Review and Exploration of China Subtropical Climate Change Research Based on Scientometric Analysis

Authors: Meng, Sun, and Xiong, Deping

Source: Tropical Conservation Science, 11(1)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/1940082918806795

Research Article

Review and Exploration of China Subtropical Climate Change Research Based on Scientometric Analysis

Tropical Conservation Science
Volume 11: 1–13

DOI: 10.1177/1940082918806795
journals.sagepub.com/home/trc

Sun Meng[1] and Deping Xiong[1]

Abstract

Never before have we had so many different ways to investigate China subtropical climate change as it is gradually becoming significant to know the details about the relationship between climate change and China, specifically in subtropical areas. To learn the current situation and emerging trends of China subtropical climate change research, this article utilizes CiteSpace to provide a general picture about the research field by analyzing 926 publications between 1990 and 2017, which are retrieved from Web of Science. According to the results, some interesting findings are illustrated in this study: (a) The papers that investigate interdecadal change and data-model comparison made great theoretical contributions to China subtropical climate change research; (b) China, the United States, Australia, and Germany are the biggest contributors to China subtropical climate change research, and most of the productive institutions are from China; (c) the emerging trends of China subtropical climate change research are "soil moisture," "net ecosystem exchange," and "autotrophic respiration"; and (d) most of China subtropical climate change studies are related to atmospheric model intercomparison project model, CO_2 fertilization, and pollen record. This article provides an overall analysis about China subtropical climate change research for researchers who are interested in this field to do further investigations.

Keywords

subtropical China, climate change, CiteSpace, scientometrics, emerging trend

Introduction

Climate change is not a new topic in various disciplines. The climate change-related records of animals and plants can be found in the mid-1700s, which came from northern European. Observational documents date back to the end of the 19th century and the early 20th century when researchers explored the sensitivity of insects to spring and summer temperatures (Bale et al., 2002; Dennis, 1993). The biological researches investigated the influence of extreme weather or change of climates on wild species. Besides, the Intergovernmental Panel on Climate Change pointed out that the extent to which recent observed changes in natural biological systems have been caused by climate change. Despite the effects of climate on wild species, some researchers believe that modern climate change is a cause of concern for biodiversity. Other anthropogenic factors such as change of land use and nitrogen fertilization are considered in recent researches. In recent years, the direct impacts of anthropogenic climate change have been broadly investigated (Hughes, 2000; Parmesan et al., 2005; Parmesan & Yohe, 2003; Peñuelas & Filella, 2001). Among these investigations, global warming has become a hot issue which greatly influences the ecosystem and human society. In recent years, many scholars have investigated global warming and climate change. Jang and Hart (2015) explored how people consider climate change and global warming in their daily conversation by analyzing the big data from Twitter. Similarly, Brewer and McKnight (2017) investigated how news programs impact audiences' perceptions toward global

[1]Business School, Yunnan University of Finance and Economics, Kunming, China

Received 15 August 2018; Revised 14 September 2018; Accepted 23 September 2018

Corresponding Author:
Deping Xiong, Business School, Yunnan University of Finance and Economics, Kunming 650221, China.
Email: xiongdeping@126.com

warming. Besides, Lykhovyd (2018) proved that the global climate change significantly influences the local climate, especially for the air temperature. In this article, the air temperature in 2025 in the Kherson region was also predicted. Thus, as one of the phenomena caused by climate change, global warming has been increasingly attracting researchers' attention.

As the world's most populous country, China is also the main emitter of greenhouse gases (Streets et al., 2001). Therefore, numerous researchers analyzed China's impact on climate change. Grumbine (2007) pointed out that China's rapid development is influencing global patterns of resource use and their associated environmental and geopolitical impacts. Yan and Yang (2010) investigated the relations between China's foreign trade and climate change. Meanwhile, W. Li, Li, Tan, and Wang (2017) found that population emigration in the mountainous areas and most of the subregions of China significantly influences vegetation change. In turn, China is also facing the problems caused by climate change. Jones (2008) found that some issues about water resource in China are related not only to the rapid growth of population and economy but also to the climate change and variability over the past 50 years. Tao, Yokozawa, Liu, and Zhang (2009) presented a covariant relationship between changes in cereal productivity because of climate change and the cereal harvest area required to meet China's food demand. Besides, J. Wang et al. (2010) analyzed how climate change impacts agriculture in China and suggested that global warming is possibly harmful to rainfed farms but beneficial to irrigated farms. As one of the countries which impact climate change and also being influenced by it, China is playing a vital role in dealing with problems caused by climate change. Therefore, some literature researched on the policies taken by China and the efforts made by China to deal with climate change-related problems (Heggelund, 2007; Hong & Zhang, 2018; Mi et al., 2017; J. Wang et al., 2009). Although some scholars investigated how China influence climate change, climate change's impact on China, and the climate change-related policies, little is addressed in terms of the overview of the climate change phenomena in specific areas of China. The growing phenomena brought by climate change also significantly impact the subtropical area of China. M. Li et al. (2018) focused on the case study in the Upper Minjiang River basin to demonstrate the influence of future climate change on debris flow hazard. Besides, Ma et al. (2018) investigated the fire history in subtropical China and its relation with climate change and human activity.

Therefore, this study focuses on the climate change in the subtropical areas of China because there are various climate change issues happen in China's subtropical areas. In addition, researching on the diverse ecosystems, atmospheric changes, and hydrographic factors in subtropical areas is of great importance to deeply understand the relationship between climate change and China. In this article, a general picture of the researches related to China subtropical climate change is given by using CiteSpace to intuitively analyze the development process, the current status, and the emerging trends of this research field.

With the growing number of China subtropical climate change research, it is necessary to know the status quo and emerging trends in this field. This article focuses on mapping knowledge domain which involves the processes of charting, mining, analyzing, sorting, and displaying knowledge (Shiffrin & Börner, 2004) to investigate China subtropical climate change research. There are various domain visualization tools such as CiteSpace, UCINET, and VOS viewer. Among these visualization tools, CiteSpace is one of the most popular methods to clearly and interpretably produce co-citation networks on the basis of article citations and reveal the structure of a particular research field (Chen, 2006). CiteSpace was developed by Chen (2004) and has been broadly applied to investigate the researches of astrobiology (Taşkın & Aydinoglu, 2015) and linguistic decision-making (D. J. Yu, Li, Merigó, & Fang, 2016). There are also many papers that research on climate change by utilizing CiteSpace. For instance, Fang, Yin, and Wu (2017) conducted a scientometric analysis of climate change and tourism by using CiteSpace. Similarly, Liu and Jiang (2018) utilized CiteSpace to analyze the hotspots and frontiers of forests respond to climate change. However, no attempt has been done to apply CiteSpace to analyze the literatures about China subtropical climate change. Even though many researchers have analyzed climate change in subtropical China from different perspectives with various methods, few of them attempted to investigate the mapping knowledge domain of China subtropical climate change. As a result, the motivation of this study is to fill the gap between scientometric analysis and the research of China subtropical climate change. Our study makes two contributions. First, a huge amount of publications is quantitatively analyzed to summarize and synthesize the arguments and ideas of the authors in China subtropical climate change research field. Second, the mapping knowledge domain of this research field is clearly illustrated. Not only the current status of China subtropical climate change research is analyzed from the historical, conceptual, and geographical perspectives, this article also suggests the hot spots and future directions of this area by using CiteSpace.

After analyzing 926 published literatures in China subtropical climate change research, which are retrieved from Web of Science (WoS) between 1990 and 2017, this article is guided by the following goals (a) to find out and

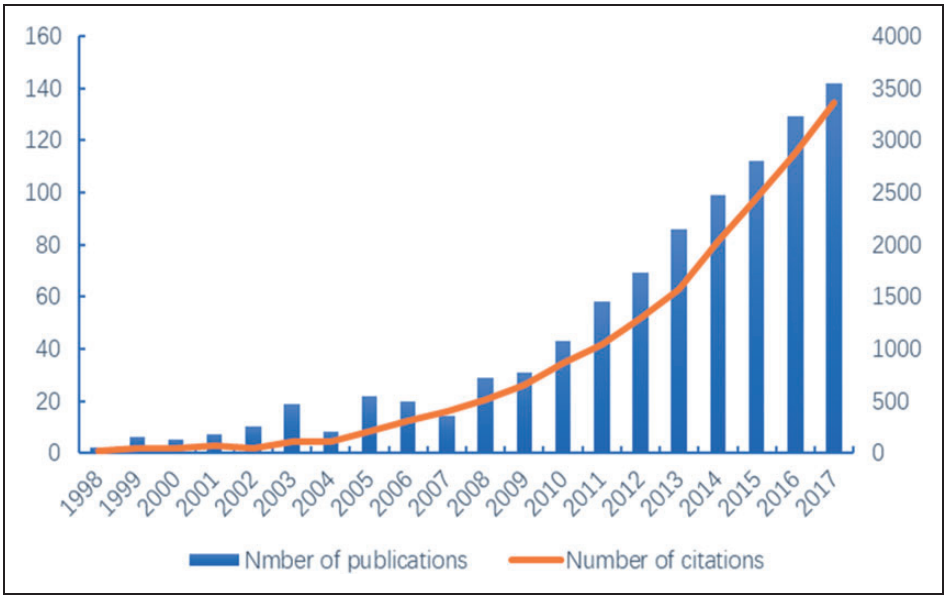

Figure 1. The number of publications and citations related to the topic "China subtropical climate change."

analyze the most cited authors and articles; (b) to illustrate the countries or regions, journals, institutions, and authors with lots of contributions to this research field; and (c) to identify the emerging topics of China subtropical climate change research. The remainder of this article is organized as follows. The number of publications of China subtropical climate change research and the citation analysis are demonstrated in the following section. The countries or regions, institutions, and authors with a large number of publications about China subtropical climate change research are illustrated and analyzed in a further section. Emerging Trends of China Subtropical Climate Change Research Section presents the emerging trends and hot topics of this research area by utilizing burst detection and keyword analysis. Lastly, the key findings are concluded in the last section. The suggestions for future research directions are also discussed in this section.

Number of Publications and Co-Citation Analysis About "China Subtropical Climate Change"

Number of Publications

The number of publications about the topic "China subtropical climate change" directly reflects the development process of this research field. Besides, it is also an obvious evidence to demonstrate whether this research topic is gaining increasing attention of scholars around the world. In this study, the articles on WoS that investigate China subtropical climate change between 1990 and 2017 are analyzed in detail, including the number of the articles and the most cited articles in different development stages.

Figure 1 illustrates the number of publications about the topic China subtropical climate change from 1990 to 2017. It is obvious that the literature on this topic are increasing as time goes by. To analyze the change in publication amount, this article divides the whole period into three phases: the initial phase, the development phase, and the rapid growth phase.

(a) The initial phase (1998–2002). It can be seen from Figure 1 that the articles about China subtropical climate change in this time period are obviously less than which in other stages. The publication amount is growing at a slow pace, from 2 papers in 1990 to 10 papers in 2002. Although there are only 30 papers get published in this phase, some of them significantly impact this research field and even provide a theoretical basis for other-related researches in the next few years. For instance, the paper entitled "East Asian monsoon climate during the Late Pleistocene: high-resolution sediment records from the South China Sea" (L. Wang et al., 1999) has 446 citations according to the record on WoS. This paper introduces the clues of past changes in East Asian monsoon climate by studying 10 sediment cores and 40 core-top samples from the South China Sea, which made theoretical contributions in terms of the method that investigates climate change in a long history and the specific climate change in China subtropical areas over the last 220,000 years.

(b) The development phase (2003–2008). It can be clearly seen from Figure 1 that there are some fluctuations for the number of publications in this stage. However, the citation amount climbed stably, indicating

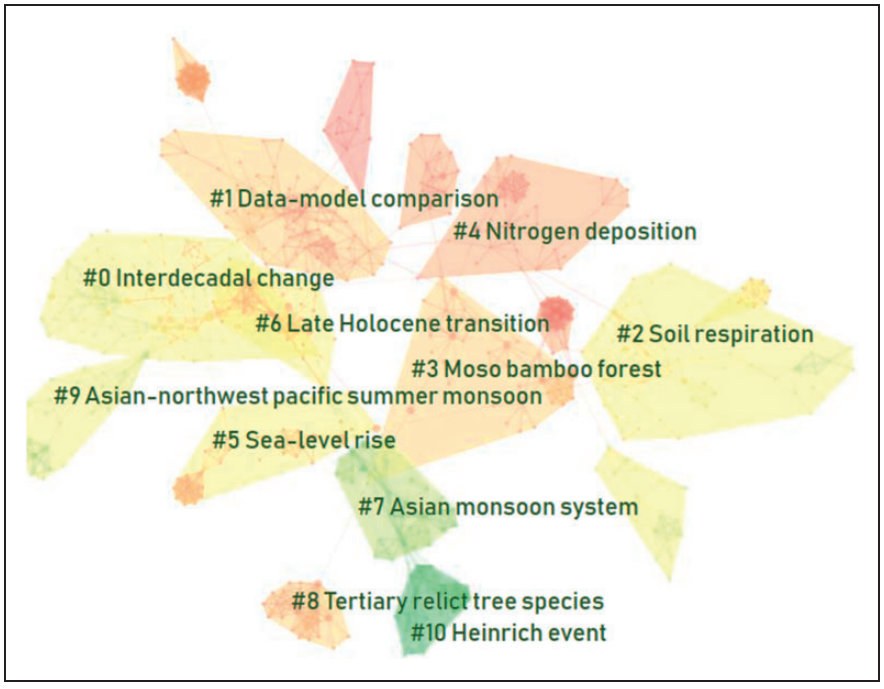

Figure 2. Cluster network of China subtropical climate change research.

this research field was gaining increasing attention. At the beginning of 21st century, many articles analyze on Asian monsoon (Ding & Chan, 2005; D. Yuan et al., 2004) were published with significant influence in this field. Thus, Asian monsoon can be one of the important elements that impact the climate change in China subtropical areas.

(c) The rapid growth phase (2009–2017). In this stage, both the citation and publication numbers increase rapidly. The issue of climate change has become important than before. South China has experienced several heavy rainstorms since 2015. In the same year, a Chinese journalist Jing Chai released a documentary named *Under the Dome* garnered over 150 million views in China, sparking widespread discussion about pollution and environmental policy in China. Climate change has become a hot topic not only for the scholars in this field but also for the public in China or even in the world. The literature related to China subtropical climate change in this phase has become more diverse. Some interesting literatures investigated the relationships between climate change and rice fields (Welch et al., 2010), the mortality in Guangzhou, China (Yang et al., 2013), and carbon fluxes (Yu et al., 2013).

Based on the aforementioned analysis, the research field of China subtropical climate change has been gaining increasing attention in the nearly 30 years. More natural impacts of climate change were discussed in the early articles, while more human factors were considered in the recent researches with the development of the society.

Co-Citation Analysis

Data collection for using CiteSpace. First, WoS is selected as the data source for bibliometric analysis because it is a huge platform that provides an access for readers to know specific information about the articles published in roughly 12,000 leading journals worldwide, which includes the Science Citation Index Expanded, the social sciences citation index, and the arts & humanities citation index databases (Van-Leeuwen, 2006). Then, by searching the topic "China subtropical climate change," 1,069 publications related to China subtropical climate change are found. To eliminate "noise" that may affect the accuracy of research results, the papers published in some databases such as Conference Proceedings Citation Index-Science, Emerging Sources Citation Index, and Book Citation Index-Science are filtered out. Ultimately, there are 926 papers about China subtropical climate change which were published between 1990 and 2017. The period (1990–2017) is chosen for two major reasons: (a) According to the search results on WoS, the earliest record related to China subtropical climate change is in 1990 and (b) as aforementioned, the related literatures have been increasing dramatically in the nearly 30 years. Therefore, it is more meaningful to investigate the research field of China subtropical climate change between 1990 and 2017 than which in other time periods.

Cluster network and the most cited articles. Co-citation can be explained as the frequency of two earlier literatures

being cited together by the later literature (Small, 1973). To better understand the mechanism of specialty development, co-citation analysis is introduced as a useful tool which identifies prominent journals, articles, and authors. The co-citation analysis of China subtropical climate change research can be obtained by utilizing CiteSpace, which can be seen from Figure 2. The articles with co-citations are divided into several clusters to make it easier for readers to know the main research areas. Detailed results about the main clusters and the most cited articles with co-citation frequency are shown in Tables 1 and 2, respectively.

Figure 2 shows the co-citation network based on the 926 references between 1990 and 2017. The corresponding data can be seen from Table 1 which lists the top 10 clusters of this research area. In Table 1, the size means the number of publications in the cluster. The log-likelihood ratio is an algorithm to calculate each label and it is also the core concept that summarizes each cluster. Moreover, the silhouette score is used to test the homogeneity of clusters. Basically, if a silhouette is greater than 0.5, then the corresponding result is reliable. The largest value of a silhouette is 1, so if the silhouette of a cluster is near to 1, the result is considered to be more reliable. According to Table 1, almost all of the silhouette scores are above 0.9, which suggests a reliable quality of each cluster. The largest cluster is no. 0 interdecadal change with 79 member references. As for the mean cite year, most of the clusters are new, but no. 7 Asian monsoon system and no. 9 Asian-northwest pacific summer monsoon are relatively old.

By knowing the top 10 clusters in China subtropical climate change research area, the top 10 cited articles with co-citation frequency of over 15 times and their clusters are demonstrated in Table 2. According to Chen, Hu, Liu, and Tseng (2012), the most cited papers have significant contributions for certain research area. Therefore, it can be seen from Table 2 that the most cited article is from no. 0 with 32 citations. This article is "How well do atmospheric general circulation models capture the leading modes of the interannual variability of the Asian-Australian monsoon?" which was written by T. J. Zhou, Bo, and Wang (2009). The authors evaluated the performance of atmospheric general circulation models and simulated the interannual variability of the Asian-Australian monsoon. Similarly, Ding, Wang, and Sun (2008) analyzed the interdecadal change of summer precipitation in East China and its relationship with the Asian summer monsoon. The atmospheric changes happen in certain time periods, the time periods here are always older than 10 years. It is crucial to capture the characteristics and reveal various connections in these atmospheric changes of Asian monsoon.

Climate change can impact the ecosystems in subtropical areas of China. Therefore, Piao et al. (2009) investigated the terrestrial carbon balance of China and its driving mechanisms during the 1980s and 1990s. G. Zhou et al. (2011) pointed out that climate change has caused more extreme hydrological risks such as droughts and floods in some watershed or other areas of Southern China. G. Zhou et al. (2013) analyzed how the monsoon evergreen broad-leaved forest reacts when facing global warming and drought stress. This research found that subtropical forests are threatened due to the lack of resilience against the climate change in a long time period.

Table 2. Top 10 Ranked Articles by Citation Counts.

Citation counts	References	Cluster no.
32	T. J. Zhou et al. (2009)	0
20	G. Zhou et al. (2011)	3
20	Piao et al. (2009)	5
19	G. Zhou et al. (2013)	3
18	Uppala et al. (2005)	0
18	Pan et al. (2011)	5
17	Ding et al. (2008)	0
16	Solomon (2007)	0
16	D. Yuan et al. (2004)	7
15	Davidson and Janssens (2006)	2

Table 1. Summary of the Largest 10 Clusters.

Cluster ID	Size	Silhouette	Label (log-likelihood ratio)	Mean (year)
0	79	0.910	Interdecadal change	2007
1	66	0.914	Data-model comparison	2011
2	59	0.982	Soil respiration	2006
3	41	0.822	Moso bamboo forest	2011
4	40	0.911	Nitrogen deposition	2013
5	33	0.974	Sea-level rise	2009
6	32	0.921	Late Holocene transition	2009
7	32	0.975	Asian monsoon system	2002
8	27	0.999	Tertiary relict tree species	2010
9	26	0.987	Asian-northwest pacific summer monsoon	2003

Through the analysis of cluster network and the most cited articles, the literatures that explore or evaluate the methods to capture characteristics of the Asian monsoon which causes atmospheric changes have made great theoretical contributions in this field. Meanwhile, the researches analyze the specific impacts of climate change and how the ecosystem responds to climate change in China subtropical areas are also of great significance for the further investigations.

Countries or Regions, Journals, Institutions, and Authors With Lots of Contribution

It is obvious that the more research outputs which were published by a country or region, journal, institution, and author, the more contributions they made in this research area. As aforementioned, the number of publications can directly indicate the development of a certain research area; it is also able to clearly show the academic contributions made by a country and or by an author. More importantly, the most productive counties or regions may face the issues of climate change, and the most productive institutions are mainly from those countries or regions. Besides, the papers written by the prolific authors are of great influence in China subtropical climate change research.

Productive Countries or Regions and Institutions

The most productive countries or regions and institutions are identified by using the records of WoS, which makes the results more accurate and objective. Based on the results given by WoS and CiteSpace, further discussion can be seen later.

The top 10 countries or regions with most of the literature about China subtropical climate change are listed in Table 3. Obviously, China occupies a prominent position in this research field. The reason is clear to see. This research specifically focuses on climate change in the subtropical areas in China. Also, China is experiencing climate change issues in the recent 30 years. As aforementioned, the Asian monsoon is one of the important factors that cause climate change in the subtropical areas of China. It also partly influences the climate in Japan, South Korea, Russia, and Australia. Therefore, these countries are also involved in this research field.

Although the impact of the Asian monsoon in the United States is neglectable, climate change happens in this country as well. Thus, investigating climate change in the subtropical areas of China is not only for Chinese scholars or institutions but also for other countries to reveal more valuable findings for the sake of the ecosystem, sustainable development, and humanity.

Table 3. Top 10 Productive Countries in China Subtropical Climate Change Research Field.

Countries and regions	Number	Percentage
China	768	82.94
United States	234	25.27
Australia	55	5.94
Germany	54	5.83
Taiwan, China	43	4.64
Japan	41	4.43
Canada	32	3.46
South Korea	28	3.02
England	24	2.59
France	15	1.62

Figure 3 presents the significant national collaboration network in this research field. The structure of this network indicates the maturity of the national collaborations. If the structure is relatively tight and close, then the collaborations among the corresponding countries are more mature. Based on the national network, it is clear to see the mature and close collaborations among the countries listed in Table 3. For instance, the construction of the Intergovernmental Panel on Climate Change indicates the co-operation among scholars around the world.

From Table 4, all of the top 10 productive institutions in China subtropical climate change research field come from China. Among these institutions, most of them belong to the Chinese Academy of Sciences. Without a doubt, the Chinese Academy of Sciences made great contributions in this research field.

Productive Journals and Authors

The top 10 prolific journals and their impact factors in 2017 are listed in Table 5. *Journal of Climate* is leading the research of China subtropical climate change with the publication number of 39. Compared with other nine journals, *Journal of Climate* has the highest value of impact factor. Therefore, this journal made great contributions to this research field. Some articles published in this journal are also influential due to their large amount of citations. For example, the paper entitled "Decadal change of the spring snow depth over the Tibetan Plateau: The associated circulation and influence on the East Asian summer monsoon" was written by Zhang, Li, and Wang (2004). The authors found that the growth of snow depth over the Tibetan Plateau from March to April leads to a wetter summer rainfall over the Yangtze River valley and a dryer summer rainfall in the southeast coast of China. The paper reasonably explained one of the various reasons that cause the climate change in some subtropical areas of China.

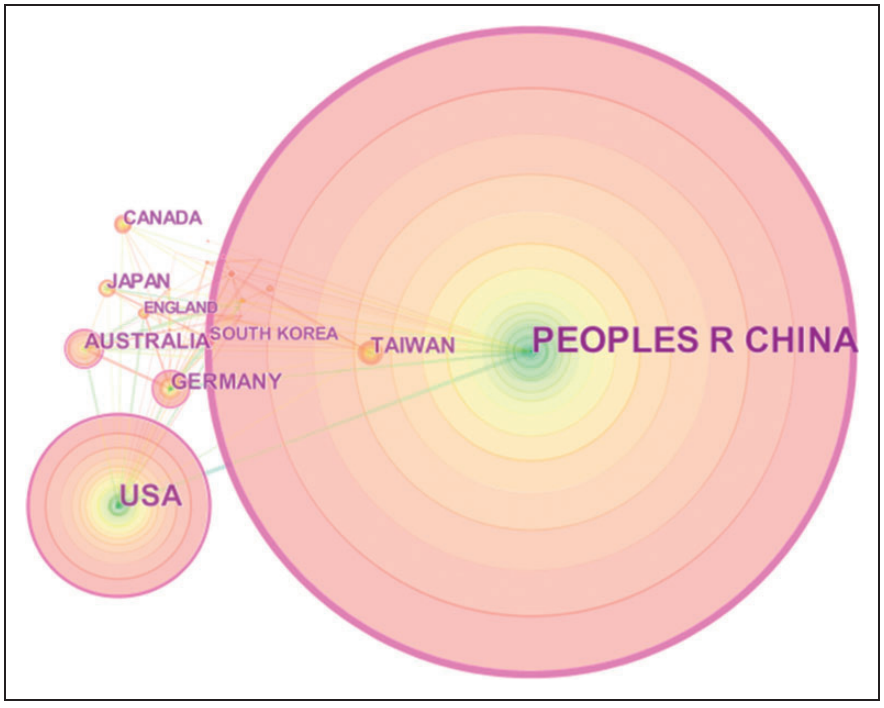

Figure 3. Significant national collaboration network.

Table 4. Top 10 Productive Institutions in China Subtropical Climate Change Research Field.

Institutions	Number of publications	Percentage
Chinese Academy of Sciences	442	47.73
University of Chinese Academy of Science CAS	139	15.01
South China Botanical Garden CAS	67	7.24
Institute of Atmospheric Physics CAS	65	7.02
Institute of Geographic Sciences Natural Resources Research CAS	57	6.16
Nanjing University	42	4.54
Nanjing University of Information Science Technology	41	4.43
Institute of Botany CAS	36	3.89
China Meteorological Administration	31	3.35
Peking University	27	2.92

Note. CAS = Chinese Academy of Sciences.

Table 5. Top 10 Productive Journals in China Subtropical Climate Change Research Field.

Journals	Number of publications	Impact factor
Journal of Climate	39	4.661
PLoS One	32	2.766
Palaeogeography Palaeoclimatology Palaeoecology	29	3.375
Journal of Geophysical Research Atmospheres	27	3.380
Scientific Reports	26	4.122
Quaternary International	20	2.163
Advances in Atmospheric Sciences	18	1.869
Chinese Science Bulletin	17	1.649
Climate Dynamics	17	3.774
Theoretical and Applied Climatology	17	2.321

Besides, the articles published by other journals also made considerable contributions to this research area, such as "Atmospheric water vapor transport associated with typical anomalous summer rainfall patterns in China" (Zhou & Yu, 2005) published by *Journal of Geophysical Research Atmospheres* also explained climate change from another point of view. However, it should be noted that even though some articles are published by other journals such as *Nature, Science and Marine Geology*, they also significantly influence the research directions in this field.

The top 10 productive authors are listed in Table 6. Zhou is the most productive author in China subtropical climate change research field. Based on the search method mentioned earlier, the results of WoS showing that there are 31 papers written by Zhou, 7 of them are published by *Global Change Biology*. Besides, Liu, Wen, and Zhang also devote themselves to this research area with the research outputs for 20, 19, and 19, respectively. Specifically, the details about significant author

collaborations are shown in Figure 4. It can be seen that the authors in this area have strong and frequent collaborations. Take the most productive author Zhou as an example, he frequently collaborates with Liu and Zhang who are also the productive authors listed in Table 6. The collaboration among these scholars accounts for 69.29% of Zhou's research outputs.

It should be pointed that the number of publications here for every listed author is not the actual amount of papers written by them. It is possible that some papers cannot be searched by WoS, or some papers are filtered out based on the search method for this study.

Table 6. Top 10 Productive Authors in China Subtropical Climate Change Research Field.

Authors	Number of publications	Percentage
G. Y. Zhou	31	3.35
J. X. Liu	20	2.16
X. F. Wen	19	2.05
D. Q. Zhang	19	2.05
G. R. Yu	17	1.84
X. M. Sun	16	1.73
H. M. Wang	16	1.73
J. H. Yan	16	1.73
H. J. Wang	14	1.51
J. Wang	13	1.40

Emerging Trends of China Subtropical Climate Change Research

The emerging trends are also what scholars concern about in the scope of China subtropical climate change research as they give scholars some inspirations in terms of new research directions and cutting-edge methodologies. The emerging trends in this research area also reflect the hydrological cycles or human activities that impact climate change during the corresponding time period.

Therefore, several interesting points can be found by analyzing the results given by CiteSpace. In this section, the reference burst detection and the keyword analysis are illustrated to show articles that have received rapid increases in citations.

Reference Burst Detection

To know the emerging trends of China subtropical climate change research, the reference burst detection is

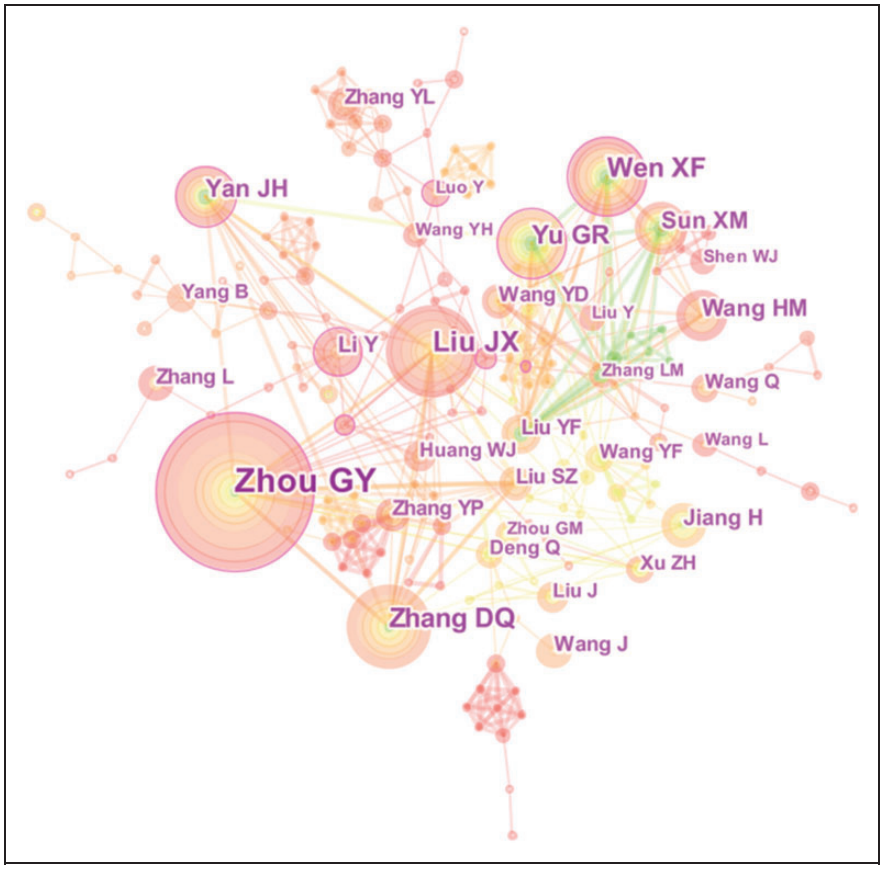

Figure 4. Significant author collaboration network.

Table 7. Top 20 References With Strongest Citation Bursts.

References	Strength	Begin	End	1989–2018
Kalnay et al. (1996)	4.0429	2000	2004	
Wang et al. (2001)	8.4390	2004	2008	
Hu et al. (2003)	5.6580	2005	2010	
Yuan et al. (2004)	6.0916	2005	2012	
Guo et al. (2002)	3.6112	2005	2010	
Uppala et al. (2005)	6.2854	2007	2013	
Zhai et al. (2005)	4.2173	2008	2013	
Yu et al. (2004)	5.6500	2008	2011	
Solomon (2007)	6.1932	2009	2012	
Wang et al. (2005)	5.0039	2010	2012	
Xie et al. (2009)	4.7613	2010	2013	
Tang et al. (2006)	4.7613	2010	2013	
Zhou and Yu (2005)	4.6863	2011	2013	
Davidson and Janssens (2006)	4.7709	2012	2014	
Yancheva et al. (2007)	3.6987	2014	2015	
Bonan (2008)	4.5777	2015	2017	

utilized in this study. As shown in Table 7, there are 20 references with strong citation bursts in a certain period of time between 1990 and 2017.

It is obvious to see that the earliest burst in this research period started from 2000. The paper with the earliest citation burst is about the NCEP/NCAR reanalysis project for 40 years (1957–1996; Kalnay et al., 1996). This project was established to analyze atmospheric fields which support related researches and climate monitoring communities. NCEP/NCAR reanalysis is a useful tool for researchers to investigate the climate change in subtropical areas of China (Cheng et al., 2005; Chu, Kim, & Chen, 2012; Infantes, Campo, Villaseñor, & Fernández, 2012).

According to the citation burst result, the paper that has the longest citation burst was written by Yuan et al. (2004). This paper focuses on the features of the last interglacial Asian monsoon. As mentioned earlier, not only is this paper important in the development phase of this research area with numerous citations but it is also the core research output in no. 7. The literature with the latest citation burst is "Forests and climate change: Forcings, feedbacks, and the climate benefits of forests" (Bonan, 2008). The author found that tropical, temperate, and boreal reforestation can decrease the disasters brought by global warming through carbon sequestration. Although this article does not specifically investigate the climate change in the subtropical areas of China, the findings can be further investigated taking the subtropical areas as the research context. It can be seen that this article was written in 10 years ago, but the citation burst happened in 2017 which can even possibly last for the next few years and become one of the hot spots. Based on the earlier analysis, global warming has become an important factor that impacts climate change around the world, and forests are playing a role to attenuate global warming.

Keyword Analysis of China Subtropical Climate Change

When talking about climate change, what springs out from people's minds? Perhaps some short words such like drought, flood, and extreme weathers can briefly conclude how they consider about climate change, or they may not just consider about these situations, they are actually suffering from some unpredictable disasters brought by climate change. Thus, keywords do not merely summarize the core concepts of an article, they may reflect some current issues or emerging trends behind the research. To directly know the research area of China subtropical climate change and reveal the focuses that related to the current issues in different time periods, the timeline view of keywords is presented in Figure 5. The analysis of keyword timeline is an effective way to show emerging trends and track topics of research over time because the timeline of keywords gives a succinctness and accurate high-level summarization of document. The changes in research topics have become an important research issue, which can help researchers to gain deeper insights into the development of a particular research field. The early keywords are presented at the left side, or vice versa.

As shown in Figure 5, the purple circles represent the key studies that are high in between centrality. It can be found that there are many keywords from 1990 to 2017. In recent years, many researchers focus on the cluster (no. 0) "AMIP model" and the cluster (no. 1) "CO_2 fertilization." "global monsoon region" is the significant keyword in no. 0. The term AMIP is Atmospheric Model Intercomparison Project which can be utilized to evaluate the radiative forcing and climate effect of short-lived chemical species in the atmosphere. J. Li and Zhang (2009) applied AMIP models to simulate the performance of the wind onset and withdrawal of the Asian summer monsoon. Also, by using AMIP simulations, W. H. Yuan (2013) found that the convection parameterization leads the main biases in rainfall diurnal cycles over subtropical China. The close relationship between the diurnal variation of convective rainfall and the closure of the convective scheme was further pointed. Besides, no. 1 "CO_2 fertilization" is also the main research direction of China subtropical climate change area. "vegetation feedback," "typical ecosystem," and "light use efficiency" are the significant keywords in this cluster. CO_2 fertilization is one of the tools for people to respond to the impacts brought by

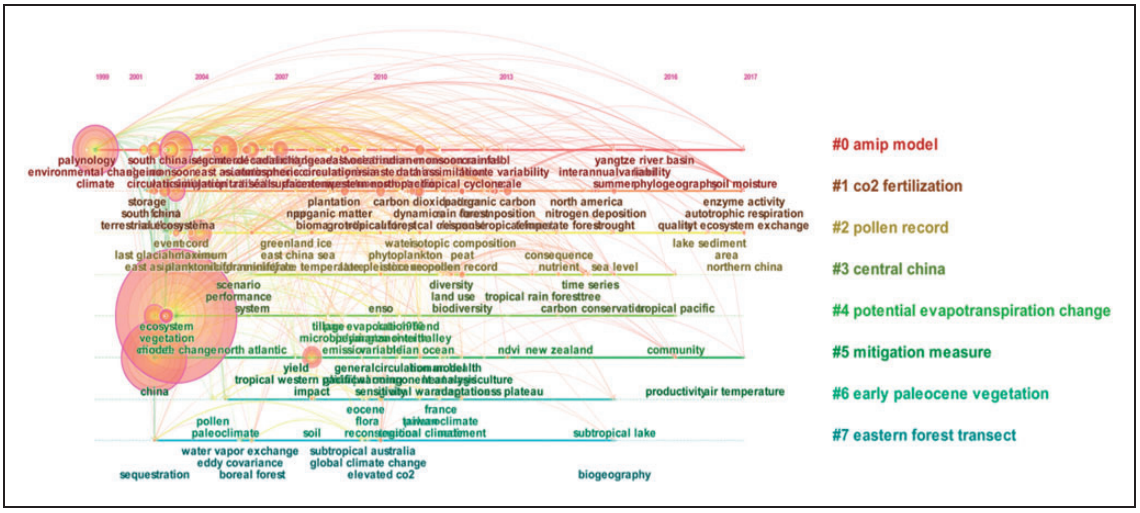

Figure 5. Timeline view of keywords.

climate change. However, Zhu et al. (2011) found that the increase of CO_2 concentration will have little contribution to vegetation changes. By studying the subtropical forest in central China, Xu, Li, Shao, Xu, and Nugroho (2014) pointed out that there are some negative elements that influence tree growth such as climate change (especially warming-induced drought) and nutrient limitation which overwhelmed the CO_2 fertilization effects in the past 30 years. From Figure 5, we can find that most related researches about CO_2 fertilization were published before 2013. Global warming phenomena have been broadly spread around the world. There are diverse agricultural industries and lots of forests in the subtropical areas of China which also have been significantly impacted by global warming. The unstable climate leads the reduction of agricultural outputs and negative impacts on the ecosystem. Therefore, CO_2 fertilization is introduced to deal with this issue and make the ecosystem as stable as possible, but the CO_2 fertilization effects are not significant based on the findings given by the above researches. Another large cluster is no. 2 "pollen record," "global monsoon region" and "typical ecosystem" are the significant keywords in this cluster. The lines connecting different nodes are the relations among different research outputs.

It can be clearly seen that most of the recent researches are on the basis of the early investigations. The keywords such as "sea surface temperature," "interannual variability," and "Indian monsoon rainfall" mentioned in the literature published between 2004 and 2010 have strong relations with the keywords discussed in other time periods. "soil moisture", "net ecosystem exchange," "autotrophic respiration," "lake sediment," and "air temperature" are the keywords which are presented in the latest papers of China subtropical climate change research area. They can be also considered as the recent research directions.

According to the results of citation bursts and the timeline view of keywords, it can be found that the researches related to the Asian monsoon attracted researchers' attention for a longer period compared with other topics. While global warming is becoming a hot issue in recent years. It is possible that global warming will also be the research directions in the next few years. Other keywords such as AMIP model, CO_2 fertilization, and sea surface temperature are also the focuses in the research area of China subtropical climate change. They reflect the dynamic changes of the natural environment and human activities.

Conclusions

This article investigates the current state and emerging trends of China subtropical climate change research by using CiteSpace. There are 926 kinds of literature retrieved from WoS which are published between 1990 and 2017. Based on the earlier results, the findings of this article are concluded as follows. First, the number of China subtropical climate change research outputs has been growing in recent years, especially from 2009 to 2017. The issue of China subtropical climate change is becoming significant in ecosystem research. Second, China, the United States, Australia, and Germany are the biggest contributors to this research field due to the specific research context. Besides, most of the institutions with great contributions to China subtropical climate change research are from these countries as well, especially from China. Third, *Journal of Climate* is the most productive journal which has published numerous articles related to this research field. However, other journals such as *Nature and Science* may publish less

literature about China subtropical climate change, but these articles also greatly impact the further related investigations. Meanwhile, the hot topics of this research area are AMIP model, CO_2 fertilization, and pollen record. AMIP model is utilized to evaluate the radiative forcing and climate effect of short-lived chemical species in the atmosphere which helps researchers learn more about the details of atmospheric changes and characteristics. There are also some discussions about CO_2 fertilization effects. The effectiveness of CO_2 fertilization is different in various environments. For example, CO_2 concentration positively affects the corn yields in Thailand, but its effect is not significant for the forests in the subtropical areas of China. Besides, pollen records provide important clues for scholars to investigate climate change. Based on the earlier analyses, atmospheric changes, global warming, and vegetation response are the hot issues that have been investigated by the scholars in China subtropical climate change research area. In addition, "soil moisture," "net ecosystem exchange," "autotrophic respiration," "lake sediment," and "air temperature" are the specific research directions of recent literature which can be also considered as the emerging trends of this research area.

It is worth researching on China subtropical climate change because China is playing a vital role in dealing with global climate change. The investigations on climate change in subtropical areas of China are meaningful for scholars to further analyze the Asian monsoon which greatly impacts the climate in Asia Pacific regions. Moreover, because of the development of global society, some human activities have been negatively influencing the ecosystem. Various environmental problems caused by climate change have become severer than ever before. It is crucial for people to learn more about climate change and its related researches to realize that our environment is being changed, and we are playing a vital role to change the ecosystem. In sum, this article provides an overall analysis of the current state and emerging trends in China subtropical climate change research area, which helps people to learn more about the climate change in the subtropical areas of China and inspires researchers who are interested in this research field.

One of the limitations of this study is that the data retrieved from WoS are not accurate enough. Some literature involved in this study are related to climate change, but the climate change in the subtropical areas of China is not specified in the scope of consideration of the literature which slightly influences the result. In the future research, the data search method should be improved to make the results more accurate. Besides, the knowledge mapping about the climate change in Asian Pacific regions is also of a great value for further global climate investigations.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Natural Science Foundation of China (Nos. 71561026 and 71873118) and Social Science Youth Foundation of Ministry of Education of China (No. 18YJC790118).

References

Bale, J. S., Masters, G. J., Hodkinson, I. D., Awmack, C., Bezemer, T. M., & Brown, V. K., et al. (2002). Herbivory in global climate change research: Direct effects of rising temperature on insect herbivores. *Global Change Biology*, *8*(1), 1–16.

Bonan, G. B. (2008). Forests and climate change: Forcings, feedbacks, and the climate benefits of forests. *Science*, *320*(5882), 1444–1449.

Brewer, P. R., & Mcknight, J. (2017). "A statistically representative climate change debate": Satirical television news, scientific consensus, and public perceptions of global warming. *Atlantic Journal of Communication*, *25*(3), 166–180.

Chen, C. M. (2004). Searching for intellectual turning points: Progressive knowledge domain visualization. *Proceedings of the National Academy of Sciences of the United States of America*, *101*(Suppl 1), 5303–5310.

Chen, C. M. (2006). CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. *Journal of the American Society for Information Science and Technology*, *57*(3), 359–377.

Chen, C. M., Hu, Z., Liu, S., & Tseng, H. (2012). Emerging trends in regenerative medicine: A scientometric analysis in CiteSpace. *Expert Opinion on Biological Therapy*, *12*(5), 593–608.

Cheng, Y., Lohmann, U., Zhang, J., Luo, Y., Liu, Z., & Lesins, G. (2005). Contribution of changes in sea surface temperature and aerosol loading to the decreasing precipitation trend in southern China. *Journal of Climate*, *18*(9), 1381–1390.

Chu, P. S., Kim, J. H., & Chen, Y. R. (2012). Have steering flows in the western north pacific and the South China sea changed over the last 50 years? *Geophysical Research Letters*, *39*(10), 10704.

Davidson, E. A., & Janssens, I. A. (2006). Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. *Nature*, *440*(7081), 165–173.

Dennis, R. L. H. (1993). Butterflies and climate change. *Global Change Biology*, *6*(4), 407–416.

Ding, Y., & Chan, J. C. L. (2005). The East Asian summer monsoon: An overview. *Meteorology & Atmospheric Physics*, *89*(1-4), 117–142. doi: 10.1007/s00703-005-0125-z

Ding, Y., Wang, Z., & Sun, Y. (2008). Inter-decadal variation of the summer precipitation in east China and its

association with decreasing Asian summer monsoon. Part I: Observed evidences. *International Journal of Climatology*, *28*(9), 1139–1161. doi: 10.1002/joc.1615

Fang, Y., Yin, J., & Wu, B. (2017). Climate change and tourism: A scientometric analysis using CiteSpace. *Journal of Sustainable Tourism*, *26*(1), 108–126.

Grumbine, R. E. (2007). China's emergence and the prospects for global sustainability. *Bioscience*, *57*(3), 249–255.

Guo, Z. T., Ruddiman, W. F., Hao, Q. Z., Wu, H. B., Qiao, Y. S., & Zhu, R. X., et al. (2002). Onset of Asian desertification by 22 Myr ago inferred from loess deposits in China. *Nature*, *416*(6877), 159.

Heggelund, G. (2007). China's climate change policy: Domestic and international developments. *Asian Perspective*, *31*(2), 155–191.

Hu, Z., Yang, S., & Wu, R. (2003). Long-term climate variations in China and global warming signals. *Journal of Geophysical Research Atmospheres*, *108*(D19), 8897–8900

Hong, D., & Zhang, Q. (2018). Coping with climate change: China's efforts and their sociological significance. *Contemporary Social Sciences*, *2018*(02):56–68.

Hughes, I. I. (2000). Biological consequences of global warming: Is the signal already apparent? *Trends in Ecology & Evolution*, *15*(2), 56–61.

Infantes, D., Campo, A. G. D., Villaseñor, J., & Fernández, F. J. (2012). Analysis of characteristics of a sharp turn from drought to flood in the middle and lower reaches of the Yangtze river in spring and summer in 2011. *Acta Physica Sinica*, *61*(10), 66–72.

Jang, S. M., & Hart, P. S. (2015). Polarized frames on "climate change" and "global warming" across countries and states: Evidence from twitter big data. *Global Environmental Change*, *32*, 11–17. doi:10.1016/j.gloenvcha.2015.02.010

Jones, T. (2008). An integrated assessment of climate change impacts on China water resources. *Advances in Water Science*, *19*(6), 772–779.

Kalnay, E., Kanamitsu, M., Kistler, R., Collins, W., Deaven, D., & Gandin, L., et al. (1996). The NCEP/NCAR 40-year reanalysis project. *Bulletin of the American Meteorological Society*, *77*(3), 437–472.

Li, J., & Zhang, L. (2009). Wind onset and withdrawal of Asian summer monsoon and their simulated performance in AMIP models. *Climate Dynamics*, *32*(7-8), 935–968.

Li, M., Tian, C. S., Wang, Y. K., Liu, Q., Lu, Y. F., & Wang, S. (2018). Impacts of future climate change (2030-2059) on debris flow hazard: A case study in the Upper Minjiang River basin, China. *Journal of Mountain Science*,*15*(08), 1836–1850.

Li, W., Li, X., Tan, M., & Wang, Y. (2017). Influences of population pressure change on vegetation greenness in China's mountainous areas. *Ecology & Evolution*, *7*(21), 9041–9053.

Liu, Q., & Jiang, H. (2018). Research hotspots and frontiers as regard to forest in response to climate change-quantitative research based on CiteSpace . *Journal of Arid Land Resources & Environment*, *2018*(01), 42–48.

Lykhovyd, P. V. (2018). Global warming inputs in local climate changes of the Kherson region: Current state and forecast of the air temperature. *Ukrainian Journal of Ecology*, *8*(2), 39–41.

Ma, T., Zheng, Z., Man, M. L., Dong, Y. X., Li, J., & Huang, K. Y. (2018). Holocene fire and forest histories in relation to climate change and agriculture development in southeastern China. *Quaternary International*, *2018*(09), 30–40. doi:10.1016/j.quaint.2017.07.035]

Mi, Z. F., Wei, Y. M., He, C. Q., Li, H. N., Yuan, X. C., & Liao, H. (2017). Regional efforts to mitigate climate change in China: A multi-criteria assessment approach. *Mitigation & Adaptation Strategies for Global Change*, *22*(1), 45–66. doi:10.1007/s11027-015-9660-1

Pan, Y. D., Birdsey, R. A., Fang, J. Y., Houghton, R., Kauppi, P. E., & Kurz, W. A., et al. (2011). A large and persistent carbon sink in the world's forests. *Science*, *333*(6045), 988–993.

Parmesan, C., Gaines, S., Gonzalez, L., Kaufman, D. M., Kingsolver, J., & Peterson, A. T., et al. (2005). Empirical perspectives on species borders: From traditional biogeography to global change. *Oikos*, *108*(1), 58–75.

Parmesan, C., & Yohe, G. (2003). A globally coherent fingerprint of climate change impacts across natural systems. *Nature*, *421*(6918), 37–42.

Peñuelas, J., & Filella, I. (2001). Responses to a warming world. *Science*, *294*(5543), 793–795.

Piao, S., Fang, J., Ciais, P., Peylin, P., Huang, Y., & Sitch, S., et al. (2009). The carbon balance of terrestrial ecosystems in China. *Nature*, *458*(7241), 1009–1013.

Shiffrin, R. M., & Börner, K. (2004). Mapping knowledge domains. *Proceedings of the National Academy of Sciences*, *101*(suppl 1), 5183–5185.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., & Averyt, K. B., et al. (2007). Climate change 2007: The physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Summary for policymakers. *Computational Geometry*, *18*(2), 95–123.

Streets, D. G., Jiang, K., Hu, X., Sinton, J. E., Zhang, X. Q., & Xu, D., et al. (2001). Climate change-recent reductions in China's greenhouse gas emissions. *Science*, *294*(5548), 1835–1837. doi:10.1126/science.1065226

Tang, X., Liu, S., Zhou, G., Zhang, D., & Zhou, C. (2010). Soil-atmospheric exchange of co2, ch4, and n2o in three subtropical forest ecosystems in southern China. *Global Change Biology*, *12*(3), 546–560.

Tao, F., Yokozawa, M., Liu, J. Y., & Zhang, Z. (2009). Climate change, land use change, and China's food security in the twenty-first century: An integrated perspective. *Climatic Change*, *93*(3-4), 433–445. doi:10.1007/s10584-008-9491-0

Taşkın, Z., & Aydinoglu, A. U. (2015). Collaborative interdisciplinary astrobiology research: A bibliometric study of the NASA astrobiology institute. *Scientometrics*, *103*(3), 1003–1022.

Uppala, S. M., Kållberg, P. W., Simmons, A. J., Andrae, U., Bechtold, V. D. C., & Fiorino, M., et al. (2005). The ERA-40 re-analysis. *Quarterly Journal of the Royal Meteorological Society*, *131*(612), 2961–3012.

Van Leeuwen, T. (2006). The application of bibliometric analyses in the evaluation of social science research. Who benefits from it, and why it is still feasible. *Scientometrics*, *66*(1), 133–154.

Wang, J., Mendelsohn, R., Dinar, A., Huang, J., Rozelle, S., & Zhang, L. (2010). The impact of climate change on China's agriculture. *Agricultural Economics*, *40*(3), 323–337.

Wang, J. N., Yan, G., Jiang, K. J., Liu, L. C., Yang, J. T., & Ge, C. Z. (2009). The study on China's carbon tax policy to mitigate climate change. *China Environmental Science*, *29*(1), 101–105.

Wang, L., Sarnthein, M., Erlenkeuser, H., Grimalt, J., Grootes, P., & Heilig, S., et al. (1999). East Asian monsoon climate during the late Pleistocene: High-resolution sediment records from the South China sea. *Marine Geology*, *156*(1–4), 245–284. doi:10.1016/S0025-3227(98)00182-0

Wang, Y. J., Cheng, H., Edwards, R. L., An, Z. S., Wu, J. Y., & Shen, C. C., et al. (2001). A high-resolution absolute-dated late pleistocene monsoon record from Hulu cave, China. *Science*, *294*(5550), 2345–2348.

Wang, Y. J, Cheng, H., Edwards, R. L., He, Y., Kong, X., & An, Z., et al. (2005). The holocene asian monsoon: links to solar changes and North Atlantic climate. *Science*, *308*(5723), 854–857.

Wang, Y. J., Cheng, H., Edwards, R. L., Kong, X., Shao, X., & Chen, S., et al. (2009). Millennial-and orbital-scale changes in the east Asian monsoon over the past 224,000 years. *Nature*, *451*(7182), 1090–1093.

Welch, J. R., Vincent, J. R., Auffhammer, M., Moya, P. F., Dobermann, A., & Dawe, D. (2010). Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures. *Proceedings of The National Academy of Sciences of The United States of America*, *107*(33), 14562–14567.

Xie, S. P., Hafner, J., Tokinaga, H., Du, Y., Sampe, T., & Hu, K. M., et al. (2009). Indian ocean capacitor effect on indo-western pacific climate during the summer following el niño. *Journal of Climate*, *22*(3), 730–747.

Xu, Y., Li, W., Shao, X., Xu, Z., & Nugroho, P. (2014). Long-term trends in intrinsic water-use efficiency and growth of subtropical Pinus tabulaeformis Carr. and Pinus taiwanensis Hayata in central China. *Journal of Soils & Sediments*, *14*(5), 917–927.

Yan, Y. F., & Yang, L. K. (2010). China's foreign trade and climate change: A case study of CO2 emissions. *Energy Policy*, *38*(1), 350–356.

Yancheva, G., Nowaczyk, N. R., Mingram, J., Dulski, P., Schettler, G., & Negendank, J. F. W., et al. (2007). Influence of the intertropical convergence zone on the East Asian monsoon. *Nature*, *445*(7123), 74–77.

Yang, J., Liu, H. Z., Ou, C. Q., Lin, G. Z., Zhou, Q., & Shen, G. C., et al. (2013). Global climate change: Impact of diurnal temperature range on mortality in Guangzhou, China. *Environmental Pollution*, *175*(175C), 131–136.

Yu, D. J., Li, D. F., Merigo, J. M., & Fang, L. (2016). Mapping development of linguistic decision making studies. *Journal of Intelligent & Fuzzy Systems*, *30*(5), 2727–2736.

Yu, G. R., Zhu, X. J., Fu, Y. L., He, H. L., Wang, Q. F., & Wen, X. F., et al. (2013). Spatial patterns and climate drivers of carbon fluxes in terrestrial ecosystems of China. *Global Change Biology*, *19*(3), 798–810.

Yu, R., Wang, B., & Zhou, T. (2004). Tropospheric cooling and summer monsoon weakening trend over East Asia. *Geophysical Research Letters*, *31*(22), 217–244.

Yuan, D., Cheng, H., Edwards, R. L., Dykoski, C. A., Kelly, M. J., & Zhang, M., et al. (2004). Timing, duration, and transitions of the last interglacial Asian monsoon. *Science*, *304*(5670), 575–578.

Yuan, W. H. (2013). Diurnal cycles of precipitation over subtropical China in IPCC AR5 AMIP simulations. *Advances in Atmospheric Sciences*, *30*(6), 1679–1694.

Zhai, P., Zhang, X., Wan, H., & Pan, X. (2005). Trends in total precipitation and frequency of daily precipitation extremes over China. *Journal of Climate*, *18*(18), 1096–1108.

Zhang, Y., Li, T., & Wang, B. (2004). Decadal change of the spring snow depth over the Tibetan plateau: The associated circulation and influence on the east Asian summer monsoon. *Journal of Climate*, *17*(14), 2780–2793.

Zhou, G., Peng, C., Li, Y., Liu, S., Zhang, Q., & Tang, X., et al. (2013). A climate change-induced threat to the ecological resilience of a subtropical monsoon evergreen broad-leaved forest in southern China. *Global Change Biology*, *19*(4), 1197–1210.

Zhou, G., Wei, X., Wu, Y., Liu, S., Huang, Y., & Yan, J., et al. (2011). Quantifying the hydrological responses to climate change in an intact forested small watershed in southern China. *Global Change Biology*, *17*(12), 3736–3746.

Zhou, T. J., Bo, W., & Wang, B. (2009). How well do atmospheric general circulation models capture the leading modes of the interannual variability of the Asian-Australian monsoon? *Journal of Climate*, *22*(5), 1159–1173.

Zhou, T. J., & Yu, R. C. (2005). Atmospheric water vapor transport associated with typical anomalous summer rainfall patterns in China. *Journal of Geophysical Research Atmospheres*, *110*(D8),104, doi:10.1029/2004JD005413.

Zhu, Q., Jiang, H., Liu, J., Peng, C., Fang, X., & Yu, S., et al. (2011). Forecasting carbon budget under climate change and CO2 fertilization for subtropical region in China using integrated biosphere simulator (IBIS) model. *Polish Journal of Ecology*, *59*(1), 3–24.