A bibliometric analysis of rice research from Meteorology and Atmospheric Sciences category based on Web of Science

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Abstract

Based on Web of Science database and using the bibliometric analysis method, the 1,950 papers were analyzed in the field of rice topic research from Meteorology and Atmospheric Sciences category during of 1968 to September 27, 2022. All papers almost written in English, were from 7,598 authors, 2,120 affiliation and 95 countries or territories, and published in 100 journals and two book series. Top five journals are Water Air and Soil Pollution (215, 11.026 %), Agricultural and Forest Meteorology (212, 10.872 %), Atmospheric Environment (166, 8.513 %), Journal of Agrometeorology (166, 8.513 %) and Environmental Research Letters (98, 5.026 %), each journal published more than 98 papers. Top five countries were Peoples R China, USA, India, Japan, and Germany. Top five organizations were Chinese Acad Sci, Natl Inst Agroenvironm Sci, Univ Chinese Acad Sci, Nanjing Agr Univ, Nanjing Univ Informat Sci & Technol, each with more than 49 papers. The top five authors were Tao Fulu, Zhang Zhao, Zheng Xunhua, Iizumi Toshichika, Hasegawa Toshihiro, each published more than 20 papers. All keywords were separated into eight clusters for different research topic. Based on ESI database, there are fourteen top papers of all highly cited paper. Visualizations offer exploratory information on the current state in a scientific field or discipline as well as indicate possible developments in the future.

Keywords: *Bibliometric analysis; Meteorology and Atmospheric Sciences; Rice; VOSviewer; Web of Science (WoS).*

Resumen

Sobre la base de datos Web of Science y utilizando el método de análisis bibliométrico, se analizaron los 1.950 artículos en el campo de la investigación temática del arroz de la categoría de Meteorología y Ciencias Atmosféricas durante desde 1968 hasta el 27 de septiembre de 2022. Todos los artículos casi escritos en inglés, eran de 7.598 autores, 2.120 afiliados y 95 países o territorios, y publicados en 100 revistas y dos series de libros. Las cinco principales revistas son Water Air and Soil Pollution (215, 11.026 %), Agricultural and Forest Meteorology (212, 10.872 %), Atmospheric Environment (166, 8.513 %), Journal of Agrometeorology (166, 8.513 %) y Environmental Research Letters (98, 5.026 %), cada revista publicó

más de 98 artículos. Los cinco principales países fueron Peoples R China, Estados Unidos, India, Japón y Alemania. Las cinco principales organizaciones fueron Chinese Acad Sci, Natl Inst Agroenvironm Sci, Univ Chinese Acad Sci, Nanjing Agr Univ, Nanjing Univ Informat Sci & Technol, cada una con más de 49 artículos. Los cinco autores principales fueron Tao Fulu, Zhang Zhao, Zheng Xunhua, Iizumi Toshichika, Hasegawa Toshihiro, cada uno publicó más de 20 artículos. Todas las palabras clave se separaron en ocho grupos para diferentes temas de investigación. Basado en la base de datos ESI, hay catorce artículos principales de todos los artículos altamente citados. Las visualizaciones ofrecen información exploratoria sobre el estado actual en un campo o disciplina científica, así como indican posibles desarrollos en el futuro.

***Palabras clave:** Análisis bibliométrico; Meteorología y Ciencias Atmosféricas; Arroz; VOSviewer; Web of Science (WoS).*

1. Introduction

Bibliometrics technique has been adopted in agriculture and food research from WoS category of Meteorology and Atmospheric Sciences, such as, bibliometric analysis of rice and climate change publications based on Web of Science (Yuan and Sun, 2022), on farmers' perceptions of climate change and its nexus with climate data and adaptive capacity (Ricart et al., 2022), global quantitative and qualitative assessment of drought research from 1861 to 2019 (Abiodun et al., 2022), mismatch between indicators of drought and its impacts on water and food securities (Kchouk et al., 2022), conceptual frameworks and methods of the food-energy-water nexus at the household level for development-oriented policy support (Itayi et al., 2021). Rice (Oryza sativa L.) is the staple food for half the world's population. Bibliometrics analysis technique has been adopted related with 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). 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). The aim of the study is to assess publications on topic of rice (Oryza sativa L.) research from Meteorology and Atmospheric Sciences category during 1968 to September 27, 2022 by bibliometric method and VOSviewer visualization tools through publication year, category, author, affiliations, country, journals, all keywords and other key features.

2. Methodology

2.1 Web of Science

The publication counts were derived from the Clarivate Analytics's WoS core collection of databases: SCIE–1900-present, SSCI –1900-present, CPCI-S –2015-present, IC-1993-present.

2.2 Data collection

Data collection was completed on September 27, 2022. The keyword of "rice" was used in the topic, document types were Article or Review, and WoS categories was Meteorology and Atmospheric Sciences, with the following query: Topic (rice) AND Document Types (Article or Review) AND Web of Science categories (Meteorology and Atmospheric Sciences). Here, the 1,950 records were downloaded and saved as plain text and selecting the export format of "full

records and cited references", and then imported into VOSviewer (version 1.6.18, 2022, Leiden University, Leiden, the Netherlands) for further citation analysis. The impact factors (IF 2021 and IF 5year) were taken from the Journal Citation Report (JCR 2021) that was updated at June 28, 2022 (Clarivate, Journal Citation Reports ™ 2021, 2022).

2.3 VOSviewer

The VOSviewer (www.vosviewer.com) were used to show the international collaboration between the authors, organizations, countries and the research trends through all keywords (Van Eck and Waltman, 2010). In this paper, default parameters values of the VOSviewer are usually used in the analysis (Van Eck and Waltman, 2022).

3. Results

3.1 Document types and languages of publications

All of 1,950 papers were identified database in SCIE (1,946 papers, ratio of total papers 99.795 %), SSCI (134, 6.872 %), Conference Proceeding Citation Index-Science (CPCI-S, 77, 3.949 %), and Arts & Humanities Citation Index (A & HCI, 1, 0.051 %). The document types were articles (1,914, 98.154 %), review articles (36, 1.846 %), and also belonged to proceedings papers (77, 3.949 %), data paper (6, 0.308 %) and early access (5, 0.256 %). All most papers (1,949) were published in English, only one paper was in French.

3.2 Publication output

Figure 1 shows the publications trend of "rice" topic from Meteorology and Atmospheric Sciences category between 1968 and 2022. The highest publication value was 186 in 2021. There are only 9 papers before 1980, and after that the papers are 34, 191, 381, 1,060, 275 papers during the period of 1981-1990, 1991-2000, 2001-2010, 2011-2020, 2021-2022, respectively. These trends reflected the increasing attention devoted to this area during the past decade.
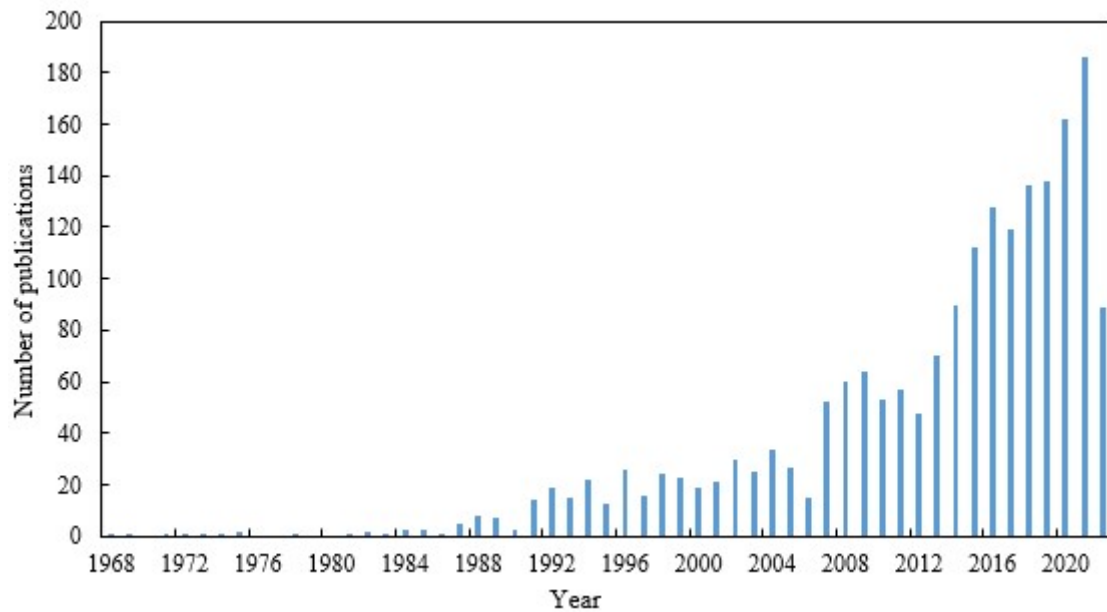
Figure 1: Trends in the quantity of rice topic papers from Meteorology and Atmospheric Sciences category from 1968 to September 27, 2022.

For the total 1,950 papers, the h-index is 121, the total number of citations was 66,991 over the period and the average citation per item is 34.35. Based on WoS core database, the first paper on the rice topic from Meteorology and Atmospheric Sciences category titled of "A physical analysis of diurnal temperature regimes in clear and turbid water layers - a problem in rice culture" written by Rose and Chapman was published in 1968 in Agricultural Meteorology (5(6):391-409).

3.3 Web of Science categories and research areas

For rice topic research from Meteorology and Atmospheric Sciences category from 1968 to September 27, 2022, there are total 27 WoS subject categories and 20 research areas. Based on the WoS categories, the total 1,950 papers were all in Meteorology and Atmospheric Sciences category and research areas, they also belong to other WoS subject categories and research areas (Table 1).

Table 1: Top 20 WoS categories and research areas for rice research from Meteorology and Atmospheric Sciences category from 1968 to September 27, 2022.

Rank	WoS categories			Research areas		
	Categories	No. papers	% Total papers	Areas	No. papers	% Total papers
1	Meteorology Atmospheric Sciences	1,950	100	Meteorology Atmospheric Sciences	1,950	100
2	Environmental Sciences	935	47.949	Environmental Sciences Ecology	942	48.308
3	Agronomy	384	19.692	Agriculture	445	22.821
4	Water Resources	305	15.641	Water Resources	305	15.641
5	Geosciences Multidisciplinary	259	13.282	Geology	259	13.282
6	Forestry	212	10.872	Forestry	212	10.872
7	Astronomy Astrophysics	71	3.641	Engineering	76	3.897
8	Agriculture Multidisciplinary	61	3.128	Astronomy Astrophysics	71	3.641
9	Engineering Aerospace	44	2.256	Biophysics	40	2.051
10	Biophysics	40	2.051	Physiology	38	1.949
11	Environmental Studies	39	2	Geochemistry Geophysics	33	1.692
12	Physiology	38	1.949	Remote Sensing	13	0.667
13	Geochemistry Geophysics	33	1.692	Telecommunications	12	0.615
14	Engineering Environmental	19	0.974	Oceanography	7	0.359
15	Remote Sensing	13	0.667	Radiology Nuclear Medicine Medical Imaging	4	0.205
16	Telecommunications	12	0.615	Mechanics	3	0.154
17	Engineering Chemical	11	0.564	Physical Geography	2	0.103
18	Engineering Mechanical	11	0.564	Immunology	1	0.051
19	Oceanography	7	0.359	Mathematics	1	0.051
20	Radiology Nuclear Medicine Medical Imaging	4	0.205	Physics	1	0.051

The top five categories included Meteorology Atmospheric Sciences (1,950 papers, 100 % of 1,950 papers), Environmental Sciences (935, 47.949 %), Agronomy (384, 19.692 %), Water Resources (305, 15.641 %) and Geosciences Multidisciplinary (259, 13.282 %). The top five research areas included Meteorology Atmospheric Sciences (1,950 papers, 100 % of 1950 papers), Environmental Sciences Ecology (942, 48.308 %), Agriculture (445, 22.821 %), Water Resources (305, 15.641 %) and Geology (259, 13.282 %). Journals or papers may be classified into two or more categories in the WoS, showed the multidisciplinary character of this research field (Elango & Ho, 2017).

3.4 Core journals

All the 1,950 publications were published in 100 journals and two book series. The two book series are Advances in Space Research (10, 0.513 %) and Advances in Space Research Series (5, 0.256 %). The top 20 core journals were displayed in the Table 2 with total articles each more than 20 papers, and also showed the Journal impact factor as IF 2021 and IF 5 year, Quartile in Category (QC) and Quartile rank (QR) among the total 94 journals in Meteorology and Atmospheric Sciences category from Journal Citation Reports ™ 2021.

Table 2: The top 20 core Journals on rice research from Meteorology and Atmospheric Sciences category indexed in the WoS.

Rank	Journal	TP	Ratio (%)	IF2021	IF 5year	QC	QR
1	Water Air and Soil Pollution	215	11.026	2.984	2.982	Q3	62
2	Agricultural and Forest Meteorology	212	10.872	6.424	7.021	Q1	17
3	Atmospheric Environment	166	8.513	5.755	6.027	Q1	19
4	Journal of Agrometeorology	166	8.513				
5	Environmental Research Letters	98	5.026	6.947	8.414	Q1	13
6	Climatic Change	96	4.923	5.174	6.058	Q1	23
7	Global Biogeochemical Cycles	89	4.564	6.5	7.067	Q1	16
8	Journal of Geophysical Research Atmospheres	84	4.308	5.217	5.302	Q1	22
9	Theoretical and Applied Climatology	67	3.436	3.409	3.518	Q3	51
10	Journal of Agricultural Meteorology	61	3.128	1.375	1.607	Q4	87
11	Atmosphere	49	2.513	3.11	3.222	Q3	59
12	Atmospheric Chemistry and Physics	41	2.103	7.197	7.32	Q1	12
13	MAUSAM	41	2.103	0.906	0.598	Q4	90
14	Advances in Space Research	38	1.949	2.611	2.368	Q3	66
15	International Journal of Biometeorology	38	1.949	3.738	3.951	Q2	43
16	International Journal of Climatology	33	1.692	3.651	4.914	Q2	45
17	Natural Hazards	30	1.538	3.158	3.685	Q3	58
18	Climate Research	28	1.436	1.459	2.365	Q4	86
19	Physics and Chemistry of the Earth	23	1.179	3.311	3.419	Q3	55
20	Advances in Atmospheric Sciences	20	1.026	3.9	3.423	Q2	42

Note: TP: Total publications; Ratio: Ratio of 1,950 (%); IF 2021: journal impact factor in 2021; IF5 year: journal impact factor of 5 years; QC: Quartile in Category; QR: Quartile rank of 94 journals in Meteorology and Atmospheric Sciences category from Journal Citation Reports ™ 2021.

The top 5 journals, top 10 journals, top 15 journals and top 20 journals published about 43.95 %, 64.31 %, 72.98 % and 81.80 % of the total 1,950 papers, respectively. The top five journals are Water Air and Soil Pollution (215, 11.026 %), Agricultural and Forest Meteorology (212, 10.872 %), Atmospheric Environment (166, 8.513 %), Journal of Agrometeorology (166, 8.513 %) and Environmental Research Letters (98, 5.026 %), each journal published more than 98 papers. Among the top 20 journals in Table 2, seven journals were in Quartile 1, three journals were in Quartile 2, six journals were in Quartile 3, three journals were in Quartile 4, and one journal has no IF in 2021 for Journal of Agrometeorology.
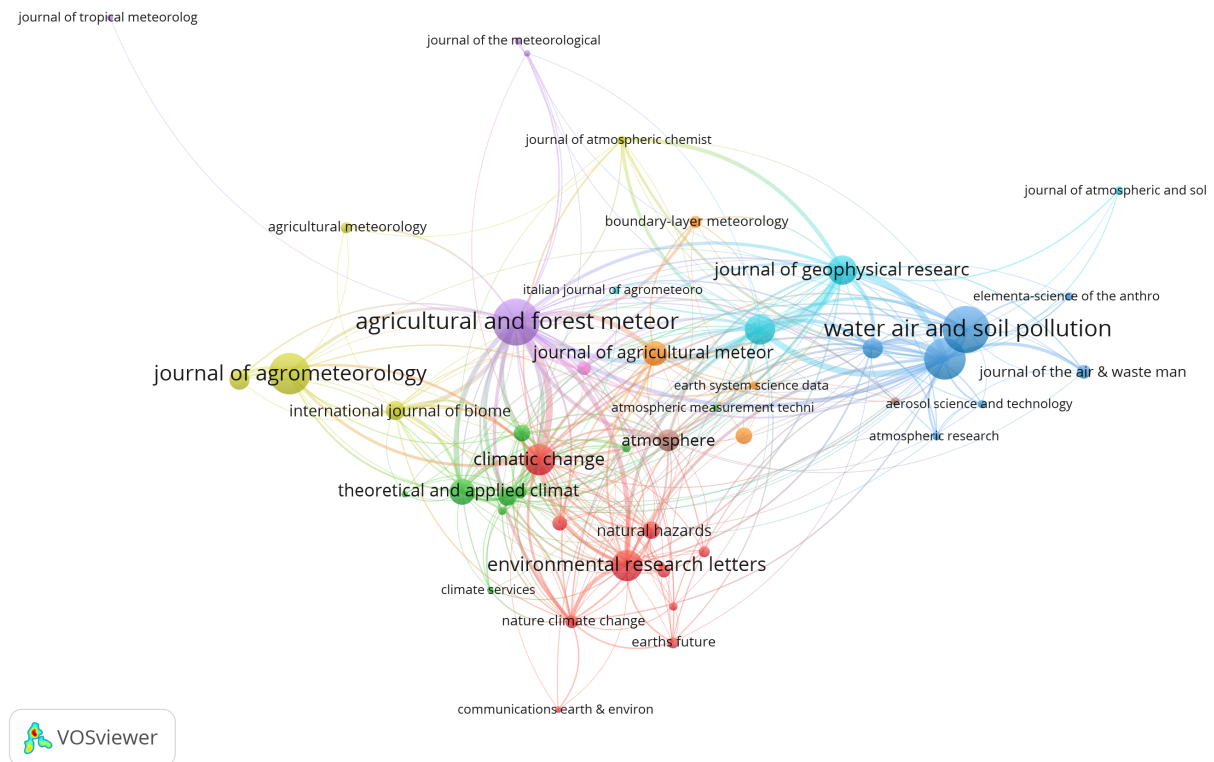
Figure 2: Network visualization maps of journals for rice research topic from Meteorology and Atmospheric Sciences category based on WoS with 47 circles and 9 clusters.

For the publication data in the citation of 100 journals analysed by VOSviewer, there were 49 journals met the thresholds of 5, and 47 journals were connected to each other. The network map of citation for 47 journals was shown nine clusters with different colours in Figure 2. The first cluster (red) had eleven journals and centred as Environmental Research Letters and Climatic Change, the second cluster (green) had nine journals and centred as Theoretical and Applied Climatology and International Journal of Climatology, the third cluster (blue) had seven journals and centred as Water Air and Soil Pollution and Atmospheric Environment, the fourth cluster (yellow) had five journals and centred as Journal of Agrometeorology and MAUSAM, the fifth cluster (violet) had four journals and centred as Agricultural and Forest Meteorology, the sixth cluster (light blue) had four journals and centred as Global Biogeochemical Cycles and Journal of Geophysical Research-Atmospheres, the seventh cluster (orange) had four journals and centred as Journal of Agricultural Meteorology and Advances in Space Research, the eighth cluster (brown) had two journals both Atmosphere and Asia-Pacific Journal of Atmospheric Sciences, the ninth cluster has only one journal of Advances in Atmospheric Sciences.

3.5 Authors co-authorship analysis

A total of 7,598 authors have dedicated to all 1,950 article and review papers, and 147 authors met the five thresholds and were separated into thirty-two clusters, but only 89 authors were connected with each other (Figure 3). 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.
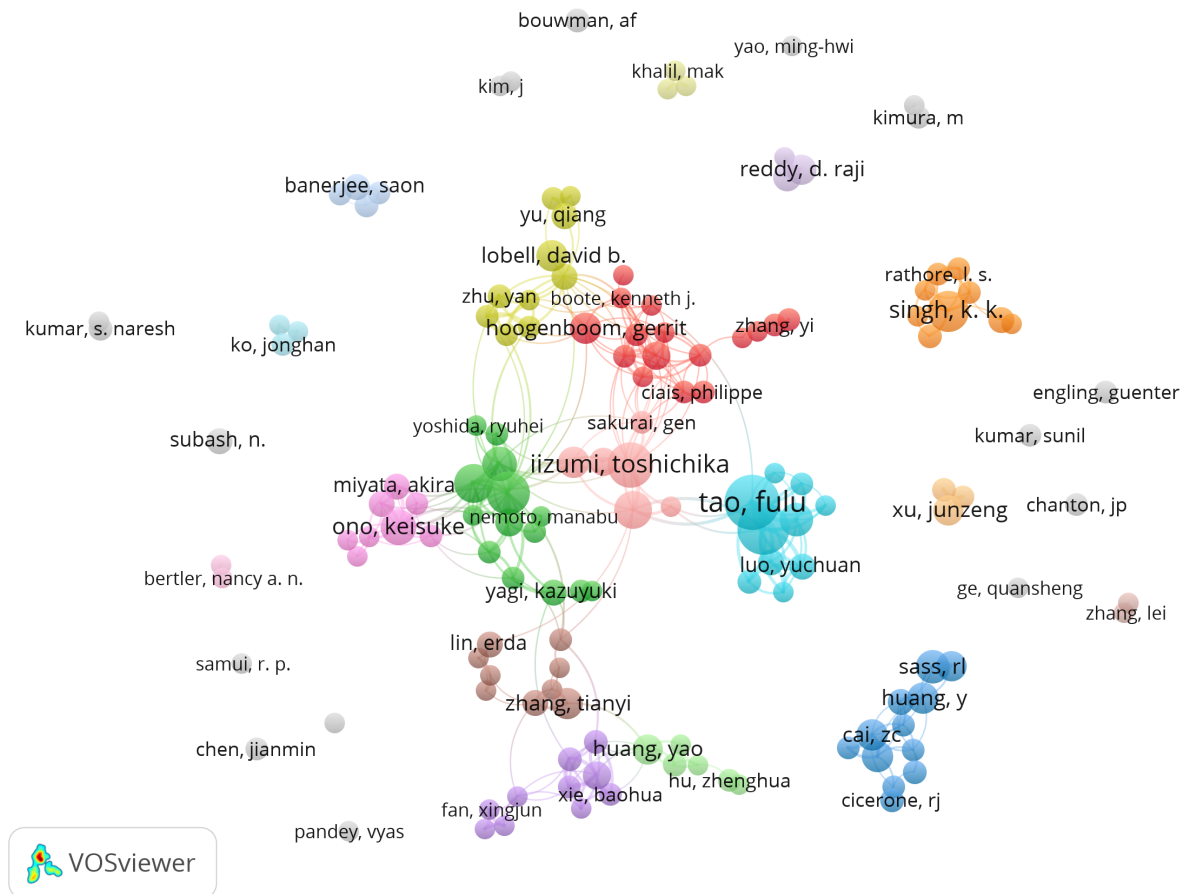
Figure 3: Network map of authors in rice research from Meteorology and Atmospheric
Sciences category during period of 1968 to 2022.

The detail of author information published papers from 1968 to 2022 along with affiliations and
countries were provided in Table 3. The top five authors were Tao, Fulu; Zhang, Zhao; Zheng
Xunhua; Iizumi, Toshichika; Hasegawa, Toshihiro; each published more than 20 papers. In Table
3, there were seven authors from Chinese Acad Sci and Beijing Normal Univ of China; eight
authors from Natl Agr & Food Res Org of Japan; four authors from USA, the organizations
were Rice University, Univ Florida, Stanford Univ; one author from Indian Meteorol Dept.

Table 3: The top twenty most prolific authors published papers in the field of rice research from Meteorology and Atmospheric Sciences category till to September 27, 2022.

| Rank	Author	Papers	Affiliations	Country
1	Tao, Fulu	30	Chinese Acad Sci	China
2	Zhang, Zhao	27	Beijing Normal Univ	China
3	Zheng Xunhua	21	Chinese Acad Sci	China
4	Iizumi, Toshichika	21	Natl Agr & Food Res Org	Japan
5	Hasegawa, Toshihiro	20	Natl Agr & Food Res Org	Japan
6	Singh, K.K.	18	Indian Meteorol Dept	India
7	Sass, RL	17	Rice University	USA
8	Kuwagata, Tsuneo	17	Natl Agr & Food Res Org	Japan
9	Yokozawa, Masayuki	15	Shizuoka Univ	Japan
10	Fisher FM	15	Rice Univ	USA
11	Ono, Keisuke	14	Natl Agr & Food Res Org	Japan
12	Ishigooka, Yasushi	13	Natl Agr & Food Res Org	Japan
13	Cai, Zu-Cong	13	Chinese Acad Sci	China
14	Chen, Yi	12	Chinese Acad Sci	China
15	Huang, Yao	12	Chinese Acad Sci	China
16	Hoogenboom, Gerrit	11	Univ Florida	USA
17	Lobell, David B.	11	Stanford Univ	USA
18	Nishimori, Motoki	11	Natl Agr & Food Res Org	Japan
19	Zhang, Tianyi	11	Chinese Acad Sci	China
20	Nishimori, Motoki	11	Natl Agr & Food Res Org	Japan

3.6 Countries/regions co-authorship analysis

There were 95 countries or regions that contributed 1,950 papers from 1968 to 2022, and 51 countries or regions met the requirement threshold as five. Table 4 list the top 20 countries or regions that published more than 26 papers. The top five countries were Peoples R China, USA, India, Japan, and Germany. From the average citations, the top five countries were Netherlands, Australia, Germany, USA and England, which their citations are more than 50.5 times per paper.

Table 4: Top 20 countries/regions publishing papers in the field of rice from Meteorology and Atmospheric Sciences category during 1968 and 2022.

Rank	Countries/Regions	Records Count	Cluster	Total link strength	Citations	Average citations
1	Peoples R China	599	3	495	18,090	30.2
2	USA	460	6	584	26,084	56.7
3	India	363	6	135	5,042	13.9
4	Japan	245	3	243	9,339	38.1
5	Germany	117	4	304	7,071	60.4
6	England	116	7	300	5,862	50.5
7	Australia	74	2	154	4,912	66.4
8	South Korea	71	3	94	1,641	23.1
9	Netherlands	68	2	161	5,903	86.8
10	Canada	54	1	139	2,235	41.4
11	France	54	1	162	1,965	36.4
12	Italy	52	1	162	2,108	40.5
13	Philippines	43	2	124	1,812	42.1
14	Taiwan	36	2	27	1,046	29.1
15	Bangladesh	32	3	38	478	14.9
16	Thailand	32	3	50	1,416	44.3
17	Brazil	31	1	84	855	27.6
18	Vietnam	30	2	37	969	32.3
19	Spain	28	1	64	1,404	50.1
20	Pakistan	26	3	37	663	25.5

The VOSviewer divided these 51 circles into seven clusters in Figure 4. The first cluster consisted of fourteen countries or regions (red) including Spain, Canada, Italy, France, Brazil, Sweden, New Zealand, Finland, Scotland, Switzerland, Russia, Denmark, Portugal and Argentina. The second cluster consisted of eleven countries or regions (green) including Netherlands, Australia, Philippines, Vietnam, Taiwan, Indonesia, South Africa, Nigeria, Singapore, Ghana and Sri Lanka. The third cluster consisted of ten countries (blue) including Thailand, Japan, Peoples R China, Pakistan, South Korea, Bangladesh, Malaysia, Egypt, Wales and Saudi Arabia. The fourth cluster (yellow) consisted of five countries or regions including of Germany, Austria, Iran, Colombia and Mexico. The fifth cluster (violet) consisted of four countries or regions including Belgium, Norway, Nepal and Czech Republic. The sixth cluster (light blue) consisted of four countries or regions including USA, India, Israel and Turkey. The seventh cluster (orange) consisted of three countries or regions including England, Kenya and Tanzania. Taiwan, as a region of China, showed the stronger research ability in the field.
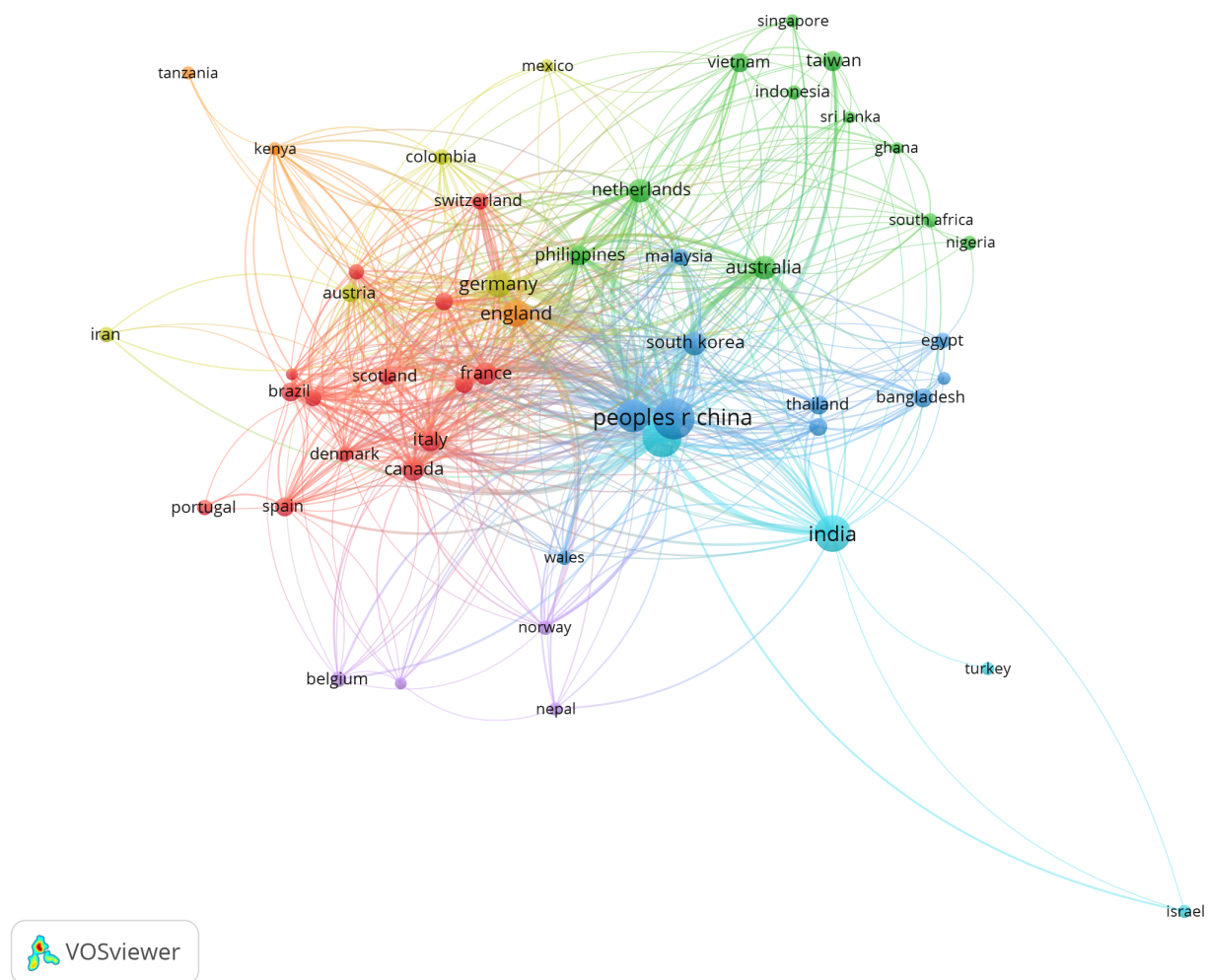
Figure 4: The country co-authorship network of rice research from Meteorology and Atmospheric Sciences from 1968 to 2022 with 51 nodes and 7 clusters.

## 3.7 Organizations (author affiliation) co-authorship analysis

The affiliations presented were updated according to the last paper published by the author until September 27, 2022. A total of 2,120 organizations had 1,950 papers, there were 210 organizations met the minimum thresholds of five.

Table 5: Top twenty organizations published papers in the field of rice research from Meteorology and Atmospheric Sciences category.

Rank	Organizations	Records	Total link strength	Citations	Average citations	Country
1	Chinese Acad Sci	244	361	9961	40.8	China
2	Natl Inst Agroenvironm Sci	67	102	4237	63.2	Japan
3	Univ Chinese Acad Sci	62	102	1156	18.6	China
4	Nanjing Agr Univ	57	96	2626	46.1	China
5	Nanjing Univ Informat Sci & Technol	49	85	670	13.7	China
6	Beijing Normal Univ	47	102	1426	30.3	China
7	Chinese Acad Meteorol Sci	39	80	1000	25.6	China
8	Natl Agr & Food Res Org	38	136	416	10.9	Japan
9	Chinese Acad Agr Sci	36	59	1897	52.7	China
10	Indian Meteorol Dept	30	23	351	11.7	India
11	Univ Florida	30	139	1001	33.4	USA
12	NASA	28	92	1284	45.9	USA
13	Punjab Agr Univ	28	5	82	2.9	India
14	Columbia Univ	27	78	1540	57.0	USA
15	Int Rice Res Inst	27	108	1614	59.8	Philippines
16	Peking Univ	25	50	1046	41.8	China
17	Rice Univ	25	20	2321	92.8	USA
18	China Agr Univ	24	64	418	17.4	China
19	Univ Colorado	23	55	1449	63.0	USA
20	Univ Tokyo	23	41	1035	45.0	Japan

Table 5 represented the top 20 organizations and institutions ranked by the number of total publications (more than 23 papers), and also showed the total link strength, citations, average citations and country. These top 20 organizations were mainly in China (9 organizations), USA (5 organizations), Japan (3 organizations), India (2 organizations), and Philippines (1 organization). Furthermore, the top five organizations were Chinese Acad Sci, Natl Inst Agroenvironm Sci, Univ Chinese Acad Sci, Nanjing Agr Univ, Nanjing Univ Informat Sci & Technol, each with more than 49 papers. In case of average citations of papers, the top five organizations were Rice Univ, Natl Inst Agroenvironm Sci, Univ Colorado, Int Rice Res Inst, Columbia Univ, with the higher average citations more than 57.0 times per paper. Among the 210 organizations met the minimum thresholds of five, there were 207 organizations connected to each other (Figure 5). These 207 institutes were divided into eleven clusters with different colors. Within the context of network formation, organizations tend to form bonds with other institutions in the same region.
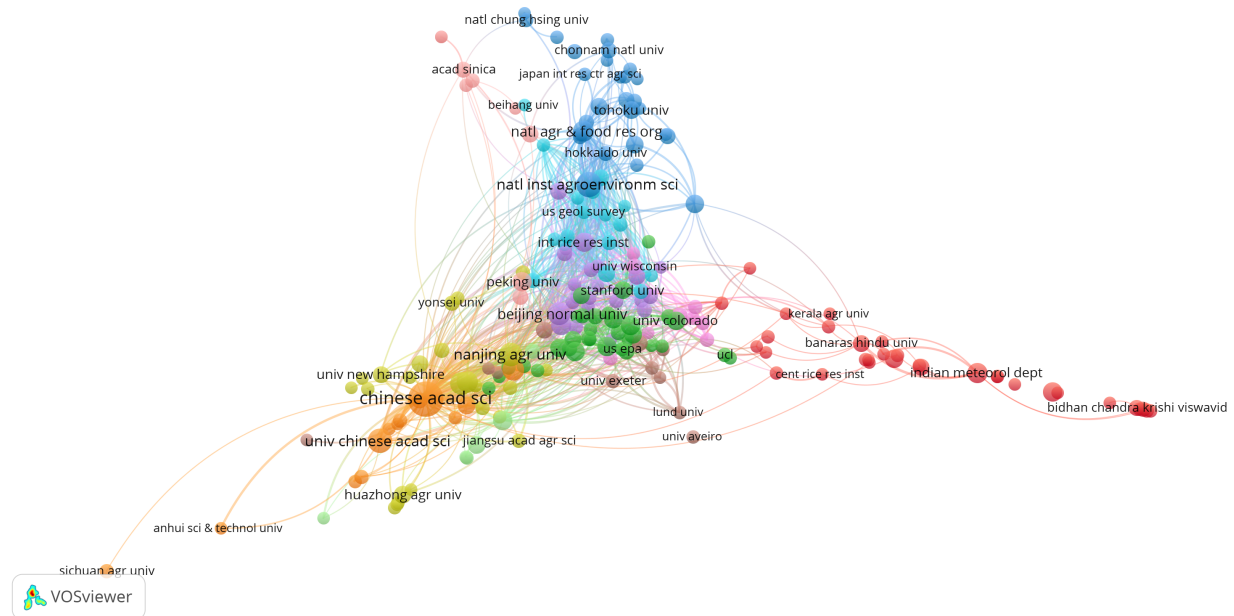
Figure 5: The organizations co-authorship network of rice research from Meteorology and Atmospheric Sciences with 207 circles and 11 clusters.

3.8 All keywords co-occurrence analysis

By the co-occurrence, author keywords, keywords plus and all keywords as unit were chosen and analysed. For the author keywords by full counting method for co-occurrence analysis, there were total 4,187 author keywords, and 170 author keywords met the five threshold level and were separated into thirteen clusters. The top twenty co-occurrence author keywords were rice, climate change, agriculture, China, methane, wheat, food security, yield, temperature, adaptation, nitrous oxide, eddy covariance, phenology, drought, biomass burning, evapotranspiration, India, ozone, crop yield, global warming, each author keywords occurred more than 20 times. There were total 4,012 keywords plus, and 520 keywords plus met the five threshold level and were separated into seven clusters. The top twenty co-occurrence keywords plus were temperature, rice, climate-change, yield, model, growth, impacts, soil, variability, impact, wheat, carbon-dioxide, water, trends, responses, management, agriculture, emissions, carbon, CO2, each keywords plus occurred more than 61 times.

Figure 6: VOSviewer co-occurrence network visualization mapping of all keywords (minimum of 5 occurrences) for rice topic research from Meteorology and Atmospheric Sciences category till to September 27, 2022.

There were total 7,467 all keywords, and only 693 all keywords met the threshold level of five and were separated into eight main clusters (Figure 6). And the research topic were on climate-change impacts for agriculture, soil greenhouse-gas emissions, evapotranspiration model of vegetation in field, effects of heavy-metals on rice growth and groundwater, biomass burning and air pollution, crop yield response to global warming temperature by climate change, grain yield models and forecast, ceres-rice model with diverse agro-environments. The top twenty co-occurrence all keywords were rice, temperature, yield, climate-change, climate change, model, growth, agriculture, wheat, impacts, soil, impact, variability, China, water, carbon-dioxide, trends, adaptation, maize, responses, each all keywords occurred more than 75 times. The same data in Figure 6 were then arranged as overlay map for most frequent all keywords in Figure 7. Blue colors in the upper-left part of soil greenhouse-gas emissions indicated earlier research topics, whereas, yellow and green colors in the lower-right part of climate change topic indicated more recent topics of interest. Yellow and green circles present those research fronts.
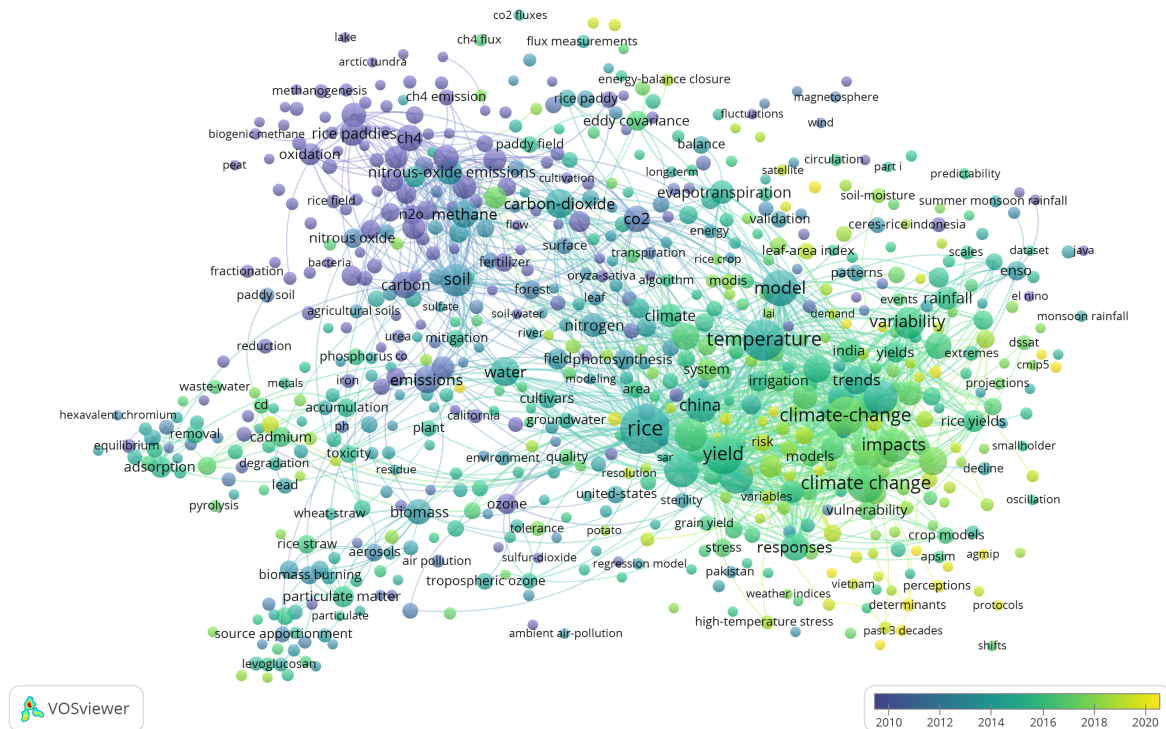
Figure 7: VOSviewer co-occurrence overlay visualization mapping of all keywords for rice topic research from Meteorology and Atmospheric Sciences category till to September 27, 2022.

Here, for total 693 all keywords, about twenty keywords were list and ranked in each cluster based on Figure 6. The first cluster (red) has 147 all keywords and focused on climate-change impacts for agriculture, and 22 most frequently used keywords as climate-change, agriculture, impacts, impact, variability, trends, adaptation, food security, management, precipitation, drought, climate, productivity, rainfall, India, rice yields, irrigation, rice yield, system, dynamics, yields, prediction, each all keywords occurred more than 31 times. This cluster was the recent research topics. The second cluster (green) has 142 all keywords and represents soil greenhouse-gas emissions, and 22 most frequently used keywords as soil, methane, CO2, carbon, CH4, methane emission, rice paddies, nitrous-oxide emissions, atmospheric methane, fields, flux, fluxes, emission, greenhouse-gas emissions, oxidation, methane emissions, N2O emissions, transport, paddy fields, denitrification, inventory, nitrous oxide, each all keywords occurred more than 30 times. This cluster was the earlier research topics. The third cluster (blue) has 120 all keywords and is focused on evapotranspiration model of vegetation in field, and 26 most frequently used keywords as model, carbon-dioxide, phenology, evapotranspiration, vegetation, field, eddy covariance, photosynthesis, forest, heat, irrigated rice, paddy rice, use efficiency, rice paddy, balance, exchange, validation, water-vapor, paddy field, area, evaporation, leaf-area index, remote sensing, respiration, seasonal-variation, surface, each keywords occurred more than 18 times. The fourth cluster (yellow) has 88 all keywords and represents the effects of heavy-metals on rice growth and groundwater, and 20 most frequently used keywords as rice, water, plants, adsorption, cadmium, accumulation, heavy-metals, removal, Bangladesh, biochar, toxicity, exposure, Oryza-Sativa L., sorption, phosphorus, lead, plant, Cd, groundwater, rice husk, each keywords occurred more than 16 times. The fifth cluster (violet) has 86 all keywords and is focused on biomass burning and air pollution, and 22 most frequently used keywords as emissions, biomass, particulate matter, ozone, biomass burning, combustion, rice straw, trace gases, United-States, aerosols, black carbon, straw, polycyclic aromatic-hydrocarbons, quality, air, emission factor, tropospheric ozone, air-pollution, source apportionment, surface ozone, pollution, emission factors, each keywords

occurred more than 15 times. The sixth cluster (light blue) has 76 all keywords and is focused on crop yield response to global warming temperature by climate change, and 21 most frequently used keywords as temperature, yield, climate change, growth, wheat, China, maize, responses, simulation, crop yield, elevated CO2, winter-wheat, uncertainty, cultivars, sensitivity, stress, crop production, food, grain-yield, heat-stress, global warming, each keywords occurred more than 20 times. This cluster was also the recent research topics. The seventh cluster (orange) has 21 all keywords and is focused on grain yield models and forecast, which they are models, grain yield, variables, river, brown planthopper, trend, GIS, regression model, Asian summer monsoon, population, water-quality, weather indices, weather parameters, damage, forecast, pests, regression, rice oryza-sativa, rice planthoppers, time, yield forecasting, each keywords occurred more than 5 times. The eighth cluster (brown) has 12 all keywords and focused on ceres-rice model with diverse agro-environments, which they are nitrogen, crop, ceres-rice, ceres-rice model, diverse agro-environments, potential yield, simulation-model, management-practices, ceres-wheat, impact assessment, sensitivity analysis, yield gap, each all keywords occurred more than 5 times.

3.9 Top papers based on Essential Science Indicators (ESI)

Top papers are the sum of hot papers and highly cited papers, based on Clarivate Analytics' Essential Science Indicators (ESI). Here, the ESI database has been updated as September 8, 2022, data covers over a 10-year and 6-month period: January 1, 2012 – June 30, 2022.

Table 6: Fourteen top papers of rice topic research from Meteorology and Atmospheric Sciences category based on ESI till to September 27, 2022.

Rank	Author	Source Title	Publication Year	Total Citations	Average per year
1	Challinor, A.J., Watson, J., Lobell, D.B., et al.	Nature Climate Change	2014	990	110
2	Teixeira, E.I., Fischer, G., van Velthuizen, H., et al.	Agricultural and Forest Meteorology	2013	431	43.1
3	Knox, J., Hess, T., Daccache, A., et al.	Environmental Research Letters	2012	362	32.91
4	Trnka, M., Roetter, R.P., Ruiz-Ramos, M., et al.	Nature Climate Change	2014	337	37.44
5	Huang, X., Song, Y., Li, M.M., et al.	Global Biogeochemical Cycles	2012	332	30.18
6	Goldewijk, K.K., Beusen, A., Doelman, J., et al.	Earth System Science Data	2017	325	54.17
7	Nisbet, E.G., Dlugokencky, E.J., Manning, M.R., et al.	Global Biogeochemical Cycles	2016	260	37.14
8	Carlson, K.M., Gerber, J.S., Mueller, N.D., et al.	Nature Climate Change	2017	230	38.33
9	Hedenus, F., Wirsenius, S., and Johansson, D.J.A.	Climatic Change	2014	212	23.56
10	Mills, G., Pleijel, H., Malley, C.S., et al.	Elementa-Science of the Anthropocene	2018	172	34.4
11	Zhou, Y., Xing, X.F., Lang, J.L., et al.,	Atmospheric Chemistry and Physics	2017	171	28.5
12	Vogel, E., Donat, M.G., Alexander, L.V., et al.	Environmental Research Letters	2019	153	38.25
13	Cao, J., Zhang, Z., Tao, F.L., et al.	Agricultural and Forest Meteorology	2021	39	19.5
14	Bai, H.Z., Xiao, D.P., Wang, B., et al.	International Journal of Climatology	2021	23	11.5

Based on ESI database, there are fourteen top papers of all highly cited paper. Table 6 show the fourteen top papers ranked by total citations. The total citations for each paper were 990, 431, 362, 337, 332, 325, 260, 230, 212, 172, 171, 153, 39 and 23, and the average citations per year were 110, 43.1, 32.91, 37.44, 30.18, 54.17, 37.14, 38.33, 23.56, 34.4, 28.5, 38.25, 19.5 and 11.5, respectively. These top papers were published in year of 2012 (2 paper), 2013(1), 2014(3), 2016(1), 2017(3), 2018(1), 2019(1) and 2021(2), respectively. The published source titles were Agricultural and Forest Meteorology (2), Atmospheric Chemistry and Physics (1), Climatic Change (1), Earth System Science Data (1), Elementa-Science of the Anthropocene (1), Environmental Research Letters (2), Global Biogeochemical Cycles (2), International Journal of Climatology (1), Nature Climate Change (3), respectively.

3.10 The most frequently cited articles

The annual citations of the nine most cited papers showed an increasing trend after year of publication (Figure 8). Here, the total citations for the nine most frequently cited articles were more than 627 times. The nine papers were authored by Ohara et al. (2007), Bouwman et al. (2002), Challinor et al. (2014), Ruddiman (2003), Bouwman et al. (1997), Portmann et al. (2010), Galloway et al. (1995), Fung et al. (1991), Lobell et al. (2011). Total citations of nine most cited papers were 1102, 1049, 990, 891, 817, 811, 719, 654 and 627 times. From the publication year to September 27, 2022, the average citation per year of the nine most citation papers were 68.88, 49.95, 110, 44.55, 31.42, 62.38, 25.68, 20.44 and 52.25 times. Among nine articles, the highest average citation per year (110) was article of Challinor et al. (2014) published in Nature Climate Change (Figure 8).
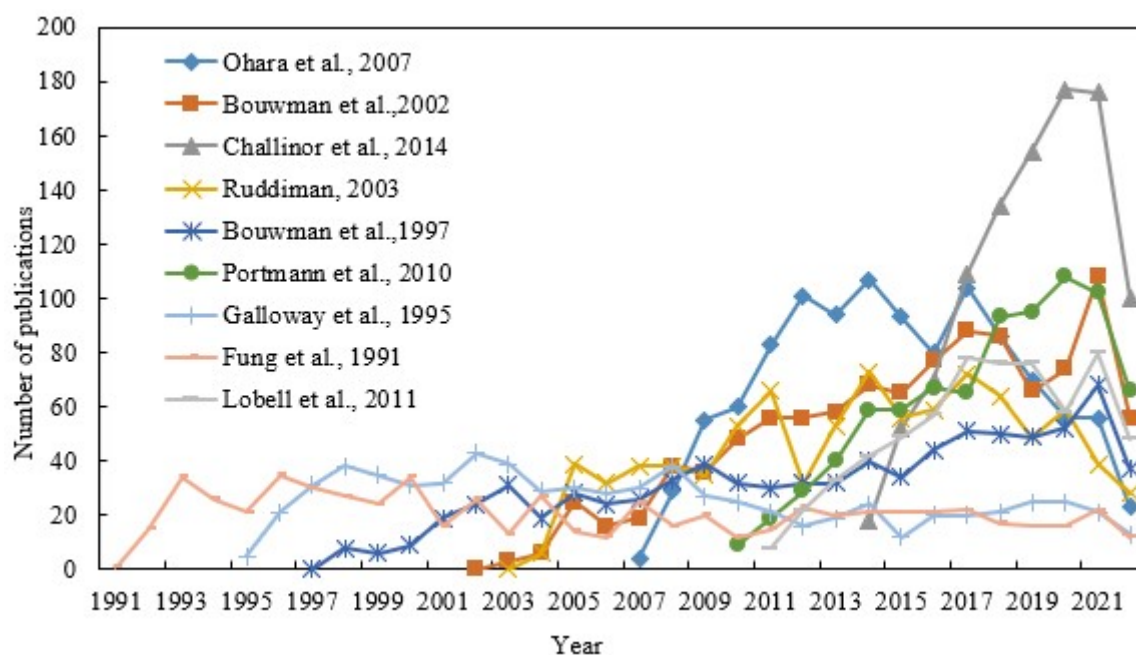
Figure 8: Comparison of the nine most cited papers from their initial publications to September 27, 2022.

4. Conclusions

This study analyzed 1,950 papers in the field of rice topic research from Meteorology and Atmospheric Sciences category from 1968 to September 27, 2022. All papers almost written in English, were from 7,598 authors, 2,120 affiliation and 95 countries or territories, and published in 100 journals and two book series. The top five Journals are Water Air and Soil Pollution, Agricultural and Forest Meteorology, Atmospheric Environment, Journal of Agrometeorology and Environmental Research Letters. Top five countries were Peoples R China, USA, India, Japan, and Germany. Top five organizations were Chinese Acad Sci, Natl Inst Agroenvironm Sci, Univ Chinese Acad Sci, Nanjing Agr Univ, Nanjing Univ Informat Sci & Technol. The top five authors were Tao Fulu, Zhang Zhao, Zheng Xunhua, Iizumi Toshichika, Hasegawa Toshihiro. All keywords were separated into eight clusters for different research topic on climate-change impacts for agriculture, soil greenhouse-gas emissions, evapotranspiration model of vegetation in field, effects of heavy-metals on rice growth and groundwater, biomass burning and air pollution,

crop yield response to global warming temperature by climate change, grain yield models and forecast, ceres-rice model with diverse agro-environments. The earlier research topic was soil greenhouse-gas emissions, and the recent or front research topic were climate-change impacts for agriculture, and crop yield response to global warming temperature by climate change.

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