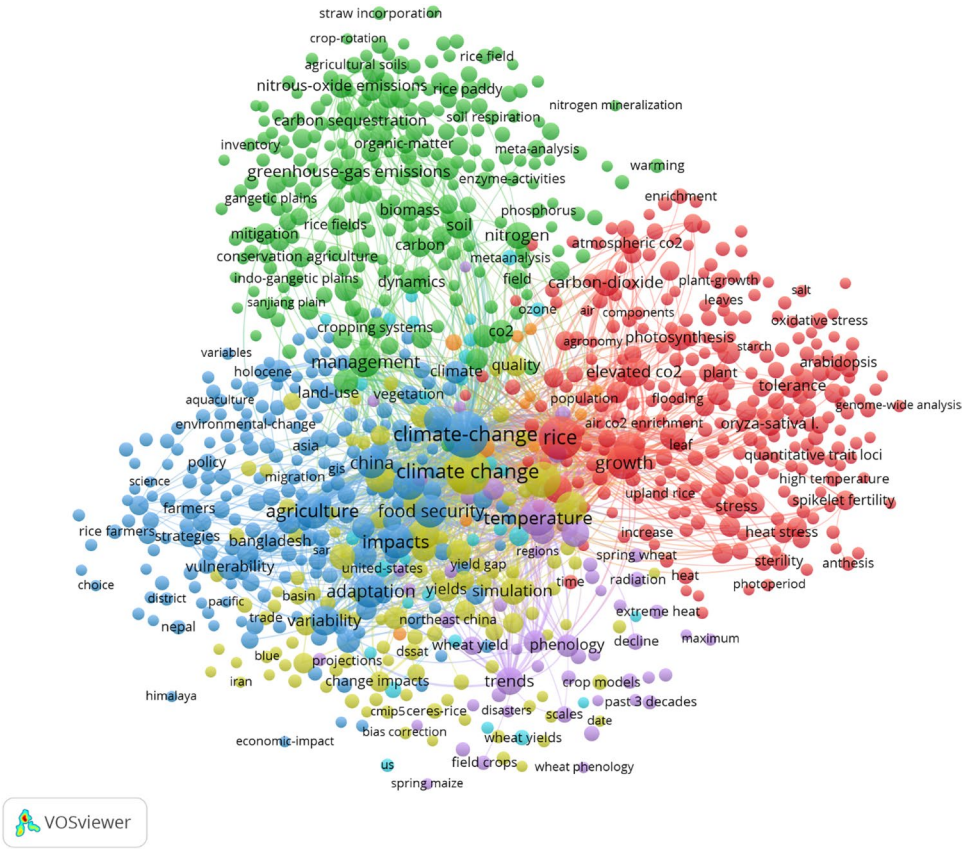

Fig. 7 VOSviewer co-occurrence network visualization mapping of most frequent all keywords (minimum of 8 occurrences) on rice and climate change topic research. Co-occurrence network of all keywords including author keywords and keywords plus. Of the all 15,029 keywords, there were only 920 keywords that met the threshold more than 8 times included in the map. After all keywords analysis, there are eight main clusters that represent eight different viewpoints on rice and climate change topic. Nodes with similar color represent a cluster of related terms

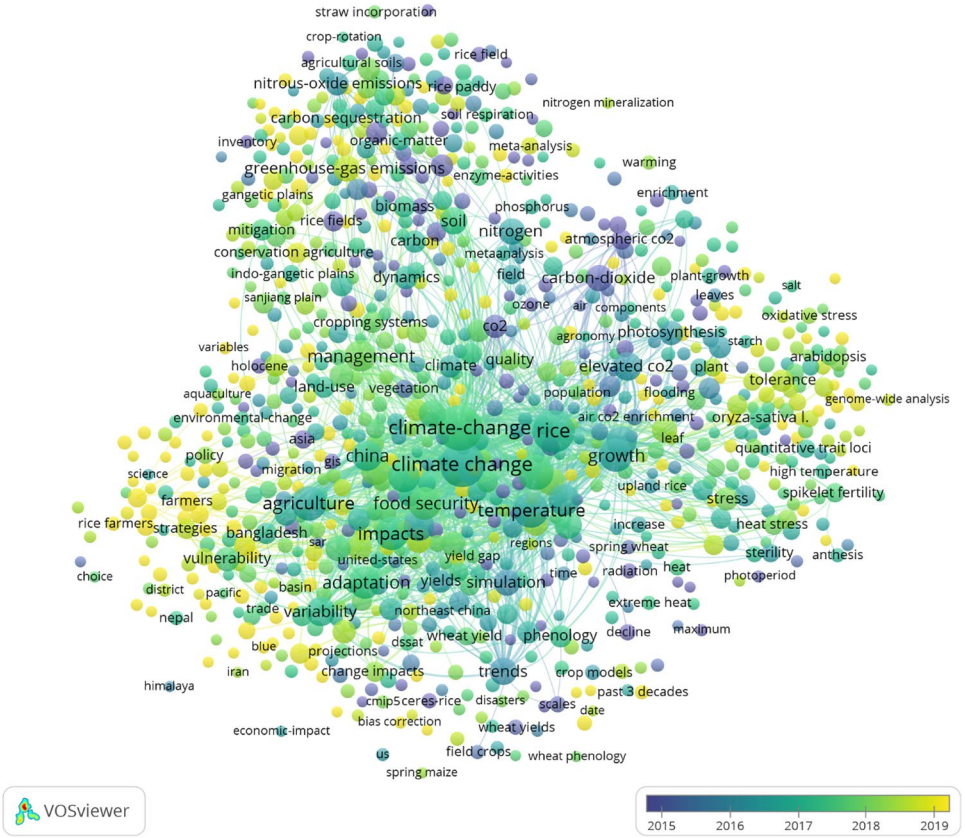

Fig. 8 VOSviewer co-occurrence overlay visualization mapping of most frequent all keywords (minimum of eight occurrences) on rice and climate change topic research from 1990 to 2022. The years in which specific keywords frequently occur are shown by different colors. Importance of all keywords is represented by their centrality in the network. More occurrences of all keywords are shown with bigger circles. More co-occurrences of keywords are shown with thicker lines

circles showing the older topic research; the keywords of adoption, famers, footprint, sustainability, climate change, and management in Figure 8 can be observed with yellow or shallow green circles showing the front research. Blue colors indicated earlier research topics, whereas yellow and green colors indicated more recent topics of interest. Yellow and green circles present those research fronts.

Visualizations conducted on large datasets (big data) offer exploratory information on the current state in a scientific field or discipline as well as indicate possible developments in the future. Here, the twenty keywords or so were list and ranked in each cluster based on Figure 7. Nodes with similar color represent a cluster of related terms. Here, the eight clusters for different topics on the climate change and rice were given, such as rice growth and yield responses to elevated CO_2, soil management and greenhouse gas emissions, climate change impacts agriculture and food security, crop yield models under climate change, crop yields response to temperature and water, weather sensitivity and air pollution, crop yields under tropical environments, and modelling for crops or climate.

The first cluster (red) is focused on rice growth and yield responses to elevated CO_2 and includes keywords as rice, growth, responses, elevated CO_2, drought, carbon dioxide, grain yield, photosynthesis, stress, tolerance, plants, *Oryza-Sativa* L., high temperature, global warming, *Oryza Sativa*, atmospheric CO_2, cultivars, heat stress, heat-stress, and night temperature; each all keywords occurred more than 65 times.

The second cluster (green) represents the soil management and greenhouse gas emissions and including keywords as management, soil, nitrogen, greenhouse-gas emissions, systems, CO_2, dynamics, nitrous-oxide emissions, methane, emissions, carbon, use efficiency, N_2O emissions, carbon sequestration, performance, biomass, mitigation, methane emission, methane emissions, and cropping systems; each all keywords occurred more than 74 times.

The third cluster (blue) is focused on climate change impacts agriculture and food security and include keywords as climate-change, agriculture, impacts, food security, adaptation, impact, China, variability, water, rice production, vulnerability, precipitation, India, sustainability, climate, food, Bangladesh, land use, risk, and strategies; each all keywords occurred more than 68 times.

The fourth cluster (yellow) represents crop yield models under climate change, and keywords include as climate change, yield, wheat, model, productivity, simulation, irrigation, crop yield, rice yield, crop production, yields, system, uncertainty, quality, resources, crop model, models, change impacts, river-basin, and evapotranspiration; each all keywords occurred more than 60 times.

The fifth cluster (violet) is focused on crop yield response to temperature and water, and keywords include

as temperature, maize, trends, winter-wheat, phenology, rice yields, crop, irrigated rice, water-use, wheat yield, decline, Northeast China, scales, challenges, crop management, growth duration, radiation, winter wheat, cultivar, and maize yield; each all keywords occurred more than 22 times.

The sixth cluster (shallow blue) is focused on weather sensitivity and air pollution, and keywords include as sensitivity, weather, United-States, metaanalysis, wheat yields, exposure, tropospheric ozone, cotton, ozone, surface ozone, integrated assessment, yield variability, climate impacts, pollution, potential impact, aerosols, benefits, economic-impacts, air pollution, air-pollution, and regression; each all keywords occurred more than 11 times.

The seventh cluster (orange) is focused on crop yields under tropical environments, and keywords include as crop yields, crop productivity, climate change impacts, ceres-wheat, pests, agroecosystems, assimilation, losses, infocrop, dynamic simulation-model, and tropical environments; each all keywords occurred more than 8 times.

The eighth cluster (brown) is only one keywords of modelling.

3.9 The most frequently cited articles

Although a great many articles have been published, a relatively small number of individuals account for a large proportion of the citations within the period. The annual citations of the eight papers showed an increasing trend after year of publication (Figure 9). The eight papers were written by Lobell et al (2011), Peng et al (2004), Smith et al (2008), Challinor et al (2014), Ruddiman (2003), Weaver and Reisen (2010), Ray et al (2012), and Ray et al (2015). Here, the total citations for the most frequently cited articles were more than 741 times. The time dependence of a single paper is called its history. In the beginning year (zero year here), generally the articles have lower citation because of same year of publication. From the publication year to 2022, the average citation per year of the most citation eight papers were 171, 71.79, 89.93, 106.67, 44.1, 64.62, 71.09, and 92.63 times. From Figure 9, it can be found that the citation per year of the papers increased until 2021, but the increase rate was different each year. Among eight articles, the highest average citation per year (171, blue color) was observed for article of Lobell et al (2011) published in *Science* (Figure 9).

4 Conclusions

Based on the Web of Science core database, a detailed analysis was conducted of rice and climate change topic research from 1990 to 2022 through the use of a bibliometric method. This study analyzed 4170 papers in the field of rice and climate change topic research, which include 86 highly cited papers and 3 hot papers. Papers were mainly written in English, from 16,363 authors, 4017 organizations, and 129 countries/territories, published in 841 journals and seven book series. The top five Journals are *Science of the Total Environment, Sustainability, Agronomy Basel*, *Agricultural and Forest Meteorology*, and *Climatic Change*. Top five countries and regions were People's Republic of China, the USA, India, Australia, and Japan. Top five organizations were Chinese Acad Sci, Nanjing Agr Univ, Univ Chinese Acad Sci, Chinese Acad Agr Sci, and Int Rice Res Inst (IRRI). Among the all authors, top five authors were Tao Fulu, Pan Genxing, Zhang Zhao, Hasegawa Toshihiro, and Iizumi Toshichika. All keywords were separated into eight clusters for different research topics. The results will help researchers clarify the

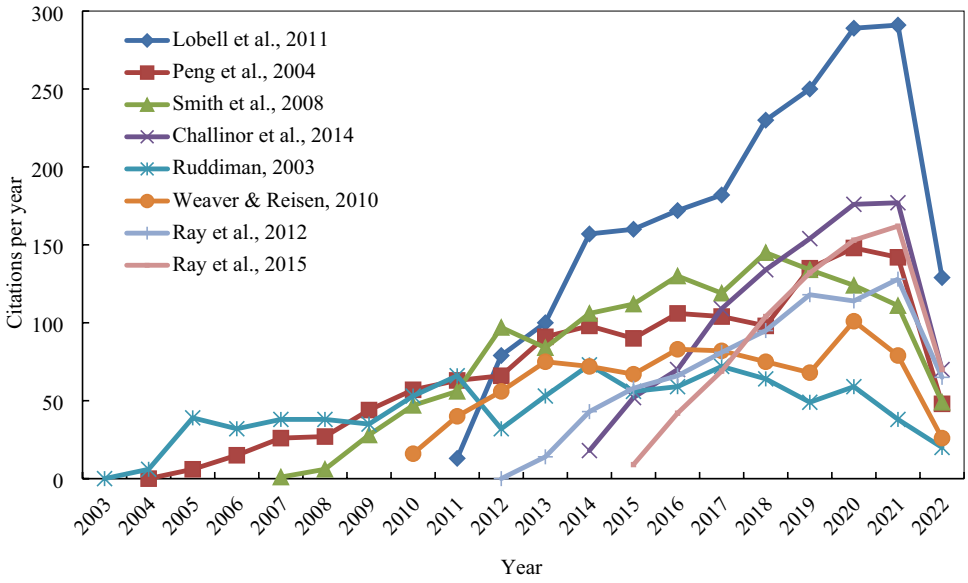

Fig. 9 Comparison of the citations per year of the most eight papers related to rice and climate change topic research from their initial publications to July 9, 2022

current situation in rice and climate change adaptation science but also provide guidance for future research.

Author contribution Conceptualization: Bao-Zhong Yuan and Jie Sun. Methodology: Bao-Zhong Yuan and Jie Sun. Formal analysis and investigation: Bao-Zhong Yuan and Jie Sun. Writing—original draft preparation: Jie Sun. Writing—review and editing: Bao-Zhong Yuan. All authors have read and agreed to the published version of the manuscript.

Funding This research was funded by Hubei Agricultural Science and Technology Innovation Center Program (2021-620-000-001-032).

Data availability Not applicable.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

References

Aleixandre-Benavent R, Aleixandre-Tudo JL, Castello-Cogollos L, Aleixandre JL (2017) Trends in scientific research on climate change in agriculture and forestry subject areas (2005–2014). J Clean Prod 147:406–418. https://doi.org/10.1016/j.jclepro.2017.01.112

Badaluddin NA, Lion M, Razali SM, Khalit SI (2021) Bibliometric analysis of global trends on soil moisture assessment using the remote sensing research study from 2000 to 2020. Water Air Soil Pollut 232(7):271. https://doi.org/10.1007/s11270-021-05218-9

Bartol T, Mackiewicz-Talarczyk M (2015) Bibliometric analysis of publishing trends in fiber crops in Google Scholar, Scopus, and Web of Science. J Nat Fibers 12(6):531–541. https://doi.org/10.1080/15440478.2014.972000

Challinor AJ, Watson J, Lobell DB, Howden SM, Smith DR, Chhetri N (2014) A meta-analysis of crop yield under climate change and adaptation. Nat Clim Change 4(4):287–291. https://doi.org/10.1038/NCLIMATE2153

Clarivate (2022a) Journal Citation Reports ™ 2021. https://jcr.clarivate.com/jcr/browse-journals. Accessed 9 July 2022

Clarivate (2022b) Essential science indicators help: about essential science indicators. http://esi.help.clarivate.com/Content/home.htm. Accessed 9 July 2022

Elango B, Ho YS (2018) Top-cited articles in the field of tribology: a bibliometric analysis. COLLNET J Scientometrics Inf Manage 12(2):289–307. https://doi.org/10.1080/09737766.2018.1529125

Fu HZ, Chuang KY, Wang MH, Ho YS (2011) Characteristics of research in China assessed with Essential Science Indicators. Scientometrics 88(3):841–862

Gimenez E, Salinas M, Manzano-Agugliaro F (2018) Worldwide research on plant defense against biotic stresses as improvement for sustainable agriculture. Sustainability 10(2):391. https://doi.org/10.3390/su10020391

Hirsch JE (2005) An index to quantify an individual's scientific research output. Proc Natl Acad Sci U S A 102(46):16569–16572. https://doi.org/10.1073/pnas.0507655102

Hu CX, Cao LZ (2018) Bibliometric and visual analysis of planthopper research between 1980 and 2017. Curr Sci 114(12):2445–2452. https://doi.org/10.18520/cs/v114/i12/2445-2452

Huang L, Chen K, Zhou M (2020) Climate change and carbon sink: a bibliometric analysis. Environ Sci Pollut Res 27(8):8740–8758. https://doi.org/10.1007/s11356-019-07489-6

Jansen DM (1990) Potential rice yields in future weather conditions in different parts of Asia. Netherlands J Agric Sci 38(4):661–680

Kane DA, Rogé P, Snapp SS (2016) A systematic review of perennial staple crops literature using topic modeling and bibliometric analysis. PLoS ONE 11(5):e0155788. https://doi.org/10.1371/journal.pone.0155788

Khan A, Khan D, Akbar F (2020) Bibliometric analysis of publications on research into cotton leaf curl disease. Discoveries 8(2):e109. https://doi.org/10.15190/d.2020.6

Kingra PK, Kaur R, Kaur S (2019) Climate change impacts on rice (Oryza sativa) productivity and strategies for its sustainable management. Indian J Agric Sci 89(2):171–180

Leal KB, Robaina LED, De Lima AD (2022) Coastal impacts of storm surges on a changing climate: a global bibliometric analysis. Nat Hazards. https://doi.org/10.1007/s11069-022-05432-6

Li JF, Wang MH, Ho YS (2011) Trends in research on global climate change: a Science Citation Index Expanded-based analysis. Glob Planetary Change 77(1–2):13–20. https://doi.org/10.1016/j.gloplacha.2011.02.005

Li XT, Mao DH, Cheng JM (2018) Study on map knowledge domains of transgenic maize based on Citespace. Am J Agric For 6(3):44–49. https://doi.org/10.11648/j.ajaf.20180603.12

Lima CO, Bonetti J (2020) Bibliometric analysis of the scientific production on coastal communities' social vulnerability to climate change and to the impact of extreme events. Nat Hazards 102(3):1589–1610. https://doi.org/10.1007/s11069-020-03974-1

Liu B, Zhang L, Wang XW (2017) Scientometric profile of global rice research during 1985–2014. Curr Sci 112(5):1003–1011. https://doi.org/10.18520/cs/v112/i05/1003-1011

Liu WS, Tang L, Gu MD, Hu GY (2015) Feature report on China: a bibliometric analysis of China-related articles. Scientometrics 102(1):503–517

Lobell DB, Schlenker W, Costa-Roberts J (2011) Climate trends and global crop production since 1980. Science 333(6042):616–620. https://doi.org/10.1126/science.1204531

Morita S, Wada H, Matsue Y (2016) Countermeasures for heat damage in rice grain quality under climate change. Plant Prod Sci 19(1):1–11. https://doi.org/10.1080/1343943X.2015.1128114

Morooka K, Ramos MM, Nathaniel FN (2014) A bibliometric approach to interdisciplinarity in Japanese rice research and technology development. Scientometrics 98(1):73–98. https://doi.org/10.1007/s11192-013-1119-0

Murphy T, Irvine K, Sampson M (2013) The stress of climate change on water management in Cambodia with a focus on rice production. Clim Dev 5(1):77–92. https://doi.org/10.1080/17565529.2013.771570

Omoregbe O, Mustapha AN, Steinberger-Wilckens R, El-Kharouf A, Onyeaka H (2020) Carbon capture technologies for climate change mitigation: a bibliometric analysis of the scientific discourse during 1998–2018. Energy Rep 6:1200–1212. https://doi.org/10.1016/j.egyr.2020.05.003

Pan XY, Lv JL, Dyck M, He HL (2021) Bibliometric analysis of soil nutrient research between 1992 and 2020. Agric-Basel 11(3):223. https://doi.org/10.3390/agriculture11030223

Peng SB (2017) Booming research on rice physiology and management in China: a bibliometric analysis based on three major agronomic

journals. J Integr Agric 16(12):2726–2735. https://doi.org/10.1016/S2095-3119(17)61804-5
Peng SB, Huang JL, Sheehy JE, Laza RC, Visperas RM, Zhong XH, Centeno GS, Khush GS, Cassman KG (2004) Rice yields decline with higher night temperature from global warming. Proc Natl Acad Sci U S A 101(27):9971–9975. https://doi.org/10.1073/pnas.0403720101
Rana IA (2020) Disaster and climate change resilience: a bibliometric analysis. Int J Disast Risk Reduct 50:101839. https://doi.org/10.1016/j.ijdrr.2020.101839
Ray DK, Gerber JS, MacDonald GK, West PC (2015) Climate variation explains a third of global crop yield variability. Nat Commun 6:5989. https://doi.org/10.1038/ncomms6989
Ray DK, Ramankutty N, Mueller ND, West PC, Foley JA (2012) Recent patterns of crop yield growth and stagnation. Nat Commun 3:1293. https://doi.org/10.1038/ncomms2296
Ruddiman WF (2003) The anthropogenic greenhouse era began thousands of years ago. Clim Change 61(3):261–293. https://doi.org/10.1023/B:CLIM.0000004577.17928.fa
Santillán-Fernández A, Salinas-Moreno Y, Valdez-Lazalde JR, Pereira-Lorenzo S (2021) Spatial-temporal evolution of scientific production about genetically modified maize. Agric-Basel 11(3):246. https://doi.org/10.3390/agriculture11030246
Schneider P, Asch F (2020) Rice production and food security in Asian Mega deltas—a review on characteristics, vulnerabilities and agricultural adaptation options to cope with climate change. J Agron Crop Sci 206(4):491–503. https://doi.org/10.1111/jac.12415
Senguttuvel P, Jaldhani V, Raju NS, Balakrishnan D, Beulah P, Bhadhana VP, Mangrauthia SK, Neeraja CN, Subrahmanyam D, Rao PR, Hariprasad AS, and Voleti SR (2022) Breeding rice for heat tolerance and climate change scenario; possibilities and way forward. A review. Arch Agron Soil Sci 68(1):115–132. https://doi.org/10.1080/03650340.2020.1826041
Smith P, Martino D, Cai ZC, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, Scholes B, Sirotenko O, Howden M, McAllister T, Pan GX, Romanenkov V, Schneider U, Towprayoon S, Wattenbach M, Smith J (2008) Greenhouse gas mitigation in agriculture. Philos Trans Royal Soc B-Biol Sci 363(1492):789–813. https://doi.org/10.1098/rstb.2007.2184
Stopar K, Mackiewicz-Talarczyk M, Bartol T (2021) Cotton fiber in web of science and scopus: mapping and visualization of research topics and publishing patterns. J Nat Fibers 18(4):547–558. https://doi.org/10.1080/15440478.2019.1636742
Sun J, Yuan BZ (2019) Visualization analysis of research on rice with fertilizer from the 'agronomy' category based on CiteSpace. Curr Sci 117(9):1449–1458. https://doi.org/10.18520/cs/v117/i9/1449-1458
Sun J, Yuan BZ (2020) A bibliometric analysis of research on rice and irrigation from the 'Agronomy' category based on the Web of Science. Curr Sci 119(3):438–446. https://doi.org/10.18520/cs/v119/i3/438-446
Sun J, Yuan BZ (2020) Mapping of the world rice research: a bibliometric analysis of top papers during 2008–2018. Ann Libr Inf Stud 67(1):56–66
Sun J, Yuan BZ (2020) Bibliometric mapping of top papers in Library and Information Science based on the Essential Science Indicators Database. Malaysian J Libr Inf Sci 25(2):61–76. https://doi.org/10.22452/mjlis.vol25no2.4
Sun J, Yuan BZ (2020) Mapping of top papers in the subject category of Water Resources based on the Essential Science Indicators. Ann Libr Inf Stud 67(2):90–102
Sun J, Yuan BZ (2021) Trend and research status of Agronomy based on the Essential Science Indicators during 2009–2019. Agron J 113(2):2184–2194. https://doi.org/10.1002/agj220628.20628
Sweileh WM (2020) Bibliometric analysis of peer-reviewed literature on climate change and human health with an emphasis on infectious diseases. Glob Health 16(1):44. https://doi.org/10.1186/s12992-020-00576-1
Tang M, Liao HC, Wan ZJ, Herrera-Viedma E, Rosen MA (2018) Ten years of Sustainability (2009 to 2018): a bibliometric overview. Sustainability 10(5):1655. https://doi.org/10.3390/su10051655
van Eck NJ, Waltman L (2010) Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics 84(2):523–538. https://doi.org/10.1007/s11192-009-0146-3
Van Eck NJ, Waltman L (2022) Manual for VOSviewer version 1.6.18. Univeristeit Leiden, Leiden, the Netherlands. https://www.vosviewer.com/
Velasco-Muñoz JF, Aznar-Sánchez JA, Belmonte-Ureña LJ, López-Serrano MJ (2018) Advances in water use efficiency in agriculture: a bibliometric analysis. Water 10(4):377. https://doi.org/10.3390/w10040377
Velasco-Muñoz JF, Aznar-Sánchez JA, Belmonte-Ureña LJ, Román-Sánchez IM (2018) Sustainable water use in agriculture: a review of worldwide research. Sustainability 10(4):1084. https://doi.org/10.3390/su10041084
Wang B, Pan SY, Ke RY, Wang K, Wei YM (2014) An overview of climate change vulnerability: a bibliometric analysis based on Web of Science database. Nat Hazards 74(3):1649–1666. https://doi.org/10.1007/s11069-014-1260-y
Wang ZH, Zhao YD, Wang B (2018) A bibliometric analysis of climate change adaptation based on massive research literature data. J Clean Prod 199:1072–1082. https://doi.org/10.1016/j.jclepro.2018.06.183
Wang YP, Liu WZ, Li G, Yan WM, Gao GY (2019) A bibliometric analysis of soil and water conservation in the loess tableland-gully region of China. Water 11(1):20. https://doi.org/10.3390/w11010020
Weaver SC, Reisen WK (2010) Present and future arboviral threats. Antivir Res 85(2):328–345. https://doi.org/10.1016/j.antiviral.2009.10.008
Wei YM, Mi ZF, Huang ZM (2015) Climate policy modeling: an online SCI-E and SSCI based literature review. Omega-Int J Manag Sci 57(SI):70–84. https://doi.org/10.1016/j.omega.2014.10.011
White-Gibson A, O'Neill B, Cooper D, Leonard M, O'Daly B (2019) Levels of evidence in pelvic trauma: a bibliometric analysis of the top 50 cited papers. Irish J Med Sci 188:155–159. https://doi.org/10.1007/s11845-018-1818-x
Yuan BZ, Sun J (2019) Bibliometric and mapping of top papers in the subject category of green and sustainable science and technology based on ESI. COLLNET J Scientometrics Inf Manage 13(2):269–289. https://doi.org/10.1080/09737766.2020.1716643
Yuan BZ, Sun J (2020) Bibliometric analysis of research on the maize based on top papers during 2009–2019. COLLNET J Scientometrics Inf Manage 14(1):75–92. https://doi.org/10.1080/09737766.2020.1787110
Yuan BZ, Sun J (2020) Mapping the scientific research on maize or corn: a bibliometric analysis of top papers during 2008–2018. Maydica 65(2):M17
Yuan BZ, Sun J (2021) Bibliometric analysis of Strawberry (Fragaria × ananassa Duch.) research publications from Horticulture category based on Web of Science. J Berry Res 11(4):721–738. https://doi.org/10.3233/JBR-210741
Yuan BZ, Sun J (2021) Bibliometric analysis of cotton research from Plant Sciences category based on Web of Science. J Nat Fibers. https://doi.org/10.1080/15440478.2021.1952139
Yuan BZ, Bie Z, Sun J (2021) Bibliometric analysis of global research on muskmelon (Cucumis melo L.) based on Web of Science. HortScience 56(8):867–874. https://doi.org/10.21273/HORTSCI15827-21
Zafar SA, Hameed A, Nawaz MA, Wei MA, Noor MA, Hussain M, Mehboob-ur R (2018) Mechanisms and molecular approaches for

heat tolerance in rice Oryza sativa L under climate change scenario. J Int Agric 17(4):726–738. https://doi.org/10.1016/S2095-3119(17)61718-0

Zhang YJ, Yu Q, Li J (2021) Bioenergy research under climate change: a bibliometric analysis from a country perspective. Environ Sci Pollut Res 28(21):26427–26440. https://doi.org/10.1007/s11356-021-12448-1