

An overview of climate change vulnerability: a bibliometric analysis based on Web of Science database

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Abstract Based on worldwide scholars' 3,004 papers published in 658 academic journals in the Web of Science database on the topic of climate change vulnerability from 1991 to 2012, this paper quantitatively analyzes the global scientific performance and hot research areas in this field by adopting bibliometric method. The results show that (1) the vulnerability researches on climate change have experienced a rapid growth since 2006, and the publications are widely distributed in a large number of source journals, while the top two productive institutions are the University of East Anglia and Potsdam Institute for Climate Impact Research; (2) the cooperation at author level is on the rise, and there are closer relationships in institutional and national levels; (3) the most widely focused research topics in this field include health issues in the socioeconomic system, food security in the field of agricultural system and the issue of water resource management, etc.; (4) according to the papers from the top journals, we find that the research areas for climate change vulnerability in those publications are located in the ecological diversity, ecosystem service, water resource management and electric power supply, etc.

Keywords Climate change · Vulnerability · Bibliometric · Backward search

1 Introduction

Global environmental change, especially climate change caused by anthropogenic activities, has seriously impacted on the operation of the earth's physical and social system

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(IPCC 2007). These environmental changes along with their negative impacts have become a main obstacle for sustainable development of human society. How to address, mitigate and adapt to climate change becomes a hot issue in both academic and political community. Therefore, the discipline of climate change vulnerability, as an important part of sustainable development, has attracted increasingly extensive attentions during recent years. The terminology ‘vulnerability’ is first used in the field of poverty and development studies and later introduced into the dominion of global environmental change by Liverman (1990). With its wide use in climate change researches, its definition from IPCC has been widely accepted by many researchers in this domain, which is defined as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC 2007). IPCC has set up a working group especially for climate change vulnerability research in the report, in accordance with its vital role in climate change studies. Consequently, quantitative analysis on development trend in the field of climate change vulnerability will not only help comb the achievements in this domain but also be beneficial for researchers to keep up with the research frontiers of this field.

As a valuable tool for literature analysis, bibliometric can effectively depict the rules of discipline development and has a wide application in different knowledge domains. Janssen et al. (2006) presented a bibliometric analysis on the resilience, vulnerability and adaptation knowledge domains within the research activities on human dimensions of global environmental change and researched the relationships between those three topics, while a later update on this topic presented by Janssen (2007) found an increased overlap among the three knowledge domains. From the SCI-Expanded database, Li et al. (2011) combined an innovative analysis, namely word cluster analysis, with bibliometric and then researched the assessment on the academic output of climate change science from 1992 to 2009. He found the main keywords in climate change science to be temperature, environment, precipitation, greenhouse gas, risk and biodiversity, while the major methods to be ‘model’, ‘monitoring’ and ‘remote sensing.’ The Dragos and Dragos (2013) adopted this view to analyze the influencing factors of the quality of researches in environmental science and ecology and concluded that environmental performance index, education financing, the number of domestic journal in ISI Thomson database, and English proficiency is among those significant factors. Based on ISI Web of Science (WOS), Blank et al. (2013) clarified how the status of research on green roofs has evolved from 1993 to 2012 and concluded the changes in the number of publications, most studied research areas, the essential trends and major challenges for this field.

Despite the increasing application of this method by numbers of domains, there have been few attempts to gather systematic data on the global scientific production of research on climate change vulnerability. In a bid to map global research trends of climate change vulnerability research, a literature review of this field is in order, considering its significance. This paper adopted the backward search strategy to select the articles from ISI WOS and employed bibliometric method to analyze the development of this discipline. The research status, including the number of articles, cooperation, key authors and hot topics are concluded to address the latest advances, research directions and leading topics of this field. Findings from these analyses can help researchers realize the breadth of climate change vulnerability research and establish future research directions.

The remaining part is organized as follows. Part 2 introduces the analytical framework, search method and literature arrangement of those selected publications. The bibliometric analyses and results discussions are presented in Sect. 3, in addition to the research trends

highlighted through an analysis on keywords. Main conclusions and remarks are displayed in Sect. 4.

2 Methodologies

2.1 Conceptual framework

This paper applies ‘climate change vulnerability’ as the search topic and adopts the backward search strategy to comb those first-hand papers. After the search process, we explore the development track of this topic based on such aspects of the quantity of papers, sources or journals, leading academic figures and institutions, cooperation and citation, hot topics. Figure 1 illustrates the framework of this paper.

Up until Dec 30th, 2012, there are 658 journals in the WOS database that includes the climate change vulnerability literatures. Based on the first literature search of the aforementioned journals, we explore the materials by using the backward search strategies, which is introduced as follows.

This backward search process contains the following four steps (see Fig. 2).

Firstly, panel discussion is used to decide the key words for the first search. A small group is organized to determine the topic search as $TS = [(\text{“climate change”}) \text{ and } (\text{vulnerability})]$. The period is from 1981 to 2012, and the types of literatures include article review and proceeding paper, while the reference databases are limited in SCI Expanded and SSCI. Then, 2,708 literatures are caught for the first time.

Secondly, synonym judgment is to find the synonyms for the words ‘climate change’ and ‘vulnerability’. The BibExcel software (Persson et al. 2009) is applied to analyze the key words of those articles. As for the words ‘climate change’ in our study, it has the similar meaning with climatic change, global warming and climate variability. Due to its univocal meaning and special consideration in this research, the word ‘vulnerability’ does not have a synonym.

Thirdly, renew topic search as $TS = [(\text{“climate change” or “climatic change” or “global warming” or “climate variability”}) \text{ and } (\text{vulnerability})]$. This new search theme is generated from the second step, and other qualifications are not changed. There are 3004 literatures in the second search.

Lastly, based on the third step, literature arrangement and analysis can be done. We process those selected articles from the aspects of author, institution, journal and discipline orientation. After this procedure, further and deep analysis will be conducted according to the framework presented in Fig. 1.

2.2 Strategies for materials arrangement

Due to the inconsistent using of key words, the literatures selected from those databases have some problems, which require the manual calibration to satisfy the needs of literature analysis. The first common problem is the author’s names. Due to those databases’ tradition of abbreviating author’s name in their earlier stage, different authors could be recognized as the same author. Thus, we compare those institutions and apply web search to address the original materials to identify the authors. Another problem arose due to the authors’ inconsistent mark for their institutions. For example, the institution of the University of California contains a number of different agencies and branches. In this regard, we adopt single organization to denote each branch separately. The end is the plurality,

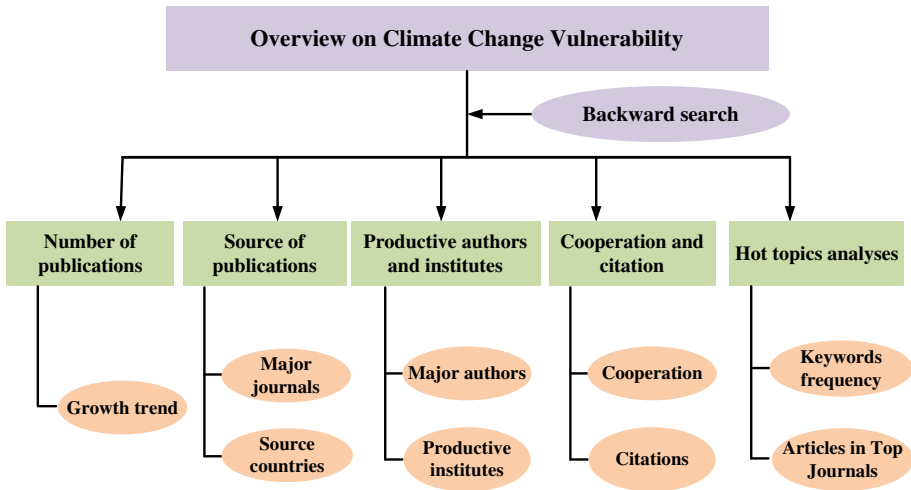
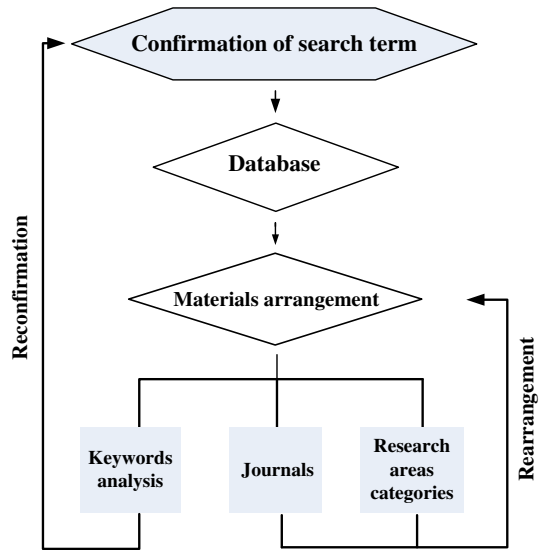


Fig. 1 Conceptual framework

Fig. 2 Illustration for backward search process



forms and case sensitivity of the keywords. For instance, the keyword ‘flood’ has different forms, respectively, flood, Flood, floods and flooding, etc. We would like to merge those forms into the same meaning. In addition, Articles originating from England, Scotland, Northern Ireland and Wales were reclassified as being from the United Kingdom (UK).

All keywords (1991–2012), both those reported by authors and those attributed by ISI as well as the words in titles and abstracts, were identified and separated for every sequencing 500 literatures into one calculation, and then, their ranks and frequencies were classified in order to thoroughly and precisely analyze the variations in trends. Different words with identical or similar meaning and misspelled keywords were grouped and considered as one single keyword.

3 Results analyses and discussions

Based on those picked data, this paper employs bibliometric method to catch the development trend in the field of climate change vulnerability research. The Price's index is applied to measure the increase in this field, and the Price law is also used to identify the key authors and the outstanding researchers in the domain. Other contents, such as the growth trend of this field, the productive intuitions, the countries which contribute to those papers, citation and cooperation and the hot topics will also be presented and analyzed.

3.1 Quantity of literatures and growth trend

The number of published academic papers is an important indicator to measure the development trend of certain scientific research. According to the results of statistical analysis, 3,004 papers have been published in the field of climate change vulnerability from 1981 to 2012, while the number changed from 4 in 1991 to 658 in 2012. Furthermore, we search the papers in the field of vulnerability research with the Topic Search of vulnerability to find the importance of the sub-area climate change vulnerability. The results show that the number of vulnerability research increases from 436 in 1991 to 4926 in 2012. Figure 3 shows the details about the changes in the number of literatures in this field.

It can also be seen from Fig. 3 that the vulnerability research and climate change vulnerability research have experienced rapid growth, especially for climate change vulnerability in recent years. In addition, climate change vulnerability research, as the emerging discipline of vulnerability research, has accounted for 0.46 % of vulnerability research outcomes in 1991, follows by 13.36 % in 2012. This fact may reveal that climate change vulnerability research was the hot area for vulnerability research and has gained wide attention by scholars around the world in vulnerability research.

The research in literature science showed that the literature growth in one subject will take on exponential form. According to Price, if we take the cumulative number of literature as the longitudinal axis and historical year as horizontal axis, the quantity of literature will be characterized by a smooth curve, approximately expressing the rule of exponential growth in that certain discipline (Jing and Kang 2000).

Figure 4 shows the increase in the literatures in the field of climate change vulnerability research. Based on the increase rate, the growth process can be roughly divided into three stages: 1991–1996 is the early stage, while 1997–2004 is the steady development stage since climate change vulnerability research has a notable growth from 2004. Because 1991–1996 is the preliminary stage of the growth of climate change vulnerability research, we started from the year 1997 to simulate the growth rule according to the Price research. Consequently, the formula to present the growth of climate change vulnerability research from 1997 to 2012 can be shown as $F(t) = 80e^{0.24t}$ ($R^2 = 0.99$). It can be seen that climate change vulnerability research satisfies the general growth rule of academic research.

3.2 Top journals with the largest number of papers

Document analysis requires statistical analysis on their origins, i.e., the key journals in this field. Those crucial journals will help to tackle the main trends of climate change vulnerability research. Table 1 shows the key journals with the higher number of published paper in this field, accounted for 34.59 % of the SCI articles in this research. The first two journals are Global Environmental Change Human and Policy Dimensions (154 papers,

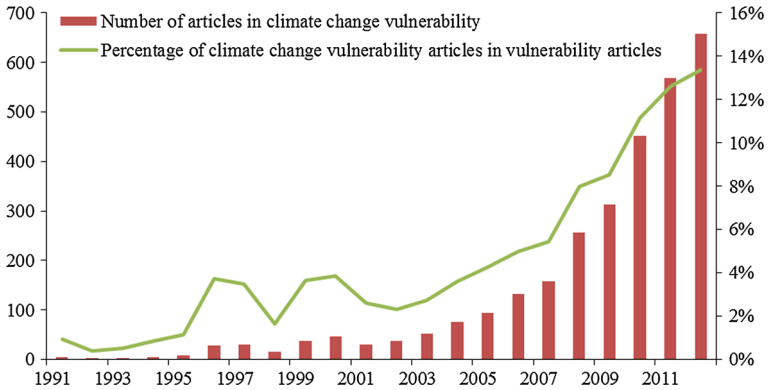


Fig. 3 Publications and growth trend in the field of climate change vulnerability

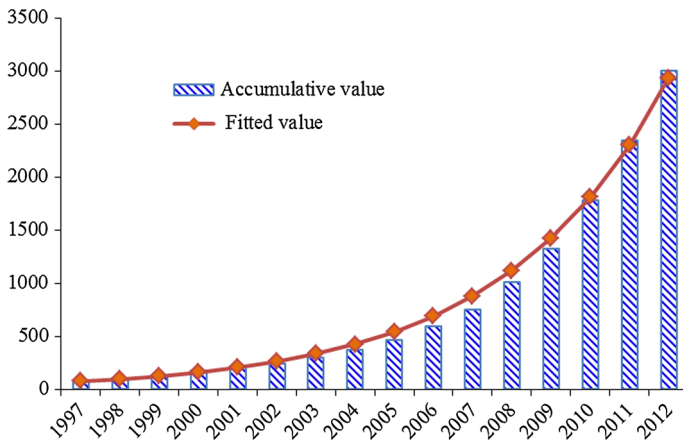


Fig. 4 Cumulative distribution of publications in climate change vulnerability

5.79 %) and Climatic Change (152 papers, 5.71 %), indicating that climate change vulnerability research papers are published in numerous journals. As far as the impact factors are concerned, most of those selected journals have an impact factor over 1, indicating their dominating academic influence.

3.3 Major productive institutions

The analysis of research institution will give us the information that which organizations stand on the frontier of this research. Based on our analysis, the selected 3,004 papers are distributed in 7,194 research institutions. The institution, which published the largest number of articles, is the East Anglia University from UK, posting a total of 83 papers and accounting for 1.15 % of all papers. The Potsdam Institute for Climate Impact Centre follows with 57 researches, accounting for 0.79 % of all papers. Other agencies that are ranking the forefront of the research institutions are James Cook University, McGill University and University of Guelph, etc. Table 2 summarizes the top 20 high-yielding

Table 1 Key journals for the publications in the field of climate change vulnerability

Rank	Journal	Numbers	Percentage
1	Global Environ Chang	154	5.79
2	Climatic Change	152	5.71
3	Climate Res	59	2.22
4	Nat Hazards	57	2.14
5	Mitig Adapt Strat Gl	53	1.99
6	Global Change Biol	49	1.84
7	Environ Sci Policy	42	1.58
8	Reg Environ Change	39	1.47
9	Ecol Soc	38	1.43
10	Clim Policy	35	1.32
11	P Natl Acad Sci USA	33	1.24
12	J Coastal Res	31	1.17
13	Curr Opin Env Sust	25	0.94
13	Forest Ecol Manag	25	0.94
15	Ids Bull-I Dev Stud	22	0.83
15	Ocean Coastal Manage	22	0.83
15	Wires Climate Change	22	0.83
18	Environ Manage	21	0.79
18	Environ Res Lett	21	0.79

institutes and their countries. It has been shown from this list that the locations of these bodies are mainly from the UK, Australia, Canada and the United States. Further, the Chinese Academy of Sciences is the only one Chinese agency labeled in the top 20 institute.

3.4 High productive and collaborative authors

Those researchers with high academic productivity usually dominate the development tendencies of climate change vulnerability research. The study on those important authors will let us stand on shoulders of giants for a broader view. There are 11,188 authors from those 3,004 articles. According to the Price law, the number of literatures from the outstanding authors should occupy half of the total number. That is to say that if we assume the article number of the lowest productive researcher among those outstanding authors is m , we can calculate it with the equation $m = 0.749(n_{\max})^{0.5}$, and n_{\max} stands for the article number of the highest productive author. In our research, $n_{\max} = 33$ and $m = 4$. Thus, the number of essential authors with at least 4 publishes papers is 233.

To further analyze the overall situation about those authors, total citation, citation per article and h-index (A scientist has index h if h of his/her N_p papers have at least h citations each, and the other $(N_p - h)$ papers have no more than h citations each) are needed (Hirsch 2005). The two productive authors are Ford JD from McGill University, Canada, and Adger WN from East Anglia University, UK, with 33 and 27 published papers, respectively.

According to the total citation, citation per article and h-index, Thuiller from The French National Center for Scientific Research, France, and Adger WN from East Anglia University, UK, are outstanding in this review. Therefore, these three important authors are

Table 2 Top 20 most productive institutes based on total number of articles

Rank	Institute	Articles	Nationality
1	University of East Anglia	83	UK
2	Potsdam Institute for Climate Impact Centre	57	Germany
3	James Cook University	56	Australia
4	McGill University	53	Canada
5	University of Guelph	52	Canada
6	University of Oxford	46	UK
7	University of Leeds	42	UK
8	Australian National University	40	Australia
9	University of Melbourne	36	Australia
10	United States Geological Survey	35	USA
11	VU University Amsterdam	32	Netherlands
12	University of Washington	31	USA
13	National Autonomous University of Mexico	31	Mexico
14	Pennsylvania State University	30	USA
15	Arizona State University	29	USA
16	University of Cape Town	29	South Africa
17	National Center of Atmospheric Research	28	USA
18	Stanford University	28	USA
19	Chinese Academy of Sciences	28	China
20	University of Southampton	28	UK

chosen to do deep analysis. As for Thuiller, his focuses are the vulnerability of ecosystem to climate change in Europe and Africa. With the particular stress on ecology, he published two papers in *Science* and *Nature* with a citation of 338 and 33, respectively. Adger WN laid particular attention on the definition of vulnerability, the conceptual framework and assessment for climate change vulnerability with concern on fishery, coastal areas and health issues related to climate change. He is prominent for one science paper published in 2005 and the highest total citation and h-index. As far as Ford JD is concerned, he paid special attention to the vulnerability of Arctic areas and Canada to climate change from the aspect of humanistic sociology. Due to his emerging role in this field, nearly all or 29/33 are published in the recent 4 years. The details about the usual journals that are chosen by the three authors reveal that *Global Environmental Change* and *Climatic Change* are major journals for their considerations.

3.5 Distribution of the paper nationalities

From the analysis on major research institutions, we can see that the USA, UK, Australia and Canada have a relative higher amount of research institutions in this field. Further analysis toward the geographical distribution of the literatures, we will catch those countries with key outputs in the field. Papers are allocated to institutions and countries on the basis of the affiliations of the first author. As shown in Fig. 5, the USA, UK, Australia and Canada are the countries with a larger proportion of more than 10 %, which corresponds with the analysis of major institutions.

In addition, seen from the viewpoint of research orientation, further analyses show that the papers from the USA, UK and Australia gave more attention on the vulnerability of ecosystem, water resource system and health issues, while more concerns from Canadian authors are located in human living items for Arctic areas to climate change, and Brazilian authors focus more on the vulnerability of energy systems, especially renewable systems, to climate change. Furthermore, the research topics of Chinese scholars reveal that those researches focus on the topic of the health issues caused by climate change (Xu et al. 2012; Tian et al. 2012), ecosystem (Wu et al. 2007), water resource system (Xia et al. 2012) and energy system (Wang et al. 2014), and the research districts contain coastal areas (Zou and Wei 2009 and 2010; Yin et al. 2012) and drought regions (Jin et al. 2010; Yuan et al. 2013).

Figure 5 also demonstrates the literature distribution on continental level and shows that most of selected articles are generally from Europe and North America area, accounting for 72.61 %. To some degree, the climate change vulnerability research in Asia, Africa and Latin America is in its initial stage or should be paid more attention. In conclusion, even though the climate change vulnerability research has attracted wide international interest, the academic research of this field in Asia, Africa and Latin America is yet to be improved.

3.6 Cooperation level and top cited articles

Scientific collaboration is an indicator of value and necessity to measure the development of certain discipline. In general, the most direct output for the scientific cooperation is the co-authored papers. In this view, the degree of cooperation, which is usually used in literature analysis, is applied in our analysis to reflect the cooperation in the field. And the cooperation degree at author level can be calculated by dividing the total number of authors by the total number of publications. The higher the cooperation degree number, the more sufficient the cooperation.

In our research, the cooperation is classified into three levels: author, institution and country. Using the similar calculation of cooperation at author level, we can finally identify the changes of cooperation in recent years, which are shown in Table 3.

It can be seen from Table 3 that the cooperation of climate change vulnerability research is on the rise at the author level in the recent decade, indicating a potentially closer relationship among the authors within the same domain and a greater opportunity for collaboration along with the rapid increase in scientific research output in climate change vulnerability. The average degree of cooperation between 1991 and 2012 is 3.71, which means that each publication in this field will have an average of 3.71 authors. The institution cooperation degree is basically above the average number, while there is no obvious change for the cooperation degree at national level. This fact indicates that the cooperation has produced remarkable changes at institution level, while the stable national cooperation level corresponds with the regional characteristic of climate change vulnerability research.

Table 4 presented those high citation publications in this field. The paper of Thomas et al. (2004) researched the vulnerability of species to climate change, which has 1,758 citations, and was published in Nature. Among those top 20 high citation articles, there are 7 papers with the first author from the USA, 6 papers from UK. Furthermore, the details about those studies indicate that there are 5 researches for the conceptual framework, definition of climate change vulnerability, 9 literatures for the research on ecosystem diversity and three papers for water resource and socioeconomical system, respectively.

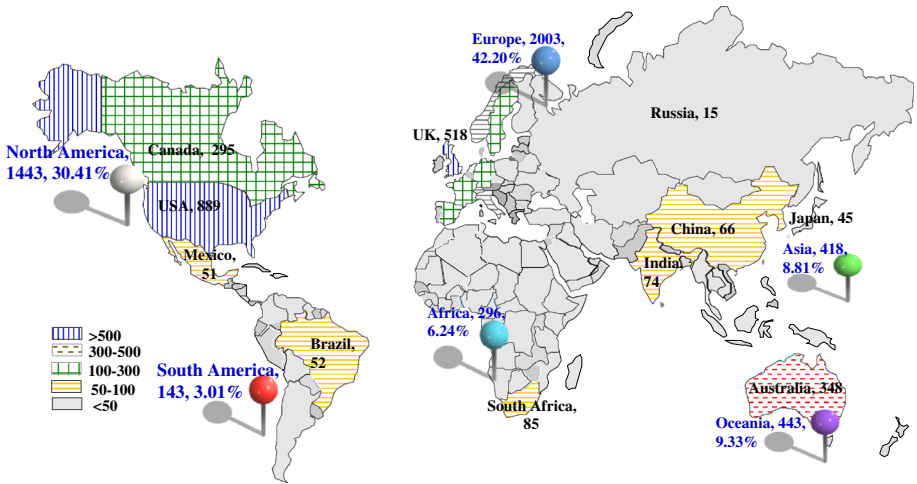


Fig. 5 Geographical distribution of publications between 1991 and 2012 according to major countries and continents

Table 3 Changes of cooperation in climate change vulnerability research (2003–2012)

Year	Author	Institution	Country
2012	3.83	2.61	1.57
2011	3.84	2.58	1.60
2010	3.87	2.64	1.66
2009	3.70	2.56	1.57
2008	3.81	2.57	1.61
2007	3.62	2.58	1.59
2006	3.62	2.59	1.51
2005	3.65	2.50	1.57
2004	3.50	2.56	1.57
2003	3.43	2.73	1.49
Average	3.71	2.38	1.58

The average cooperation is calculated for the period between 1991 and 2012

3.7 Hot topics

3.7.1 Analysis on the amount and content of keywords

To clear up the hot topics is the key to grasp the development trends of one discipline. As a research field develops, the researchers will converge at certain important research directions or conduct intensive studies at the different levels, reflecting the maturity of this subject. Thus, targeting hotspots or the latest advances in this domain will help track the trends, reserve the existing knowledge in this research tradition and better the understanding about this research.

Firstly, we did the statistic about the number of keywords in those papers by randomly selecting 100 samples from the 658 published papers in 2012. Figure 6 demonstrates the distribution of the number of keywords in this random survey.

Table 4 Top cited articles in the field of climate change vulnerability

	Author	Journal	Country and institute	Citations
1	Thomas et al. (2004)	Nature	UK/Univ Leeds	1,758
2	Vorosmarty et al. (2000)	Science	USA/Univ New Hampshire	643
3	Nepstad et al. (1999)	Nature	USA/Woods Hole Res Ctr	573
4	Thuiller et al. (2005)	P NATL ACAD SCI USA	France/CNRS	521
5	Turner et al. (2003)	P NATL ACAD SCI USA	USA/Clark Univ	466
6	Smit and Wandel (2006)	Global Environ Chang	Canada/Univ Guelph	443
7	Folke (2006)	Global Environ Chang	Sweden/Stockholm Univ,	423
8	Schroter et al. (2005)	Science	Germany/Potsdam Inst Climate Impact Res	345
9	Adger (2006)	Global Environ Chang	UK/Univ E Anglia	342
10	Kiesecker et al. (2001)	Nature	USA/Penn State Univ	334
11	Knops et al. (1999)	Ecol lett	USA/Univ Nebraska	314
12	Hulme et al. (2001)	Clim Res	UK/Univ E Anglia	300
13	Loya et al. (2001)	Ecol Lett	Israel/Tel Aviv Univ	297
14	Oki and Kanae (2006)	Science	Japan/Univ Tokyo	287
15	Reynolds et al. (2007)	Science	USA/Duke Univ	248
16	Dulvy et al. (2003)	Fish Fish	UK/Centre Environment Fisheries	244
17	Adger et al. (2005)	Science	UK/Univ E Anglia	236
18	Kelly and Adger (2000)	Clim Change	UK/Univ E Anglia	222
19	Araujo et al. (2006)	J Biogeogr	Spain/CSIC	219
20	Yohe and Tol (2002)	Global Environ Chang	USA/Wesleyan Univ	214

Generally speaking, more keywords mean high probability to be cited or searched, which also lead to the complexity for the publisher. The reality is that most of journals have the restriction on the number of keywords. It can be seen from Fig. 6 that the majority of researchers in this field would like to choose 4–6 keywords, which accounts for 66 % of our survey.

Secondly, content analysis on the keywords tells us the hot foci of this field. After using the software BibExcel to collate the keywords, 8,494 keywords are generated from those 3,004 literatures. After merging and categorizing the keywords, we can get the statistics about the content of keywords. As shown in Table 5, we can see that besides the words ‘vulnerability’ and ‘climate change’, other keywords focus on the adaptive capacity, socioeconomical system, natural disasters, agricultural systems and water resource systems, etc. Among them, the socioeconomical systems mainly involved in the social management of climate change vulnerability and the vulnerability of health system to climate change, while natural disasters are more concerned about the vulnerability caused by droughts and floods. This may indicate that the relationship between human actions and the effects of climate change (the socioeconomic dimension of vulnerability), which was well documented and argued in nature hazards vulnerability (Wei et al. 2004), will be increasingly important in this field.

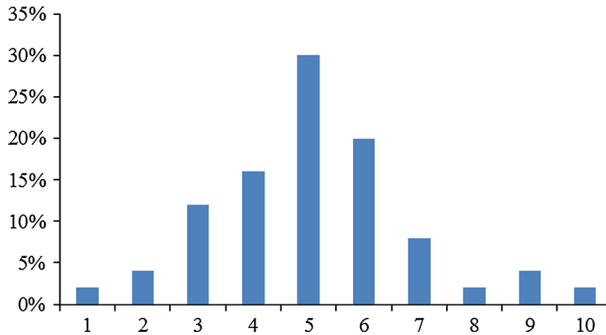


Fig. 6 Distribution of the number of keywords from 100 samples

In addition, the limitation of the study area is very common in keywords, which is highlighted in Table 5. This is because regional research is the characteristic or nature of climate change vulnerability research. According to the proposed conceptual framework from Fussel (2007), five parts of this framework have been represented in Table 5, namely, the source of vulnerability factors (drought as the external vulnerable factor of social system), the vulnerable system (such as socioeconomic systems), the valued attribute(s) of the vulnerable system (such as human health in social systems), hazard (climate change, natural disasters as a potentially damaging influence on the system of analysis), research domain (socioeconomic or biophysical). The only one that is not reflected in our research is the time dimension of vulnerability research, namely the dynamic or static characteristics of one study. In conclusion, the above facts highlight the interdisciplinary nature on climate change vulnerability research, and the dynamic climate change vulnerability analysis will be the theme of future research.

Figure 7 illustrates the variation tendency of each keyword in Table 6. As can be seen from this chart, the words ‘climate change’, ‘vulnerability’ and ‘adaptive capacity’ have no change over time, while the vulnerability research on socioeconomic system experienced rapid growth. This fact reveals that the discussion of ‘adaptive capacity’ is interdependent with the vulnerability research, and social aspect of vulnerability will be highlighted in the near future. Furthermore, the vulnerability research of water resource system increased quickly in the period 2010–2012, which accounted for 66.33 % of the entire time period (1991–2012). In addition, further analysis on the words ‘health’ and ‘food security’ also indicates that the two words are also emerging research hotspots in the last 5 years. In short, the current research focuses on the health issues in socioeconomic system, food security in agricultural system and water resource system. With Table 6 and Fig. 7, the comparison between mitigation and adaption also tells that compared with the discussion of mitigation, the consideration of adaptive capacity stands in a dominant position in climate change vulnerability research. This dominant place on climate change vulnerability study does not appear in early stage. Along with the development of vulnerability research, however, the adaptive capacity was attached greater importance than mitigation.

3.7.2 Analysis on articles in top journals

The publications in top journals not only reflect the index for the competitiveness of one research field but also represent the top journals’ attention paid to the key issues in a

Table 5 Frequency of keywords in climate change vulnerability research

Climate change (1,242)	
Climate change	1,029
Global warming	51
Climate variability	34
Climatic change/environmental change/global change/global environmental change	128
Vulnerability (717)	
Vulnerability	484
Impact/impacts	179
Risk/risks	54
Adaptive capacity (698)	
Adaptation/climate change adaptation/climate adaptation	464
Adaptive capacity	119
Resilience	115
Water resource	
Water resources/water balance/watershed management/water management	98
Sea-level rise	
Sea-level rise/sea-level rise	77
Agriculture (160)	
Agriculture	71
Food security	43
Natural hazards (258)	
Drought	79
Flood/flooding/flood hazard	72
Natural hazards/hazard/disasters	62
Socioeconomical system (452)	
Social governance/management/planning	178
Health/public health/mortality	79
Poverty/equity/development/economy	65
Region (346)	
Arctic/Inuit/Canada	104
Africa/South Africa	67
Bangladesh/India	36
Australia	35
Developing countries	20
Europe	20
China	11
Mitigation	
Mitigation	50

subject, which helps to understand the pivotal progress in this field. This paper selects Science, Nature and Nature Climate Change to research the publications in top journals with respect to the study area, the study object and the nationality of the first author.

Finally, 23 papers from those three journals are presented in Table 6. Those researches pay great attention to the climate change vulnerability at regional level and in developed countries. From the research content, the top journals mainly focus on ecological system

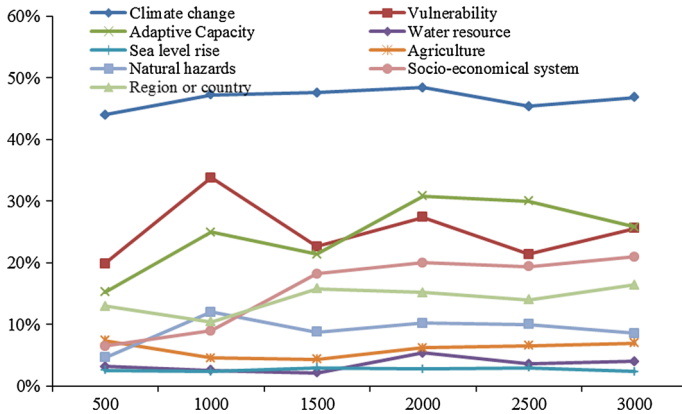


Fig. 7 Variation trends in the percentage of keywords in periods over time. *Note:* the number is the percentage of each keyword in every 500 literatures based on the time from 1991 to 2012

vulnerability analyses, and there are relative few literatures or emerging concern on socioeconomical system. In conclusion, the vulnerability of socioeconomical system and the vulnerability research in developing countries will be future direction for climate change vulnerability analysis.

In addition, the research scope of the above three top journals is also different. The journals of *Nature* and *Science* focus on the climate vulnerability change research on ecological system and water system. The foci of *Nature Climate Change*, however, are relatively wide and the health issues, and the power system are recent hotspots for climate change vulnerability research in this journal. This reveals that potential hot topics for future study may be located in the vulnerability of energy systems to climate change.

4 Conclusions and remarks

Based on the WOS database, this paper takes reverse thinking to search the literatures and researches the current situation of climate change vulnerability field from numerous aspects, such as the number of documents, literature sources, high-yielding authors and high-yielding institutions, etc. Main conclusions are demonstrated as follows.

- (1) This field has experienced a fast development since 2006 and followed an exponential growth curve with time. This reveals climate change vulnerability research is a younger discipline. Meanwhile, the percentage of climate change vulnerability researches in vulnerability researches has increase a lot. The top three journals with most published papers in this field are *Global Environmental Change*, *Climatic Change* and *Climate Research*, while there is wide distribution for papers to be published in lots of journals.
- (2) Furthermore, high-yielding authors include Ford JD from McGill University Canada and Adger WN from University of East Anglia UK and high-yielding institutions are University of East Anglia UK and Potsdam Institute for Climate Impact Research. While the cooperation remains unchanged at national level, it improves a lot at the author and institution level in recent decade. While there are many voices among European and American countries, the academic researches of this field in Asia, Africa and Latin America are yet to be improved or in its initial stage.

Table 6 Analysis of publication in journals of Nature, Science and Nature Climate Change

Research level	Research areas	Study object	Authors	Nationality of the first author	Top journals
Global	USA and European Union	Electric power system	van Vliet et al. (2012)	Netherlands	Nature Climate Change
	Global	Human health	Peduzzi et al. (2012)	Switzerland	Nature Climate Change
		Methodology and framework	Hallegatte et al. (2011)	France	Nature Climate Change
		Ecosystem (forest)	Choat et al. (2012)	Germany	Nature
		Ecosystem (species)	Thomas et al. (2004)	UK	Nature
		Methodology	Dawson et al. (2011)	UK	Science
		Water resource system	Vorosmarty et al. (2000)	USA	Science
		Water resource system	Oki and Kanae (2006)	Japan	Science
Biodiversity	Pereira et al. (2010)	Portugal	Science		
Country or Union	Mexico	Forest reserve	Ponce-Reyes et al. (2012)	Australia	Nature Climate Change
	European Union	Biodiversity	Thuiller et al. (2011)	France	Nature
	European Union	Ecosystem	Schroter et al. (2005)	Germany	Science
Region	Coastal zone	Sea-level rise	Sallenger et al. (2012)	USA	Nature Climate Change
	Coastal zone	Ecosystem	Adger et al. (2005)	UK	Science
	Coastal zone	Water resource system	Ferguson and Gleeson (2012)	Canada	Nature Climate Change
	Mississippi delta region	Ecosystem	Day et al. (2007)	USA	Science
	Glacier river	Biodiversity	Jacobsen et al. (2012)	Denmark	Nature Climate Change
	Arctic tundra	Forest carbon sinks	Mack et al. (2011)	USA	Nature
	Amazon river basin	Forest reserve	Nepstad et al. (1999)	USA	Nature
	Great Barrier Reef	Ecosystem	Nott and Hayne (2001)	Australia	Nature
	West part of USA	Ecosystem (species)	Kiesecker et al. (2001)	USA	Nature

Table 6 continued

Research level	Research areas	Study object	Authors	Nationality of the first author	Top journals
	North part of USA	Ecosystem (vegetation)	Doak and Morris (2010)	USA	Nature
	South part of USA	Forest reserve	Chen et al.(2011)	USA	Science

- (3) The word frequency analysis shows that the early researches on climate change vulnerability focus on ecosystems and water resource systems while the recent studies switch to the topics of health, food safety and other socioeconomic aspects of vulnerability. The analysis on the literatures published in top journals indicates that those studies focus more on the coastal zone area, frozen tundra, river basins and forest areas. Those facts point out the deficiency of research on the social aspects of climate change vulnerability, and the dynamic climate change vulnerability will be emphasized in future study.
- (4) Finally, as far as the country or region of the authors is concerned, scholars in Asia and Africa are not active or productive in this field and the authors from the USA, Britain and Australia are more concerned about the climate change vulnerability in ecosystems and water resource systems; Brazilian scholars pay more attention to the vulnerability in energy systems, particularly renewable energy systems. Due to the particular attention to the natural aspect of vulnerability in the beginning and middle period of this field, further research may allocate more energy on the social aspect of vulnerability to climate change.

In a bid to reduce subjective human factors on the search results, backward method is applied in this paper to conduct word frequency analysis, disciplinary analysis and journals analysis for the first round of the literature search, optimizing the above search terms, subject distribution, journal selection from three levels. Besides the general analysis on those literatures, this paper maps the research performance of this field via word frequency analysis, including those hotspots, the publications in those top journals. The conclusions in this study may shed light on a comprehensive and systematic grasp of climate change vulnerability studies. In general, this review will be a new action toward the goal of bettering the understanding of the progress in this field.

The analyses in this paper, however, are based on the SCI-Expanded and SSCI database from WOS, which does not contain the entire literatures of this field from 1991 to 2012. Furthermore, the selection from other sources is complex and requires strict procedures. This coverage inadequacy in this field should be supplemented by choosing some materials from the publications of those identified key authors, which will be beneficial to the coverage and rationality of the results.

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