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Feature extraction and classification of climate change risks: a bibliometric analysis

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Abstract Risks brought by climate change are inevitable obstacles to global development. Clarifying the features of climate change risks helps us to further understand and cope with climate change. There lacks a systematic review of climate change risks in terms of feature extraction and classification. The bibliometric analysis can be used to analyze and extract climate change risk features. The literature in the field of climate change was searched in the Web of Science database. Coauthors, citations, bibliographic coupling, co-citations, and keyword co-occurrence were analyzed. From five dimensions including nature, politics, economy, society, and culture, the risk features of climate change were extracted and summarized. Through text mining and cluster analysis, the climate change risk feature system was established, which is embodied in five different aspects: ecosystem and sustainability; uncertainty, vulnerability, and efficiency; behavior and decision-making; governance and management; and adaptation and mitigation. The feature system reflects that the current climate change risk presents strong variability and that the risk boundary is gradually blurred. The areas affected by risk are expanding and deepening. The strategies and governance for addressing risks are gradually diversified. This research contributes to the domain of climate change risk identification and assessment. The features of climate change indicate that we need to adjust policymaking and managerial practices for climate change in the future. Interdisciplinary cooperation, human cognition and preferences, public participation in global governance, and other unnatural factors related to climate change should be strengthened with a more positive attitude.

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Introduction

Climate change is an important challenge to be faced in the context of the upheaval of today's world. It is closely related to all aspects of human political, economic, social, and environmental activities. Specific manifestations of climate change include rising temperature, changing rainfall patterns, and frequent or severe extreme weather events, such as heat waves, drought, floods, cold waves, and storms (Ghadge et al., 2019). These manifestations are accompanied by various risks hidden within climate change, which bring great challenges to human society. Many scientific research institutions, international organizations, and governmental departments have defined the risks of climate change. According to the Intergovernmental Panel on Climate Change (IPCC), the risk of climate change impacts is caused by the interaction between hazards (triggered by events or trends related to climate change) and characterized by vulnerability (vulnerable) and exposure (people, assets, or ecosystems at risk) (IPCC, 2014). Similarly, the probabilities and consequences of climate change risks are often imprecise, and the risks come from a combination of exposure, sensitivity, and adaptability to climate hazards (USGCRP, 2018). Scientists from China assessed the risks of climate change from six aspects: agriculture; water resources; coastal and offshore resources and environment; forests and other natural ecosystems; the cryosphere environment; and major projects, human health, and the environment (NARCC, 2015).

The academic community has recently conducted many studies on the topic of climate change risks, most of which focus on the impact of climate change on nature, social economy, and human health and solutions in different fields. In a study of forests in northern Finland (Venalainen et al., 2020), it was found that climate change will increase abiotic and biological risks. For example, it will increase the risk of large-scale forest fires, and the probability of pests and wood rot being present in coniferous forests will also increase (Venalainen et al., 2020). Coastal regions are areas that are greatly affected by climate change. Some recent literature has proposed several important actions for coastal projects in response to climate change. This includes strengthening policy makers' awareness of the climate change risks, formulating a more comprehensive risk framework, and building a bridge between theory and practice to promote the better realization of disaster-reduction policies (Toimil et al., 2020). In addition to natural risks, studies have discovered that climate change driven by extreme weather conditions has a significant impact on food production, natural resources, and transportation around the world. Climate change and supply chains influence each other through natural disasters and greenhouse gas (GHG) emissions, respectively (Ghadge et al., 2019). It is worth mentioning that due to the strong dependence on specific climatic conditions, the ski tourism industry is considered to be the most directly affected tourism market (Steiger et al., 2017). It will not only affect the social economy but also affect the lifestyle and healthcare of the public. Specifically, climate change affects water, sanitation, personal hygiene (WASH) and other elements of human life; and these elements are influencing factors for diseases such as cholera and malaria. The impact of climate change on WASH factors will also affect the spread of those diseases (Jones et al., 2020). For some specific populations, such as children, due to their physical and cognitive immaturity, the impact of climate change on them will be more obvious (Anderko et al., 2020). In response to the risks of climate change, many international organizations have made important contributions. By examining the challenges faced thus far when applying risk-based methods, decision scientists of the IPCC warned against continuing to apply objective risk assessment to the assumptions or prescriptions of the decision-making process (Tangney, 2019). There are also some studies that emphasize the need to link disaster risk reduction (DRR) with climate change adaptation (CCA) to achieve more effective use of resources and to avoid overlaps (Islam et al., 2019). Although the academic community has carried out many very important explorations on the risk of climate change, the results of these explorations are not well sorted out, and the application efficiency in practice is low. It is necessary to review the literature on climate change risk, which will help to have a deeper understanding of the research results in this field.

The existing literature fully discusses the impacts of climate change risks on many specific aspects of nature and human society. Unstable temperature and precipitation threaten forests, wetlands. and other ecosystems. Global warming promotes the rise of sea levels and affects economic production and coastal engineering in coastal areas. Some methods and paths to address the risk of climate change have also been proposed. Scientists and policymakers are working together to build a collaborative framework to address climate change. It is not difficult to find that climate change often first produces natural risks such as extreme weather and disasters, and then gradually produces risks in different dimensions on social public life, economic facilities, policy-making process and public risk attitude of human society (Wang et al., 2021; Ye et al., 2021). This is also consistent with the "disaster-exposure-vulnerability" generation path of climate change risk proposed by IPCC (IPCC, 2014). This means that climate change risk presents a feature system with coupling relationship in natural, social, economic, political, cultural, and other dimensions. Some recent literatures also show that the current climate change risk assessment needs to pay attention to the interaction between natural disasters and social, economic, and other factors (Simpson et al., 2021). However, the existing review research mainly focuses on two aspects. One is exploration of the impacts of climate change on biodiversity and land use (Oliver & Morecroft, 2014), water, ecosystems, food security, health, and other fields (McMichael & Lindgren, 2011; Cramer et al., 2018). The other is discussion of mitigation and adaptation strategies for climate change (Magnan et al., 2016). Although there are many discussions on the features of climate change risk in the existing literature, most of them focus on a specific aspect of climate change and its management strategies. The features of climate change risk from the natural, political, economic, social and cultural dimensions have not been systematically extracted.

To fill this gap, we use bibliometric analytical methods to extract and analyze features of climate change risk from the natural, political, economic, social, and cultural dimensions. We believe that this approach will help to clarify the coupling relationship between natural risk and unnatural risks of climate change, and have a deeper understanding of the existing climate change risk research results. Bibliometric analysis adopts statistics and visualization methods to explore the structure and patterns of certain disciplines, which provides an opportunity (Tang et al., 2018). This method is relatively promising and effective. It has been used in smart city and urban development (Guo et al., 2019; Peponi & Morgado, 2020), sustainable construction (Araújo et al., 2020), foreign direct investment (FDI) (Jiang et al., 2019), building information modeling (BIM) (Jin et al., 2019), and other research fields. This study aims to extract and analyze the features of climate change risks leveraged by using the bibliometric analytical method to obtain a deeper understanding of the risk patterns. To this end, we initially searched and identified papers published on climate change risks in recent years. VOSviewer software was then adapted to analyze the themes, keywords, authors, institutions, and co-citation and coauthor networks of these papers, whereby the analytical results were further explained and discussed.

Material and methods

Clarifying the scope and aim of this research was the first step in this paper. For the classification analysis and feature extraction of the multiple risk sources of climate change, this research mainly adopted bibliometric methods. We divided the risk factors caused by climate change into five key dimensions: nature, society, economy, politics, and culture and conceptualized them as well as research topics such as "climate change" and "risk." The follow-up works are shown in Fig. 1.

In step 2, we used the Web of Science (WoS) database as the main search method and conducted a literature search in the form of "TI = (climate change) AND TI = (risk)" using top journals in the field of climate change (such as climatic change, risk analysis, and nature climate change) as the basis for auxiliary retrieval. The literature retrieval data were screened based on the PRISMA review method (Fig. 2). Through four steps of identification, screening, eligibility, and inclusion, a total of 2027 articles were obtained as research data with a time span of 1990–2021. Figure 3 shows the trend of publication quantity of the literature data over the years and the themes at different stages. The literature data for knowledge extraction and analysis under the five risk dimensions were collected. In addition, during the literature data retrieval process, the database and the journal homepage were retrieved separately according to triangulation methodology. The database mainly extracted key information such as title, abstract, and keywords; and for the journal homepage, it conducted a full-text summary and analysis of the retrieved related literature.

In step 3, relying on the VOSviewer bibliometric software, we further conducted a visual analysis of the literature data in the dimensions of authors, articles, journals, institutions, and countries/regions. First, a comparative analysis of the literature data was

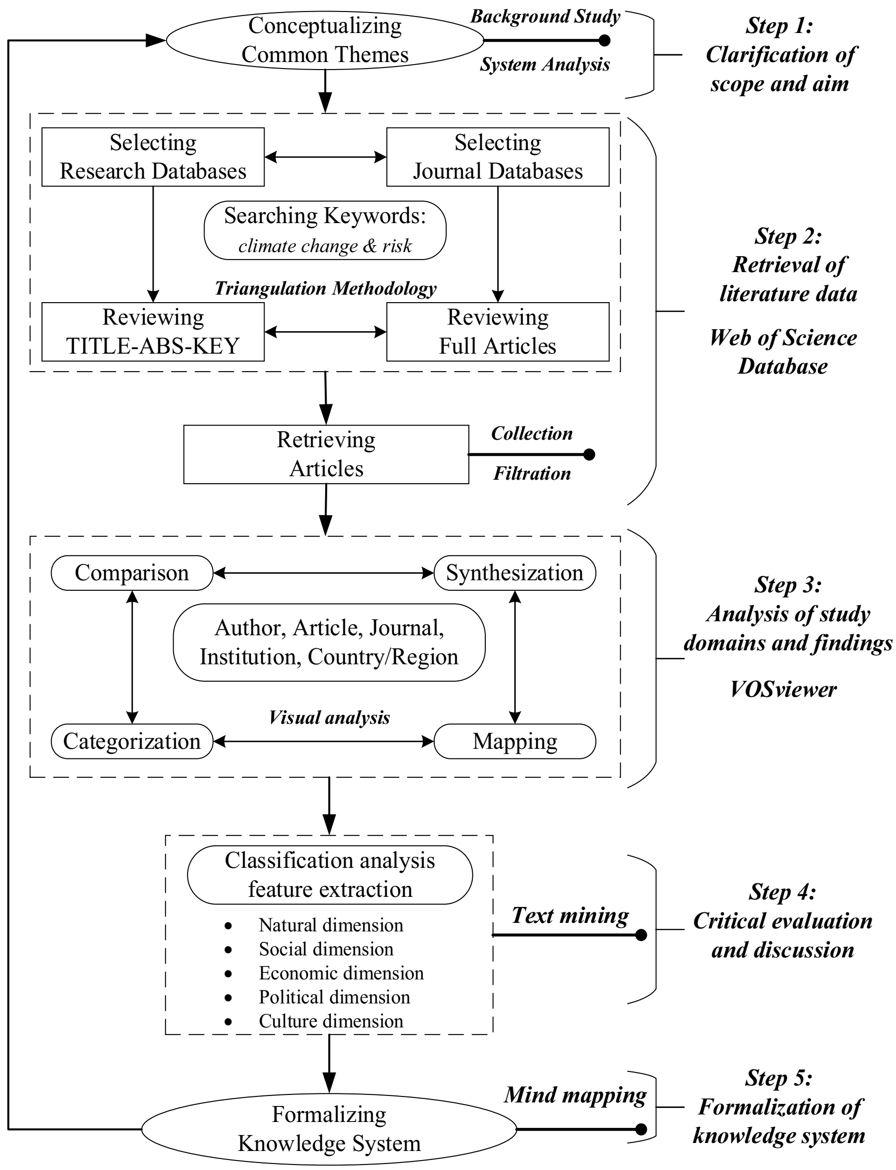


Fig. 1 Research design for classification analysis and feature extraction of multiple risk sources of climate change based on bibliometric analysis

conducted to summarize the mainstream research perspectives and scope. Second, an integrated analysis of similar research fields and dimensions was demonstrated. Then, we performed a cluster analysis of the literature data in the abovementioned dimensions. Finally, the internal research relationship and degree of influence were summarized through visual network analysis.

Evaluation and discussion of the results were conducted in step 4. Through text mining, risk source classification analysis and feature extraction from the five dimensions of climate change, namely, natural, social, economic, political, and cultural risks, we identified the impact factors caused by climate change. These results will be fully discussed and compared with the existing research. Finally, based on a mind map method, the relationship among research findings was visually expressed to form an analytical framework for the key influencing factors of climate change risk sources.

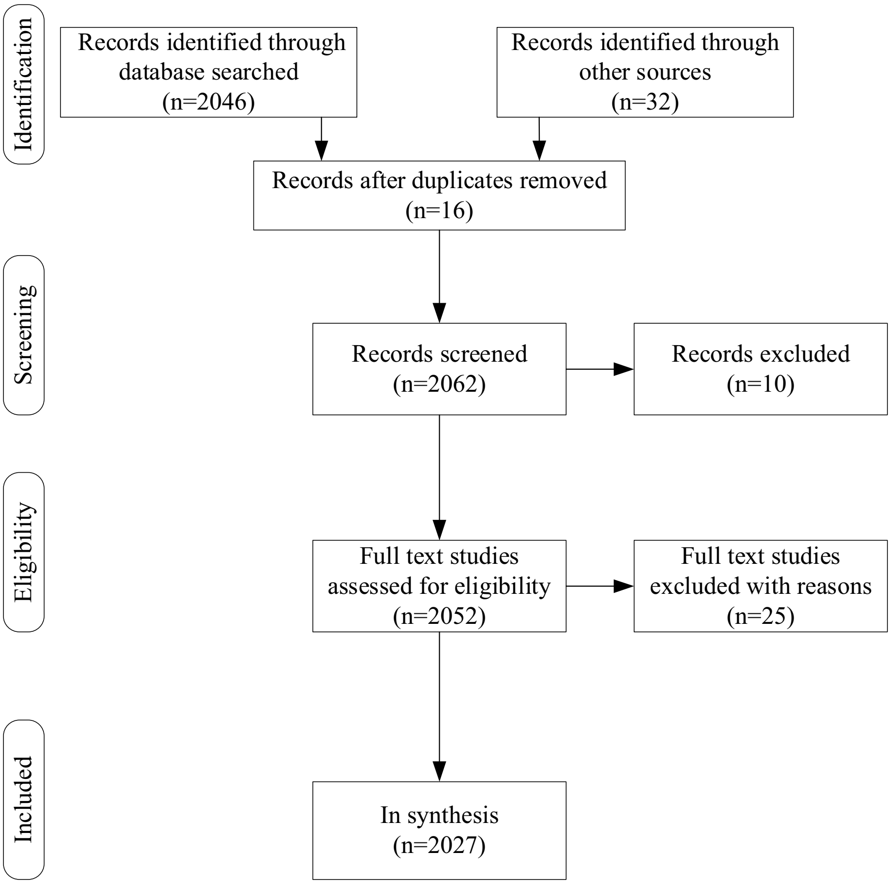


Fig. 2 PRISMA flowchart

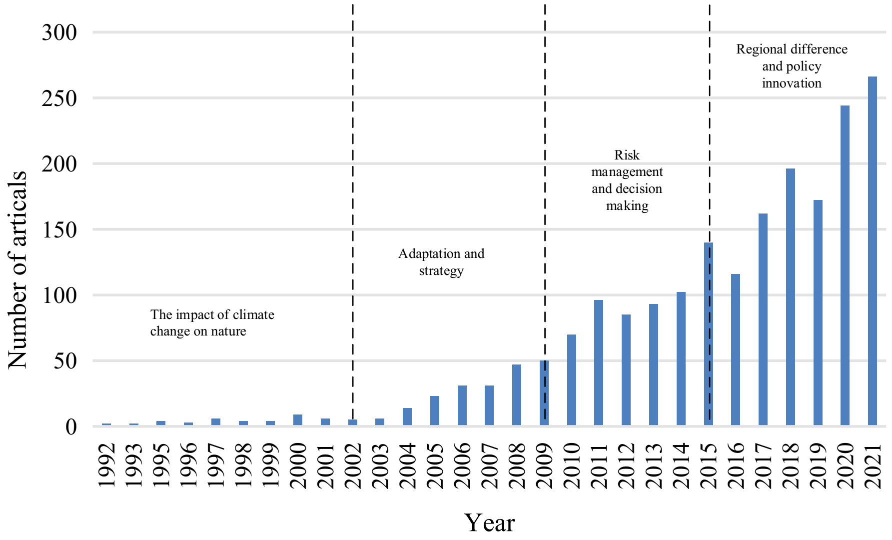


Fig. 3 Frequency and trend of literature data based on year

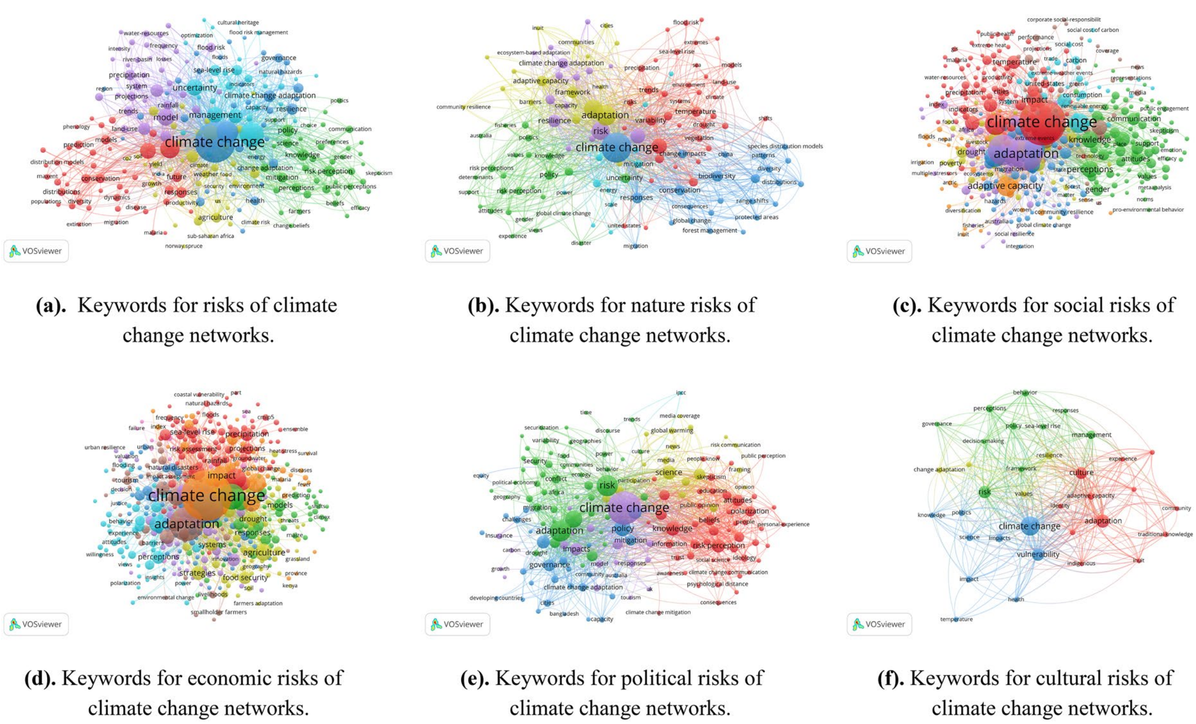
Results and analysis

Based on the literature data screening process and criteria in the research design in the Web of Science database and journal sources between 1990 and 2021, the key subject term "TI=(climate change) AND TI=(risk)" was found to be effective. The number of documents was 2027. In this part, the co-authors, citations, bibliographic coupling, mutual citation, and keyword co-occurrence of the above literature data were analyzed. In order to reduce the length of the article, this section only shows the analysis results of keyword co-occurrence and constructs the feature system of climate change risk on this basis. The results of co-authors (Figs. 7, 8 and 9, Tables 3, 4 and 5), citations (Figs. 10 and 11, Tables 6 and 7), bibliographic coupling (Figs. 12 and 13, Tables 8 and 9), and co-citation (Figs. 14 and 15, Tables 10 and 11) can be read in the Appendix 1, 2, 3 and 4 of this paper.

Keyword co-occurrence

Keyword co-occurrence analysis aims to mine the frequency of different keywords appearing in multiple articles to establish the network relationship structure among keywords in the field of climate change risk, thereby identifying the main research topics and trends in this field. Therefore, VOSviewer software was used to perform keyword co-occurrence analysis on comprehensive climate change risk literature and to further explore the keyword feature information of natural, social, economic, political, and cultural, five-dimensional climate change risk research literature.

In the WoS database, "climate change" and "risk" were used as the topic words for retrieval. Keywords for different dimensions (such as "nature" and "social") were added when searching the literature of different dimensions. Peer-reviewed journal papers were retained, and the retrieved academic papers were used for keyword co-occurrence analysis by VOSviewer, as shown in Fig. 4. The overlapping diagram of keyword co-occurrence (Figs. 16, 17, 18, 19, 20 and 21, Tables 12, 13, 14, 15, 16 and 17) can be read in Appendix 5. In the network graph, the size of the node and the strength and distance of the connection between nodes are used to indicate the research frequency of keywords in the literature. If the distance between two keywords is



(a). Keywords for risks of climate change networks.

(b). Keywords for nature risks of climate change networks.

(c). Keywords for social risks of climate change networks.

(d). Keywords for economic risks of climate change networks.

(e). Keywords for political risks of climate change networks.

(f). Keywords for cultural risks of climate change networks.

Fig. 4 Keyword mapping networks. **a** Keywords for risks of climate change networks. **b** Keywords for nature risks of climate change networks. **c** Keywords for social risks of climate change networks. **d** Keywords for economic risks of climate change networks. **e** Keywords for political risks of climate change networks. **f** Keywords for cultural risks of climate change networks

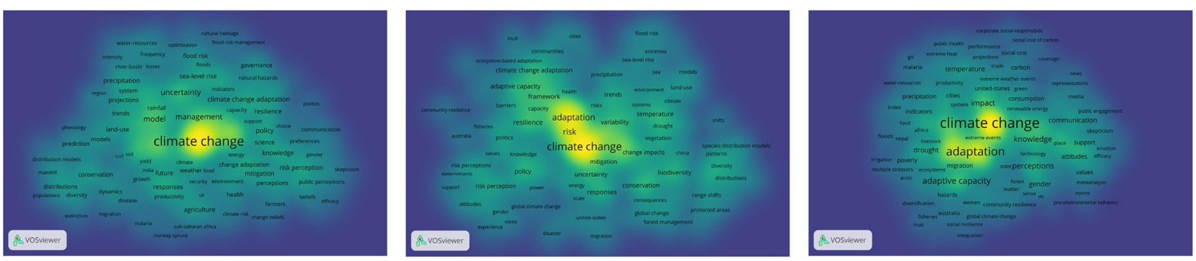
Table 1 Keyword extraction and category information

Topic words	Total literature	Minimum frequency	Total keywords	Effective keywords	Categories
Climate and climate change	2027	10	6853	239	5
Nature and climate and climate change	432	5	2036	133	6
Social and climate and climate change	523	5	2366	424	5
Economic and climate and climate change	506	5	2543	468	5
Political and climate and climate change	432	5	2213	173	6
Culture and climate and climate change	191	5	704	103	4

smaller or the relationship is closer, it indicates that the number of co-occurrences is greater.

Table 1 shows the minimum frequency of keywords, total number of keywords, and effective keywords in different dimensions. It was found that the co-occurrence of keywords in the climate change risk literature could be divided into different categories, which are represented by different colored nodes and lines. Each category gathers the frequently appearing and associated keyword information of this group of research literature. Meaningless information (such as climate change, USA, trends, and framework) and integrating information with the same meaning (such as impact and impacts) were filtered out. The most influential keywords in different categories according to occurrences and total link strength are the basis for classification analysis and feature extraction of multiple risk sources of climate change.

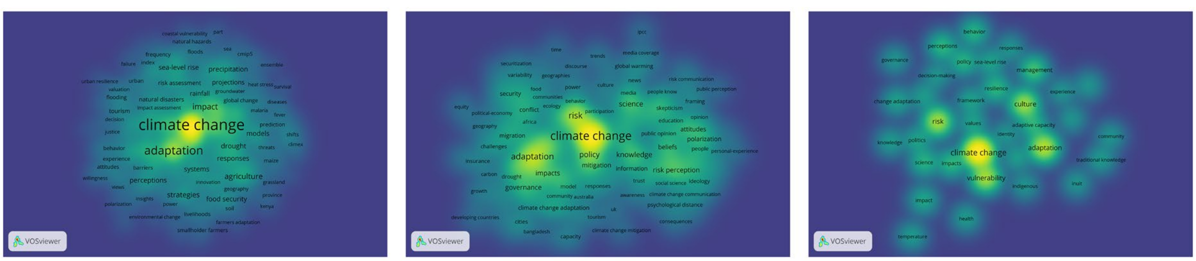
The total link strength reveals the relationship strength between different keywords; that is, the greater the total link strength is, the stronger the relationship between the keyword and its linked



(a). Keyword intensity for risks of climate change networks.

(b). Keyword intensity for nature risks of climate change networks.

(c). Keyword intensity for social risks of climate change networks.



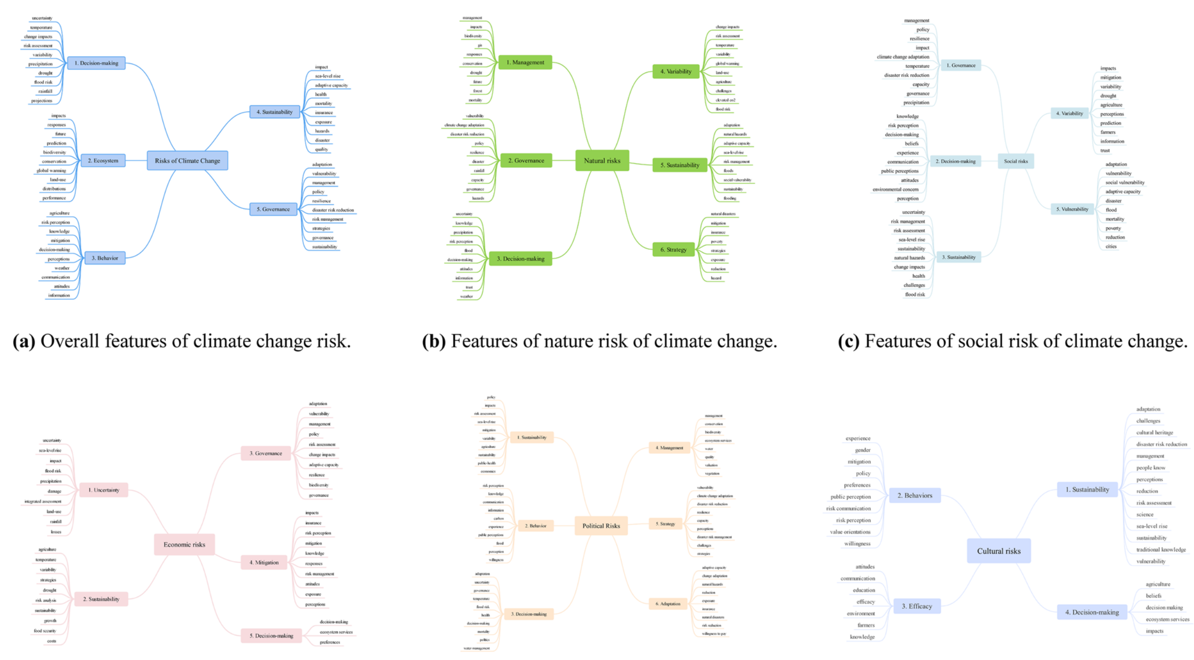
(d). Keyword intensity for economic risks of climate change networks.

(e). Keyword intensity for political risks of climate change networks.

(f). Keyword intensity for culture risks of climate change networks.

Fig. 5 Keyword intensity visualizations. **a** Keyword intensity for risks of climate change networks. **b** Keyword intensity for nature risks of climate change networks. **c** Keyword intensity for social risks of climate change networks. **d** Keyword intensity for economic risks of climate change networks. **e** Keyword intensity for political risks of climate change networks. **f** Keyword intensity for culture risks of climate change networks keywords. In addition, the average standardized citation index reveals the influence of the keyword in the field of climate change risk, which is calculated by the ratio of the total citation frequency of literature to its annual average citation frequency. Figure 5 shows the density of keywords. The color indicates the density of different keyword classifications, while font size indicates the frequency of keyword co-occurrence. Red represents the most intensive keyword category, followed by yellow, green, and so on.

Through keyword co-occurrence analysis, this study found that (1) in the overall characteristic dimension of climate change risk, vulnerability, uncertainty, management, and adaptation are the keywords with high frequency, which indicates that the current climate change risk has great vulnerability and uncertainty. Improving adaptability through management means is an important way to deal with climate change risk. (2) In the dimension of natural risk of climate change, natural disasters, biodiversity, and disaster risk reduction are the keywords with high frequency, which indicates that natural disasters caused by extreme climate events are the main natural risks of climate change and pose a serious threat to global biodiversity, so it is necessary to take the initiative to reduce disaster risks. (3) In the dimension of social risk of climate change, resilience, sustainability, risk assessment, and decision-making are the keywords with high frequency, which indicates that climate change poses an important challenge to social resilience and sustainable development, and climate change elements should be fully considered in future social risk assessment and decision-making. (4) In the dimension of economic risk of climate change, agriculture, preferences, and insurance are the keywords with high frequency, which shows that the economic risk of climate change is mainly reflected in the field of agriculture. Climate disasters will have negative impacts on economic performance. Financial instruments such as commercial insurance also help to deal with the risk of climate change. (5) In the dimension of political risk of climate change, policy, communication, and governance are the keywords with high frequency, which shows that climate change affects the formulation and implementation of policies in the political field, and the political instability caused by risk also requires the government to strengthen



(a) Overall features of climate change risk. **(b)** Features of nature risk of climate change. **(c)** Features of social risk of climate change.

(d) Features of economic risk of climate change **(e)** Features of political risk of climate change. **(f)** Features of culture risk of climate change.

Fig. 6 Feature extraction of climate change risks. **a** Overall features of climate change risk. **b** Features of nature risk of climate change. **c** Features of social risk of climate change. **d** Features of economic risk of climate change. **e** Features of political risk of climate change. **f** Features of culture risk of climate change communication with the public and innovate the way of government governance. (6) In the dimension of cultural risk of climate change, cultural heritage, public perception, and knowledge are the keywords with high frequency, which shows that a series of changes brought by climate change impact the social cultural tradition. Improving the public's perception and understanding of climate change risk can effectively deal with the risk impact. The creation of new knowledge, such as scientific and technological progress, can also enhance the adaptability to climate change risks.

Feature system of climate change risks

Based on the above keyword co-occurrence results, this part further uses text mining and cluster analysis to summarize the overall risk of climate change, and extracts the features and key factors of climate change risk sources from the five risk dimensions of natural risk, social risk, economic risk, political risk, and cultural risk (shown in Fig. 6).

Table 2 shows the final feature system climate change risk in this study. Through cluster analysis and text mining, we classify the overall features of climate change and the features reflected in the five dimensions of nature, society, economy, politics, and culture into five categories: ecosystem and sustainability; uncertainty, vulnerability, and efficacy; behavior and decision-making; governance and management; and adaption and mitigation. It covers the process of cognition, judgment, impact, and resolution of climate change risks. In addition, we fully compare our research results with the existing research in Sect. 4, hoping to further improve our theoretical framework.

Discussion

In this section, we will fully discuss the feature system of climate change risk constructed in this study. Firstly, we expound the specific performance and impact of different risk features from the theoretical

Table 2 Feature system of climate change risks

Primary risk feature	Secondary risk feature	Embodiment of risk feature
Ecosystem and sustainability	• Global warming • Biodiversity reduction • Land use out of control • Extreme weather events • Agriculture	➢ Sea level rise ➢ Coastal salinization ➢ Lower food productivity ➢ Irregular temperature ➢ Precipitation ➢ Increased forest mortality ➢ Reduction in wetland area
Uncertainty, vulnerability, and efficacy	• Climate fluctuation • Gap between the rich and the poor • Poverty alleviation • Public health	➢ Drought and flood disasters ➢ Unstable river runoff ➢ Reduction of production capacity of enterprises ➢ Unemployment of urban residents ➢ Agricultural production mode ➢ Malaria, dengue fever, and other diseases
Behavior and decision-making	• Risk perception • Willingness to participate • Information exchange • Decision preference • Risk attitude	➢ Policy makers and stakeholders ignore climate change and its impacts ➢ Lack of understanding of climate change policy and report text ➢ Public does not support climate change policy
Governance and management	• Policy making • Risk management • Resilience governance • Risk assessment	➢ Differences in climate change governance models ➢ Multi-agent participation in climate action ➢ Management organization of climate change ➢ Collection and dissemination of climate information
Adaption and mitigation	• Risk resolution • Insurance mechanism • Public welfare protection	➢ Coastal disaster reduction project ➢ Greenhouse gas emission reduction project ➢ Energy saving and emission reduction technology ➢ Catastrophe insurance mechanism ➢ Social security mechanism of disaster

level, and compare it with the existing research results to further enrich the findings of this study. Secondly, we will put forward some practical and managerial implications on the basis of theory.

Ecosystem and sustainability

The potential environmental damage and ecological imbalance brought by climate change to ecosystems are the most significant risk features of climate change. The Third National Climate Change Assessment Report issued by Chinese governmental departments and research institutions assessed the risk of climate change to natural ecosystems from agriculture, water resources, coastal zones, forests, cryospheres, and other aspects (NARCC, 2015), reflected in global warming, biodiversity reduction, land use imbalance, and other aspects. The new climate is observed disproportionately in some protected areas, showing the characteristics of being hotter and drier and having more seasonal precipitation (Wiens et al., 2011). The increase in the frequency and duration of drought and heat related to climate change may fundamentally change the forest structure in many areas, and the mortality of trees will also increase with climate change factors and physiological factors related to climate change (such as diseases and pests), which will cause the loss of forest carbon and associated atmospheric feedbacks (Allen et al., 2010). The disappearance of some existing climatic areas increases the risk of extinction of species with narrow geographical or climatic distributions and causes damage to existing communities. There is a close correspondence among the regions where the climate has changed and the previously identified biodiversity hotspots. For these regions, some common conservation measures (such as assisted migration and network reserves) may not be able to fully protect biodiversity (Williams et al., 2007). There are also studies pointing out the risks of climate change to human health and survival, which mainly focus on thermal stress, extreme weather events, and infectious diseases, and discussing future food production and food security issues.

With the destruction of ecosystems, the sustainability of global development comes into question, which is reflected in the impact of changes in the natural environment on human society, the economy and people's lives, as well as the sustainable implementation of public sector plans. The unpredictability of climate change risk includes sudden changes in temperature, global warming, out-of-control land use, flood disasters, and so on. These natural phenomena pose great challenges to global sustainable development. The most significant impact of this phenomenon is on the agricultural field and coastal areas. Coastal agriculture is characterized by low-lying terrain and soil salinization. The fluctuations in temperature and precipitation, population migration, pollution, and the change in land-use policy are the major challenges to the sustainability of coastal agriculture (Gopalakrishnan et al., 2019). These areas are densely populated and developing rapidly. In some countries (especially China), urbanization promotes the flow of the population to coastal areas (McGranahan et al., 2016). With the rapid development of the economy and industry in these areas, different regional cultures also blend. The destruction of cultural heritage caused by climate change will shake people's traditional cognition and affect the economic and cultural sustainability of these areas. To address the impact of climate change on public health and public welfare, the government may issue ambitious climate change response bills or economic programs to address these problems. However, if these measures fail to achieve effective mitigation of the climate change risks, they will also threaten political sustainability. The UK Climate Change Act issued in 2008 is an example. The passage of the act is regarded as a milestone commitment to climate change action, but the results of its implementation are not satisfactory. There are also differences in the carbon budget and decarburization in the electric power sector. Some supporters and political leaders of the act have also been criticized by the public (Lockwood, 2013).

Uncertainty, vulnerability, and efficacy

The uncertainty of climate change risk refers to the unpredictability and variability of risk impact, which is manifested in the impact of natural climate disasters such as sea level rise, floods, water, and soil loss on society and the economy, which will vary with changes in limited conditions. The occurrence of extreme weather will increase the uncertainty of climate change and pose new challenges to the security of food systems in the future (Thornton et al., 2014). A large-scale survey of farmers in 12 midwestern states of the USA measured the uncertainty of climate change from three dimensions of cognition, arbitrariness, and response. Climate scientists should regard the uncertainty of climate change as a multidimensional concept (Singh et al., 2020).

The feature of vulnerability of climate change risk is the potential negative impact of climate change risk on public welfare, which is embodied in the urban gap between the rich and the poor, poverty alleviation, public health, and so on. In the process of urbanization in some regions of East Africa, uncertain climate change has exacerbated the social gap between the rich and the poor in cities, has posed great challenges to the economic growth of these cities, and has further aggravated poverty for the urban poor (Kithiia, 2011). The impact of climate change on human health challenges the public health systems of some underdeveloped countries and aggravates vulnerability to climate change (Bulto et al., 2006). To date, some studies have used a livelihood vulnerability index (LVI) to evaluate climate change vulnerability in some areas by collecting data from social demography, social networks, health, food, and water security (Hahn et al., 2009).

The efficiency of climate change is reflected in the migration of cultural cognition and attitudes of some social groups (such as farmers) caused by climate change, which has an impact on the efficiency of social, economic, and environmental operations. Agriculture is vulnerable to climate change and greenhouse gases (GHGs), and farmers face the pressure of adjusting their mode of agricultural production to cope with climate change (Arbuckle et al., 2015). A study showed that the belief in climate change of farmers in the Midwest region of the USA affects their perception and attitude towards weather and climate risks and will affect their adaptation strategies, which will affect farmers' groups and agricultural production efficiency (Mase et al., 2017).

Behavior and decision-making

Although climate change is a natural phenomenon, due to the intensification of human activities, the relationship between climate change risk and human behavior, especially cognitive behavior, is increasingly close. The cognitive behavior of decision-makers and climate change stakeholders, including risk perception, willingness to participate, and information exchange, has a significant impact on the consequences of risk. Whether these individuals are willing to accept the reality, system, and capacity of climate change and whether they are willing to integrate climate change risk assessment and management into development strategy are the embodiment of policy makers' perception of climate change risk. Ignoring these factors will pose a threat to vulnerability to climate change risk (O'Brien et al., 2006). A study among the British public also showed that the willingness of individuals to participate has an impact on the UK's substantial emission reduction of greenhouse gases, and guidance plans should be formulated accordingly; therefore, citizens and communities can reduce their dependence on carbon and improve their willingness to participate in greenhouse gas emission reduction actions (Lorenzoni et al., 2007). Information exchange is a factor that affects communication between policy makers and the public. Climate change-related policies and information should be conveyed in a public-oriented way so that nonscientists can understand. In contrast, it will further increase the risk of climate change. For example, the summary for policy makers (SPM) published by the IPCC is the most widely read part of the IPCC report. However, some studies have shown that this part has low readability, which is not conducive to public reading (Barkemeyer et al., 2015).

Climate change risk is also reflected in the decision-making of risk managers and stakeholders. Uncertainty in risk assessment and unnatural factors derived from climate fluctuations will affect the decision-making process. With the development of evaluation technology in modern society, people can use a variety of complex methods to address these decision-making problems. The analysis and modeling methods involved in these problems are also considered by many researchers (Yousefpour et al., 2011). However, our research shows that unnatural factors such as decision preference, risk attitude, and trust need to be considered in the decision-making process in the context of risk needs. Decision preference reflects the decision-making differences caused by the differences in cognition, culture, and experience of decision-makers in the process of decision-making. A national survey of the American public found that Americans' perceptions of climate change risks are quite different, and their support for climate change mitigation policies and several carbon tax proposals has also changed, which is strongly influenced by experience factors and social and cultural factors, including emotion, image, and values (Leiserowitz, 2006). In the past decade, the judgment of climate change has mostly been based on imprecise prediction, and different people's attitudes towards climate change risk are also quite different (Viscusi & Zeckhauser, 2006). Therefore, in the process of policy debate and formulation, whether to take positive policy action to address these problems is still widely agreed upon. We believe that a clear risk attitude will help us understand and determine adaptation programs to address climate change risks. To achieve these goals, we need reform measures to bring different social subjects into the decision-making process (Connelly et al., 2018). In addition, some studies have emphasized the role of news media in decision-making. These studies speculated that the development of media culture, technology. and practice has created opportunities to enhance public understanding of climate change policies (Smith, 2005).

Governance and management

The features of governance and management describe the response measures of all sectors of society to climate change, including policy-making, risk management, resilient governance, and other aspects. The governance of the national response to climate change does not happen in a vacuum. Different countries will respond to different incentives when they adopt climate protection plans. Some studies have divided climate change governance into four response modes: risk (policy measures to address climate risks and impacts), politics (compromise schemes of political interest groups), economy (product of reasonable calculation of economic costs and benefits), and policy diffusion (reflection of state government policy learning and imitation) (Yi & Feiock, 2015).

Climate change governance has three traditional governance methods: technology (features of clean technology, infrastructure, and planning of space that compose the urban form), politics (issues of distribution and access to resources and institutions in society), and ecology (understanding the resilience of the biophysical system and its thresholds to cope with external perturbations). The existing research shows that only one of the three traditional methods alone is not enough to address future climate change (Boyd & Juhola, 2014). The governance of climate change is a complex collective action problem that needs to be solved by multiple subjects with a comprehensive approach. The future research agenda of climate governance needs to further explore the relationship among the three traditions to better determine the contradiction, complementarity, or compatibility. However, not all national or local governments are actively and fully involved in climate issues. Especially for urban governance, cities with perfect climate change management organizations can better put forward comprehensive climate change policies and promote climate action agendas to promote the implementation of the plan (Lee & Painter, 2015), which requires proper climate governance arrangements of urban governments, including the cooperation of researchers, nongovernmental organizations, and government officials.

Risk management combines risk assessment with risk perception and focuses on reducing the loss caused by natural disasters in climate change, which is an effective risk management path. In this process, adaptive management and risk-based management should be combined to distinguish different risk levels (Kuklicke & Demeritt, 2016). In the management of extreme weather and risk caused by climate, climate information is very valuable. Climate information is an important prerequisite for making informed decisions in risk management, which is of great help to prevent extreme weather from becoming a disaster and threatening livelihood. From monitoring institutions to communities, climate information needs to establish a systematic relationship between information producers and users (Srinivasan et al., 2011). In addition, risk management in climate change needs effective financial support.

Adaption and mitigation

The features of climate change adaptation and mitigation aim to describe the strategy of addressing the challenges of climate change risks, which is mainly manifested in risk resolution, insurance mechanisms, public welfare, and other aspects. The current research has explored the theory and practice of disaster risk reduction (DRR) and climate change adaptation (CCA). To better strengthen the communication and contact between the two fields, Europe has developed a set of RAMSET (risk assessment model simulation for emergency training exercise) mechanisms to bridge the gap between scientific and legal/policy issues of EU countries and to improve the ability of risk adaptation and mitigation (Abad et al., 2020).

In recent years, some projects to adapt to and to mitigate climate change have been launched, which have become an important strategy to address the risk of climate change. These projects mainly focus on the emission reduction and removal of greenhouse gases. They can be divided into five different categories: anthropogenic emission reduction (AER), territorial or domestic removal of greenhouse gas (D-GGR), transterritorial removal of greenhouse gas (TGGR), regional to planetary targeted climate modification (TCM), and climate change adaptation (including local targeted climate and environmental modification, abbreviated CCAM) measures (Boucher et al., 2014). In the process of developing and operating these climate engineering projects, technical factors are considered to be some of the most important factors. In addition to the continuous efforts of scientific researchers, technological progress also requires the transformation and application of scientific research achievements. Therefore, promoting the global spread of some important patents (such as renewable energy, carbon capture, and storage technology) is a necessary means to adapt to and to mitigate the risk from climate change (Raiser et al., 2017).

In extreme weather events (such as floods and typhoons), financial insurance is considered to play an important role in hedging the impacts of climate change. In some countries that are vulnerable to climate change (such as the Netherlands), insurance can largely alleviate the threat and burden of floods on the social economy and residents' lives (Botzen & van den Bergh, 2008). For the agricultural sector, insurance mechanisms can effectively prevent farmers from suffering losses caused by climate change. Some studies have shown that crop diversification can also replace financial insurance to some extent to mitigate risks (Falco et al., 2014). At present, in most developed countries, insurance mechanisms have gradually become an important means to protect private property from loss, while in some developing countries (such as China), the public welfare provided by the government is still the main way to address the risk of climate change.

Practical and managerial implications

The risk of climate change challenges traditional management methods. We can obtain some implications for future practice and management by extracting and analyzing the features of climate change risk. From the view of this paper, the uncertainty and vulnerability of climate change risk is an important feature threatening the survival and development of human beings. It is different from the general natural risk and often cannot be felt by the senses. This indicates that we need to use means other than traditional management methods and pay attention to perception, belief, and other factors to face the threat. This kind of nontraditional management mode requires us to reconstruct the existing social system, including the structural adjustment of the existing social contract, the meaning of security, and the modes of development (Pelling, 2011). It is not only the system reform of the operation level but also the transformation of the value level. Through knowledge, innovation, and education, the ability of the entire society to address uncertainty and vulnerability at different levels is built.

The urgency of climate change risk to ecosystems and sustainable development also tells us that we need to participate in global climate governance with a more positive attitude. Climate change is a global public problem, and it is difficult for a single organization or governmental department to address it alone. Strengthening the coordination of governance policies is a necessary way to improve the performance of disaster reduction. In the implementation of climate change risk adaptation and mitigation strategies, strengthening the participation of multiple subjects can effectively promote the exchange and understanding of information and ensure the implementation effects of the strategy.

Conclusions and future work

In this study, the natural, social, economic, political, and cultural risk sources of climate change were classified and analyzed. We searched the relevant literature in the field of climate change risk and analyzed the literature data in topics that included authors, articles, journals, institutions, countries/regions, keyword co-occurrence, etc.

We realize that climate change risk has had a profound impact on nature and human society. Therefore, in the process of extracting climate change risk features, this study creatively considers the relationship of natural risk characteristics and unnatural risk. Through clustering and integration analysis, we summarized the five dimensions of climate change risk features that include nature, society, economy, politics, and culture; that is, based on keyword co-occurrence analysis, we gained insight into the influencing factors and key features of climate change risk sources in the literature data. On this basis, using text mining and cluster analysis, this paper further extracts the features and key factors of climate change risk sources under five risk dimensions and then forms a basic analytical framework for establishing a risk index system that includes five categories and a total of 11 key features. We fully discuss these features and introduce some information on them.

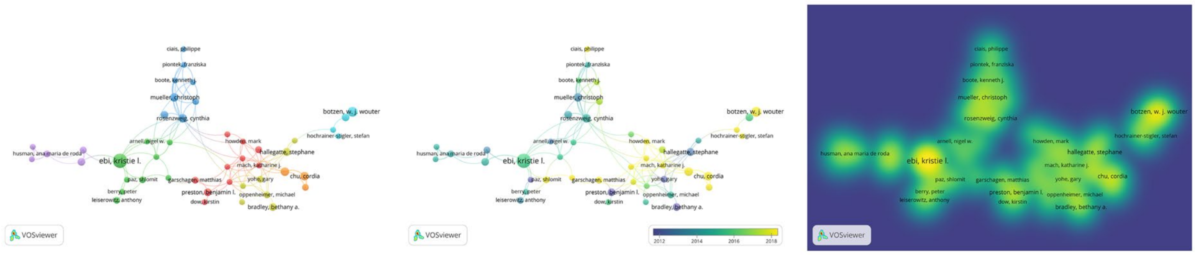
Through the literature review, it is not difficult to find that climate change risk is becoming an important issue in global development, which is also a common concern of many researchers. Our research extracted and analyzed the features of climate change risk. We think that the risk features of climate change are mainly reflected in the following aspects. The features of ecosystems and sustainability reflect all kinds of natural disasters and ecological problems caused by climate change, as well as damage to ecosystems and obstacles to sustainable global development. The feature of uncertainty, vulnerability, and effectiveness mainly describes the unpredictability of climate disasters and the impact of climate change on social well-being and public life. Behavior and decision-making features reflect the impact of human cognition, willingness, and other behavioral factors on risk judgment and decision-making in judging and responding to climate change risks. Governance and management features mainly describe the governance principles and methods for some climate change risks. Adaptation and mitigation features reflect some specific climate change risk mitigation and adaptation strategies. In conclusion, the impact of climate change on our world is comprehensive. We need to address this important challenge in a more active, collaborative, and profound way in the future.

The limitation of this bibliometric study should be addressed in future work. First, the data collection procedure in this study was limited to the WoS database, and the top international journals in the field of climate change were included during the retrieval search. Although the WoS database is the largest and most extensive database in the world and our literature data may cover most of the research in the field of climate change, it is still necessary to include other international databases in the retrieval search in future research to ensure data integrity to the greatest extent. Second, although we used a scientific literature review method in data screening, due to the lack of relevant literature on climate change in the context of risk and strict-screening criteria formulated by other research teams, the inclusion of some literature may be limited. We have avoided the influence of researchers' subjective factors in data analysis through sufficient text mining and comparison with other studies. In the future, researchers can ensure the scientificity of research work by strengthening interdisciplinary links.

In addition, there are some knowledge gaps in climate change research itself, specifically in the following aspects. There is a lack of connection between natural science research and policy research on climate change. The conclusions of scientific research are also uncertain; for example, different prediction methods and models will bring different conclusions. Furthermore, the outbreak and spread of COVID-19 also bring challenges to the current global governance structure. The differences between countries and regions and the conflicts of interest between developed and developing countries will affect the global governance of climate change in the future. Future research needs more interdisciplinary cooperation to strengthen the connection between science and policy. Unremitting efforts of future researchers are required to determine how to address the problem of climate change in the possible global pattern in the future, how to coordinate the developmental interests of developed and developing countries under the background of the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement, and how to promote future climate change work.

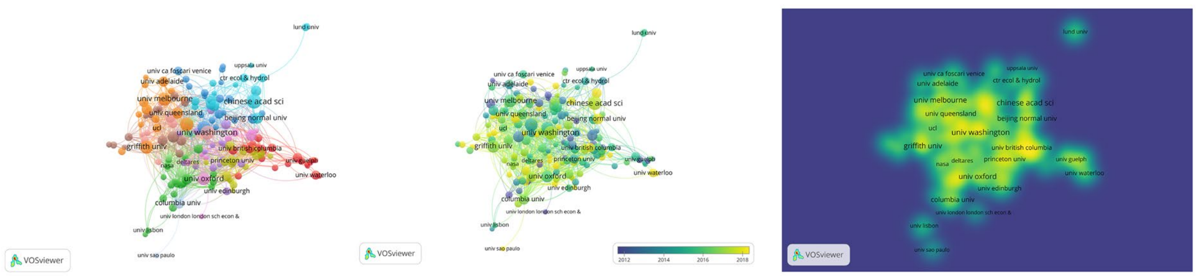
Appendix 1. Analysis of co-authorship

(see Figs. 7, 8 and 9, see Tables 3, 4 and 5)



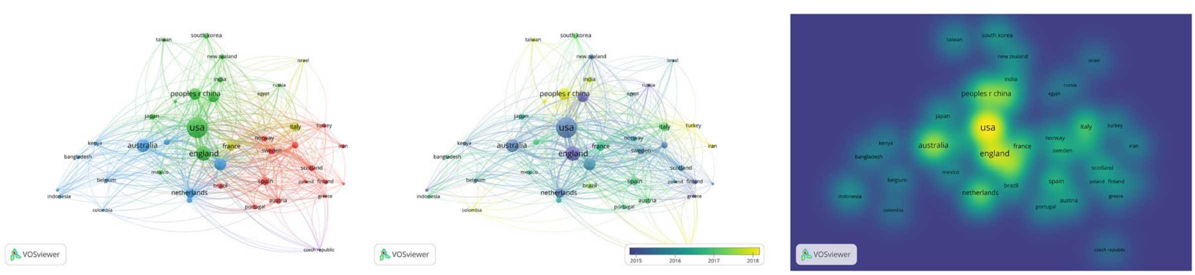
(a) (b) (c)

Fig. 7 Co-author relationship. **a** Network diagram. **b** Overlapping diagram. **c** density diagram



(a) (b) (c)

Fig. 8 Co-author organization relationship. **a** Network diagram. **b** Overlapping diagram. **c** Density diagram



(a) (b) (c)

Fig. 9 Co-author country/region relationship. **a** Network diagram. **b** Overlapping diagram. **c** Density diagram

Table 3 Co-author relationship information

Label	Cluster	Weight < total link strength >	Weight < citations >	Score < avg. citations >
Mach, Katharine J	1	10	201	67
Birkmann, Joern	1	9	206	68.6667
O'neill, Brian C	1	9	170	56.6667
Howden, Mark	1	7	34	11.3333
O'neill, Brian	1	7	69	23
Garschagen, Matthias	1	4	67	16.75
Lawrence, Judy	1	4	113	28.25
Preston, Benjamin L	1	4	408	81.6
Van aalst, Maarten K	1	3	469	156.3333
Dow, Kirstin	1	1	79	26.3333
Ebi, Kristie L	2	11	338	19.8824
Cramer, Wolfgang	2	8	614	204.6667
Lotze-campen, Hermann	2	8	393	131
Paz, Shlomit	2	5	348	87
Arnell, Nigel W	2	4	773	257.6667
Berry, Peter	2	4	147	49
Campbell-lendrum, Diarmid	2	3	156	52
Gattuso, Jean-Pierre	2	3	346	115.3333
Leiserowitz, Anthony	2	1	1178	294.5
Rosenzweig, Cynthia	3	19	1018	169.6667
Mueller, Christoph	3	12	1296	216
Stehfest, Elke	3	12	1128	282
Piontek, Franziska	3	11	1016	338.6667
Boote, Kenneth J	3	10	969	323
Ruane, Alex C	3	10	960	320
Solecki, William	3	2	128	25.6
Ciais, Philippe	3	1	71	23.6667
Hallegatte, Stephane	4	9	452	90.4
Takahashi, Kiyoshi	4	9	808	269.3333
Oppenheimer, Michael	4	7	346	86.5
Yohe, Gary	4	6	430	107.5
Ranger, Nicola	4	2	191	63.6667
Bradley, Bethany A	4	1	456	91.2
Kanae, Shinjiro	4	1	1645	548.3333
Husman, Ana Maria De Roda	5	8	127	31.75
Semenza, Jan C	5	7	206	41.2
Suk, Jonathan E	5	7	194	48.5
De nijs, Ton	5	6	82	27.3333
Sterk, Ankie	5	6	82	27.3333
Aerts, Jeroen C. J. H	6	3	340	68
Ward, Philip J	6	3	210	70
Botzen, W. J. Wouter	6	2	150	18.75
Hochrainer-stigler, Stefan	6	1	63	21
Mackey, Brendan	7	9	79	13.1667
Chu, Cordia	7	6	83	13.8333
Rutherford, Shannon	7	5	43	10.75

Table 4 Co-author organization relationship information

Label	Cluster	Weight < total link strength >	Score < avg. citations >
Univ British Columbia	1	25	14.0667
Univ Colorado	1	21	71.7692
Nature Conservancy	1	17	21
Colorado State Univ	1	14	29.8462
Cornell Univ	1	14	25
Nasa	2	39	135.25
Univ Maryland	2	35	35.5556
Univ Twente	2	34	12
Univ Denver	2	25	14
Univ Bristol	2	24	237.5714
Univ Leeds	3	33	391.6923
Vrije Univ Amsterdam	3	29	66.4231
Univ Durham	3	19	560.5556
Univ Zurich	3	15	13.1667
Czech Acad Sci	3	14	18.8
Natl Ctr Atmospher Res	4	42	36.0667
Pacific Northwest Natl Lab	4	32	25.6667
Princeton Univ	4	32	104.5714
Us Epa	4	22	40.5
Noaa	4	20	31.0833
Natl Inst Environm Studies	5	27	165.8
Univ East Anglia	5	25	27.8889
Carnegie Inst Sci	5	23	179
Univ Witwatersrand	5	22	522.5556
Monash Univ	5	19	72.25
Chinese Acad Sci	6	36	20.7647
Univ Cambridge	6	35	287.7647
Csic	6	31	173.75
Univ Chinese Acad Sci	6	24	6.1176
Univ Nacl Autonoma Mexico	6	23	306.0625

Table 5 Co-author country/region relationship information

Label	Cluster	Weight < total link strength >	Score < avg. citations >
Spain	1	146	92.7195
Switzerland	1	132	116.8833
Austria	1	108	64.6818
Sweden	1	86	31.4516
Norway	1	83	36.8571
Usa	2	426	61.3949
England	2	425	78.699
Canada	2	156	56.6258
People's Republic of China	2	154	38.0057
Japan	2	75	64.0714
Germany	3	335	38.298
Australia	3	230	80.2895
Netherlands	3	211	100.193
Denmark	3	90	32.3171
South Africa	3	85	114.8039
France	4	205	69.8283
Italy	4	157	68.301
Egypt	4	19	13.7
Israel	4	19	63.1818
Czech Republic	5	39	30.8

Appendix 2. Analysis of citations

(see Figs. 10 and 11, see Tables 6 and 7)

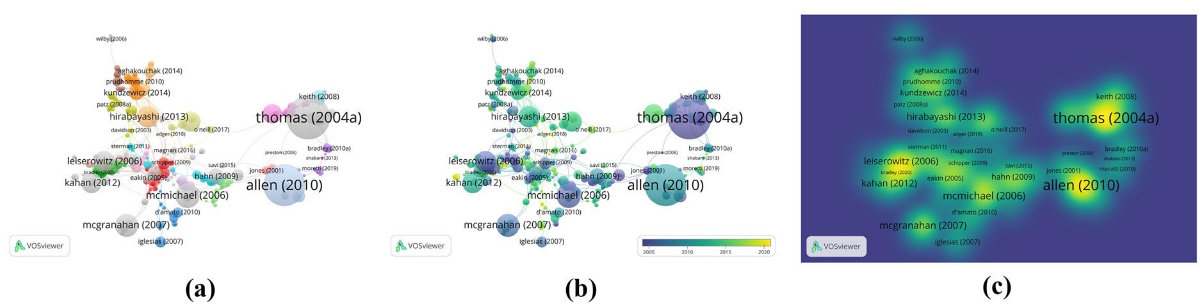


Fig. 10 Document citation relationship. **a** Network diagram. **b** Overlapping diagram. **c** Density diagram

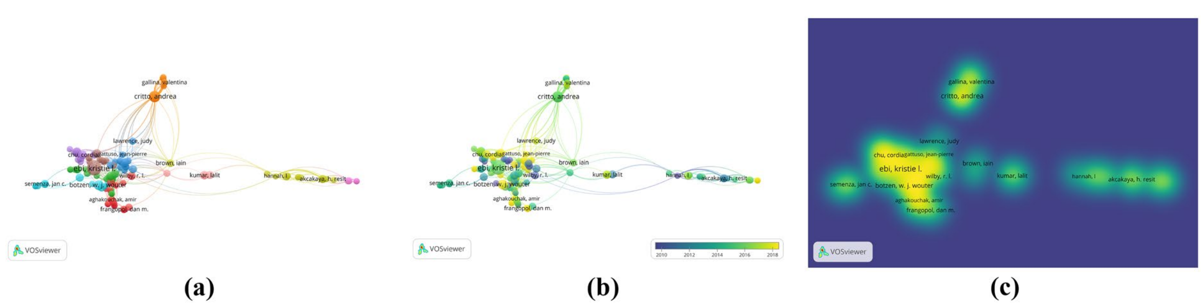


Fig. 11 Author citation relationship. **a** Network diagram. **b** Overlapping diagram. **c** Density diagram

Table 6 Document citation relationship information

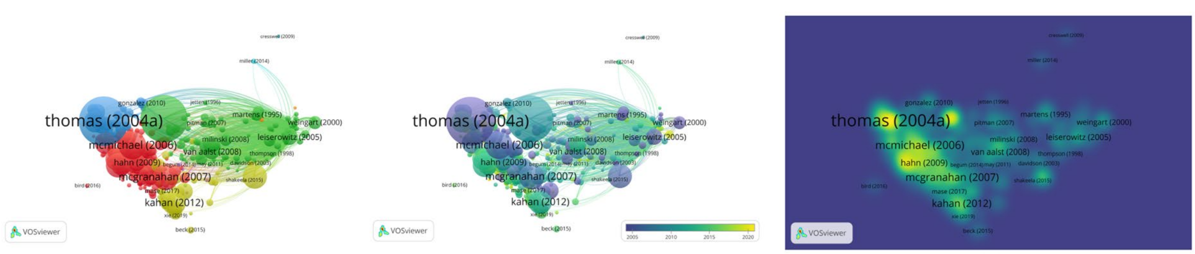
Label	Description	Cluster	Weight <links>	Score <citations>300>
Thomas et al. (2004)	Title: Extinction risk from climate change Source: Nature	10	27	3795
Allen et al. (2010)	Title: A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests Source: Forest ecology and management	4	5	2864
McMichael et al. (2006)	Title: Climate change and human health: present and future risks Source: Lancet	20	9	1127
McGranahan et al. (2007)	Title: The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones Source: Environment and urbanization	14	5	933
Leiserowitz (2006)	Title: Climate change risk perception and policy preferences: the role of affect, imagery, and values Source: Climatic change	2	25	797
Milly et al. (2002)	Title: Increasing risk of great floods in a changing climate Source: Nature	5	7	793
Rosenzweig et al. (2014)	Title: Assessing agricultural risks of climate change in the twenty-first century in a global gridded crop model intercomparison Source: Proceedings of the National Academy of Sciences of the United States of America	12	2	647
Kahan et al. (2012)	Title: The polarizing impact of science literacy and numeracy on perceived climate change risks Source: Nature climate change	15	4	632
Hirabayashi et al. (2013)	Title: Global flood risk under climate change Source: Nature climate change	5	6	569
Urban (2015)	Title: Accelerating extinction risk from climate change Source: Science	6	5	438
O'Connor et al. (1999)	Title: Risk perceptions, general environmental beliefs, and willingness to address climate change Source: Risk analysis	15	20	433
Leiserowitz (2005)	Title: American risk perceptions: is climate change dangerous? Source: Risk analysis	2	14	400
Keith et al. (2008)	Title: Predicting extinction risks under climate change: coupling stochastic population models with dynamic bioclimatic habitat models Source: Biology letters	6	8	392
Palmer and Ralsanen (2002)	Title: Quantifying the risk of extreme seasonal precipitation events in a changing climate Source: Nature	3	4	373
Van Aalst et al. (2008)	Title: Community level adaptation to climate change: the potential role of participatory community risk assessment Source: Global environmental change-human and policy dimensions	7	8	342
Scholze et al. (2006)	Title: A climate-change risk analysis for world ecosystems Source: Proceedings of the National Academy of Sciences of the United States of America	4	4	335
Araujo et al. (2005)	Title: Reducing uncertainty in projections of extinction risk from climate change Source: Global ecology and biogeography	10	2	329
Hahn et al. (2009)	Title: The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change-a case study in mozambique Source: Global environmental change-human and policy dimensions	1	4	326

Table 7 Author citation relationship information

Label	Cluster	Weight < total link strength >	Score < avg. citations >
Kanae, Shinjiro	1	32	548.3333
Takahashi, Kiyoshi	1	31	269.3333
Hallegatte, Stephane	1	24	90.4
Frangopol, Dan M	1	18	12
Yang, David Y	1	18	12
Rosenzweig, Cynthia	2	48	169.6667
Mueller, Christoph	2	34	216
Ruane, Alex C	2	32	320
Stehfest, Elke	2	31	282
Piontek, Franziska	2	30	338.6667
Howden, Mark	3	29	11.3333
O'neill, Brian C	3	28	56.6667
Van aalst, Maarten K	3	28	156.3333
Mach, Katharine J	3	25	67
O'neill, Brian	3	25	23
Akcakaya, H. Resit	4	50	189.8
Keith, David A	4	41	179.25
Fordham, Damien A	4	36	153
Araujo, Miguel B	4	35	222
Hannah, L	4	34	1554.3333
Forino, Giuseppe	5	65	17.1667
Von Meding, Jason	5	65	17.1667
Chu, Cordia	5	55	13.8333
Kelman, Ilan	5	43	53.4
Mercer, Jessica	5	36	113.6667

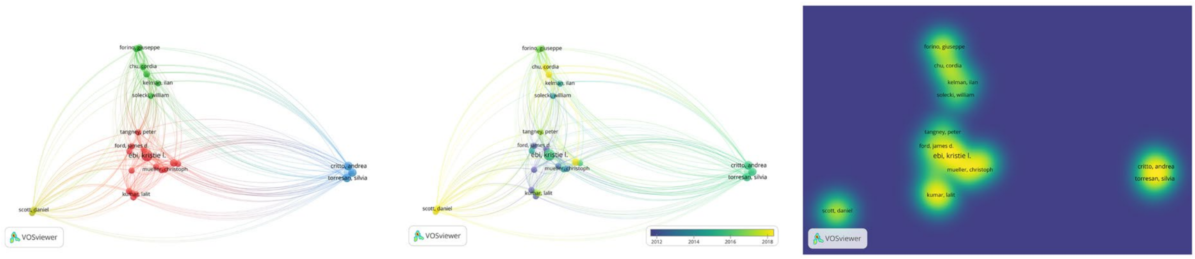
Appendix 3. Analysis of bibliographic coupling

(see Figs. 12 and 13, see Tables 8 and 9)



(a) (b) (c)

Fig. 12 Document coupling relationship. **a** Network diagram. **b** Overlapping diagram. **c** Density diagram



(a) (b) (c)

Fig. 13 Author coupling relationship. **a** Network diagram. **b** Overlapping diagram. **c** Density diagram

Table 8 Document coupling relationship information

Label	Description	Cluster	Weight <total link strength>	Weight <citations>
Kunreuther et al. (2015)	Integrated risk and uncertainty assessment of climate change response policies, climate change	4	389	55
van der Linden (2015)	The social-psychological determinants of climate change risk perceptions: towards a comprehensive model, journal of environmental psychology	4	287	128
Safi et al. (2012)	Rural nevada and climate change: vulnerability, beliefs, and risk perception, risk analysis	4	285	72
Prabhakar et al. (2009)	Climate change and local level disaster risk reduction planning: need, opportunities and challenges, mitigation and adaptation strategies for global change	2	280	38
Bradley et al. (2010)	Climate change increases risk of plant invasion in the eastern United States, Biological Invasions	6	242	116
McMichael et al. (2006)	Climate change and human health: present and future risks, Lancet	5	241	1127
Helgeson et al. (2012)	The role of knowledge, learning and mental models in public perceptions of climate change related risks, learning for sustainability in times of accelerating change	4	234	21
Bradley (2009)	Regional analysis of the impacts of climate change on cheatgrass invasion shows potential risk and opportunity, global change biology	6	233	124
Ewert et al. (2015)	Crop modelling for integrated assessment of risk to food production from climate change, environmental modelling & software	1	231	101
Bradley (2010)	Assessing ecosystem threats from global and regional change: hierarchical modeling of risk to sagebrush ecosystems from climate change, land use and invasive species in Nevada, USA, Ecography	6	229	78
Oliver and Morecroft (2014)	Interactions between climate change and land use change on biodiversity: attribution problems, risks, and opportunities, Wiley Interdisciplinary Reviews-Climate Change	6	225	108
Botzen and Van de Bergh (2009)	Managing natural disaster risks in a changing climate, Environmental Hazards-Human and Policy Dimensions	9	225	36
Morueta-Holme et al. (2010)	Climate change risks and conservation implications for a threatened small-range mammal species, Plos one	6	217	77

Table 8 (continued)

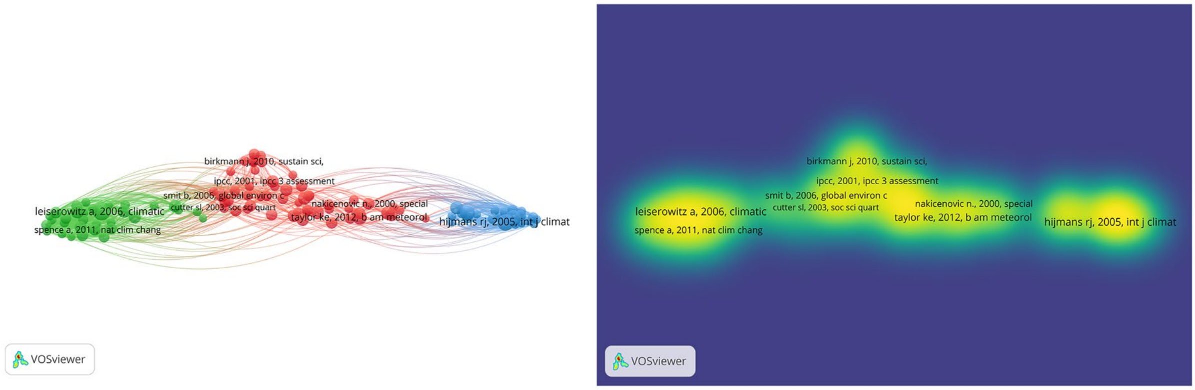
Label	Description	Cluster	Weight < total link strength >	Weight < citations >
van Aalst et al. (2008)	Community level adaptation to climate change: the potential role of participatory community risk assessment, Global Environmental Change-Human and Policy Dimensions	2	216	342
Carlton and Jacobson (2013)	Climate change and coastal environmental risk perceptions in Florida, Journal of Environmental Management	4	213	47
van der Linden (2014)	On the relationship between personal experience, affect and risk perception: the case of climate change, European Journal of Social Psychology	4	213	46
Wilby and Keenan (2012)	Adapting to flood risk under climate change, Progress in Physical Geography-Earth and Environment	3	206	120
Naujokaitis-Lewis et al. (2013)	Uncertainties in coupled species distribution-metapopulation dynamics models for risk assessments under climate change, Diversity and Distributions	6	205	24
Campbell-Lendrum and Woodruff (2006)	Comparative risk assessment of the burden of disease from climate change, Environmental Health Perspectives	5	203	72

Table 9 Author coupling relationship information

Label	Cluster	Weight < total link strength >	Score < avg. citations >
Ebi, Kristie L	1	481	19.8824
Rosenzweig, Cynthia	1	347	169.6667
Botzen, W. J. Wouter	1	315	18.75
Aerts, Jeroen C. J. H	1	312	68
Bradley, Bethany A	1	297	91.2
Preston, Benjamin l	1	249	81.6
Tangney, Peter	1	241	25.8
Mueller, Christoph	1	205	216
Ellis, Christopher J	1	204	15.2
Ford, James D	1	197	27
Wilby, R. L	1	191	123.8
Hallegatte, Stephane	1	177	90.4
Akcakaya, H. Resit	1	166	189.8
Kumar, Lalit	1	154	17
Semenza, Jan C	1	122	41.2
Forino, Giuseppe	2	1051	17.1667
Von meding, Jason	2	1051	17.1667
Chu, Cordia	2	959	13.8333
Mackey, Brendan	2	682	13.1667
Kelman, Ilan	2	199	53.4
Solecki, William	2	137	25.6
Critto, Andrea	3	2018	28.9
Marcomini, Antonio	3	2018	28.9
Torresan, Silvia	3	2018	28.9
Scott, Daniel	4	1127	34.5
Steiger, Robert	4	1124	39.8

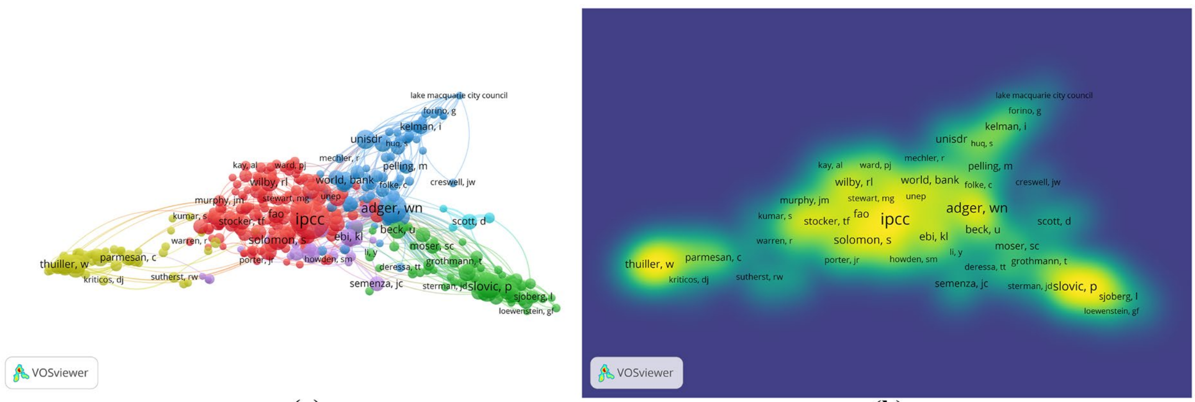
Appendix 4. Analysis of co-citations

(see Figs. 14 and 15, see Tables 10 and 11)



(a) (b)

Fig. 14 Density diagram of cited reference relationship. **a** Network diagram. **b** Density diagram



(a) (b)

Fig. 15 Cited author relationship. **a** Network diagram. **b** Density diagram

Table 10 Cited reference relationship information

Label	Cluster	Weight < total link strength >	Weight < citations >
Smit B, 2006, Global Environ Chang, v16, p282, https://doi.org/10.1016/j.gloenvcha.2006.03.008	1	194	49
Adger Wn, 2006, Global Environ Chang, v16, p268, https://doi.org/10.1016/j.gloenvcha.2006.02.006	1	139	35
Schipper L, 2006, Disasters, v30, p19, https://doi.org/10.1111/j.1467-9523.2006.00304.x	1	128	33
Moss Rh, 2010, Nature, v463, p747, https://doi.org/10.1038/nature08823	1	126	51
Thomalla F, 2006, Disasters, v30, p39, https://doi.org/10.1111/j.1467-9523.2006.00305.x	1	126	34
Leiserowitz A, 2006, Climatic Change, v77, p45, https://doi.org/10.1007/s10584-006-9059-9	2	446	81
O'connor RE, 1999, Risk Anal, v19, p461, https://doi.org/10.1023/a:1007004813446	2	318	50
Brody Sd, 2008, Environ Behav, v40, p72, https://doi.org/10.1177/0013916506298800	2	300	39
Spence A, 2011, Nat Clim Change, v1, p46, https://doi.org/10.1038/nclimate1059	2	278	40
Leiserowitz AA, 2005, Risk Anal, v25, p1433, https://doi.org/10.1111/j.1540-6261.2005.00690.x	2	259	40
Phillips SJ, 2006, Ecol Model, v190, p231, https://doi.org/10.1016/j.ecolmodel.2005.03.026	3	314	66
Hijmans RJ, 2005, Int J Climatol, v25, p1965, https://doi.org/10.1002/joc.1276	3	309	74
Thomas CD, 2004, Nature, v427, p145, https://doi.org/10.1038/nature02121	3	257	64
Elith J, 2006, Ecography, v29, p129, https://doi.org/10.1111/j.2006.0906-7590.04596.x	3	204	35
Parmesan C, 2003, Nature, v421, p37, https://doi.org/10.1038/nature01286	3	168	45

Table 11 Cited author relationship information

Label	Cluster	Weight <total link strength>	Weight <citations>
IPCC	1	6079	550
Wilby, RL	1	1734	109
Solomon, S	1	1602	146
Rosenzweig, C	1	1543	87
Jones, RN	1	1503	97
Slovic, P	2	3960	215
Leiserowitz, A	2	3089	149
Lorenzoni, I	2	2099	106
Weber, EU	2	1959	93
Spence, A	2	1901	91
Adger, WN	3	4903	293
Unisdr	3	1849	126
Birkmann, J	3	1794	106
Smit, B	3	1744	102
Cutter, SL	3	1704	90
Thuiller, W	4	1990	135
Elith, J	4	1858	120
Phillips, SJ	4	1724	124
Araujo, MB	4	1678	104
Hijmans, RJ	4	1599	117
Ebi, KL	5	1527	102
Mcmichael, AJ	5	1506	123
Ford, JD	5	1123	69
World Health Organization	5	956	80
Semenza, JC	5	913	78
Scott, D	6	1184	87
Steiger, R	6	689	42
Gossling, S	6	426	24
Becken, S	6	326	26

Appendix 5. Analysis of keywords co-occurrence

(see Figs. 16, 17, 18, 19, 20 and 21, see Tables 12, 13, 14, 15, 16 and 17)

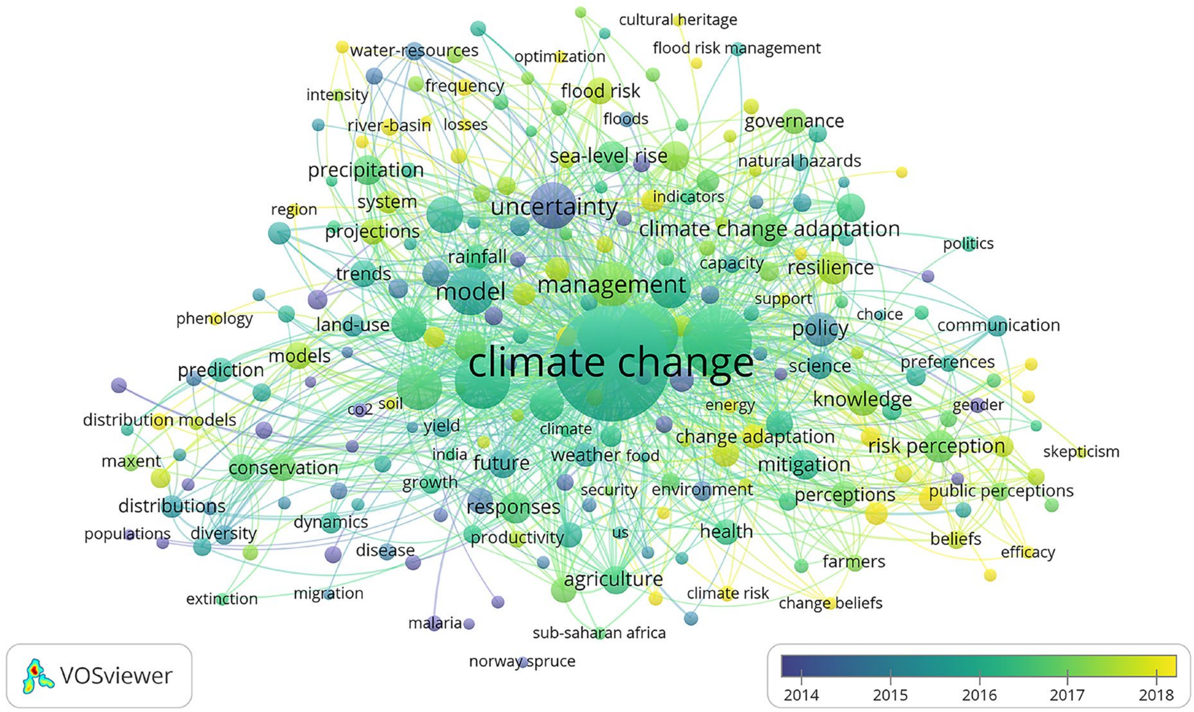


Fig. 16 Overlapping diagram of keywords co-occurrence in "climate change risk"

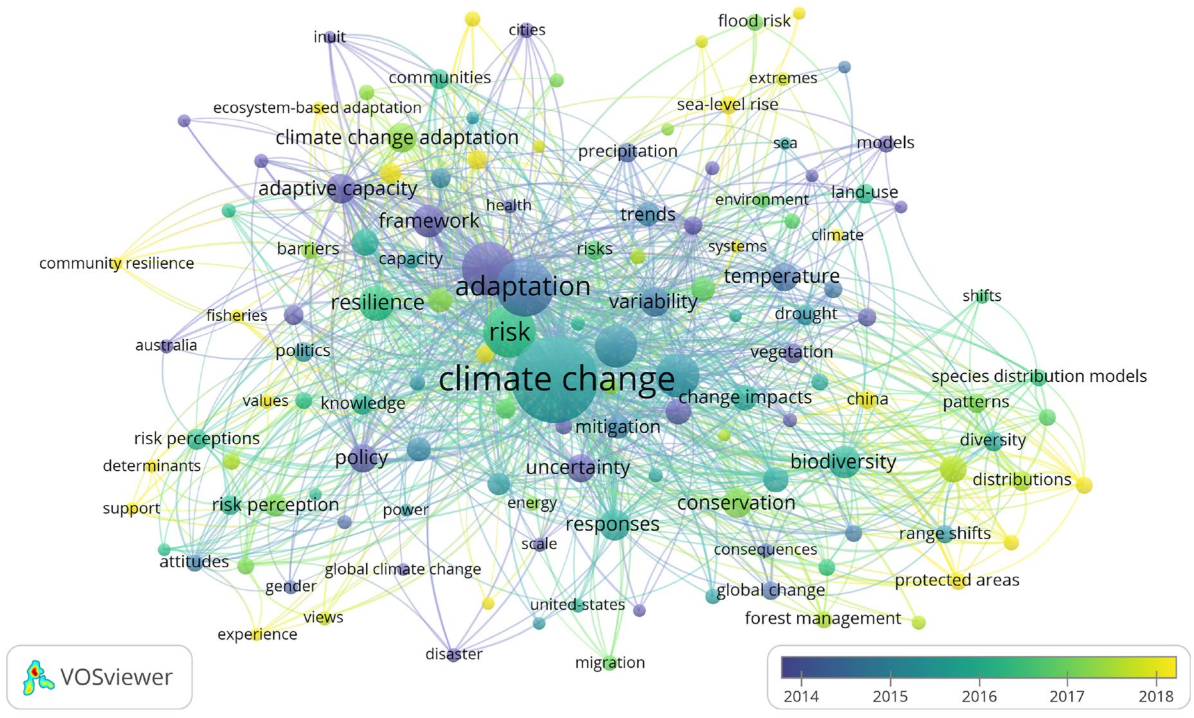


Fig. 17 Overlapping diagram of keywords co-occurrence in "nature risk of climate change"

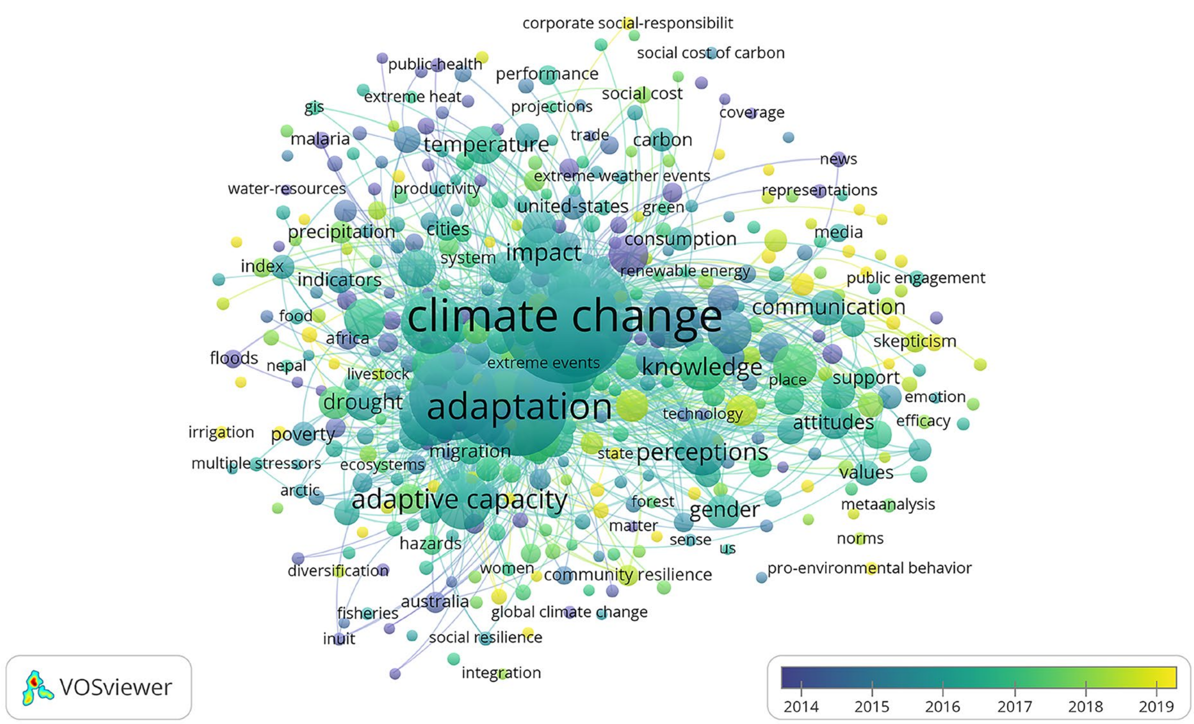


Fig. 18 Overlapping diagram of keywords co-occurrence in "social risk of climate change"

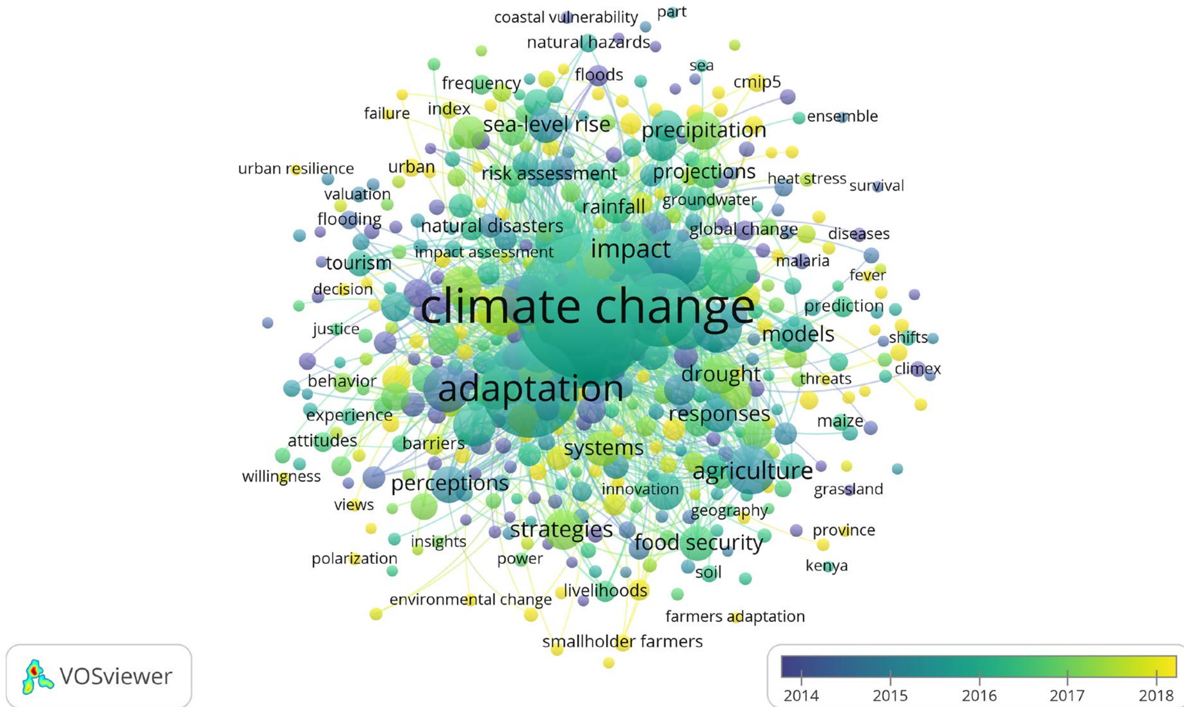


Fig. 19 Overlapping diagram of keywords co-occurrence in "economic risk of climate change"

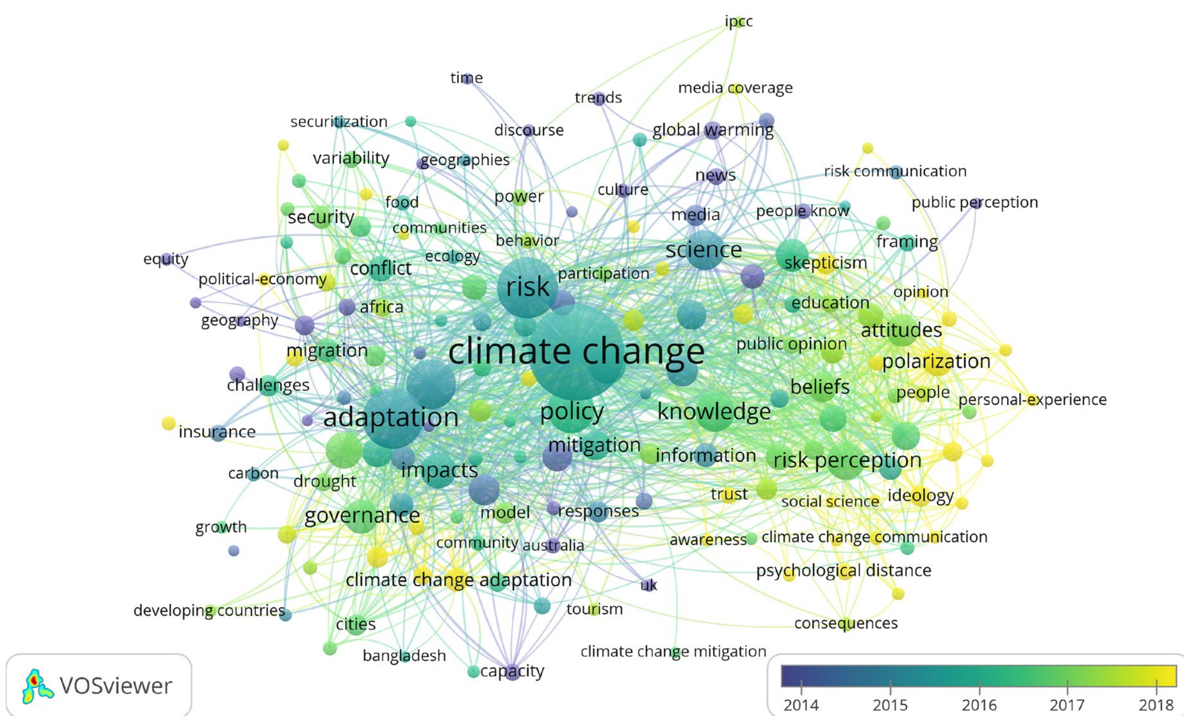


Fig. 20 Overlapping diagram of keywords co-occurrence in "political risk of climate change"

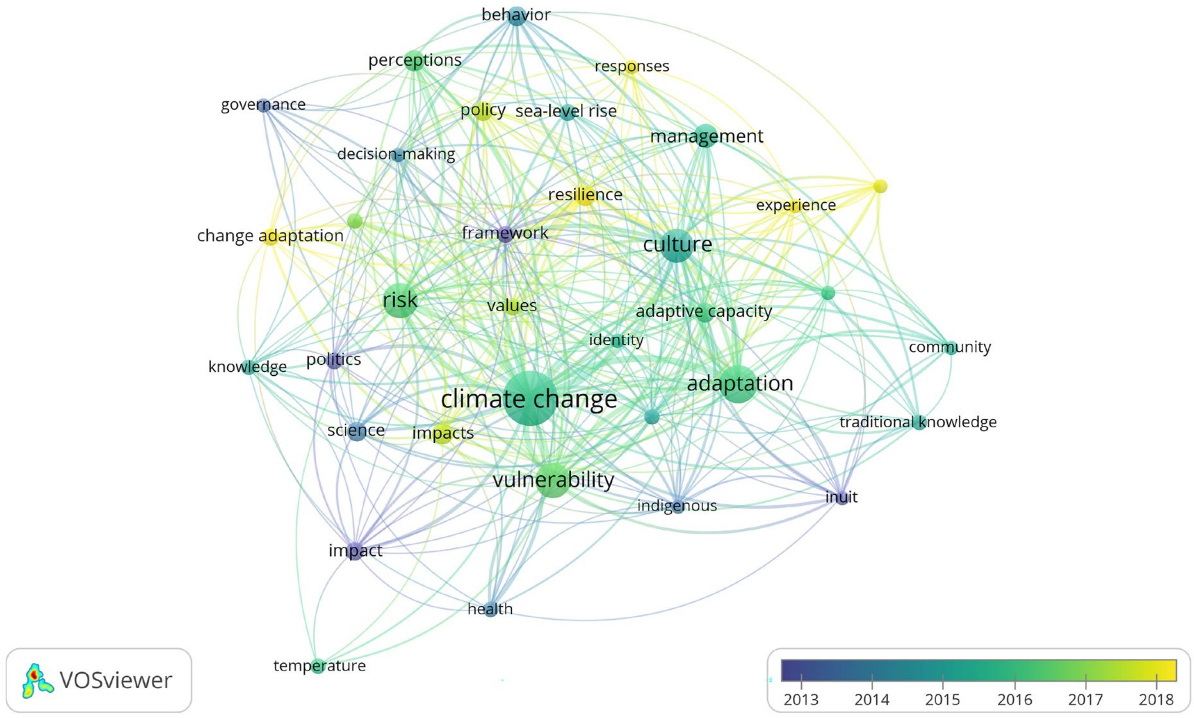


Fig. 21 Overlapping diagram of keywords co-occurrence in “culture risk of climate change”

Table 12 Keywords co-occurrence information in "climate change risk"

Label	**Cluster**	**Weight < total link strength >**	**Score < avg. citations >**
Impacts	1	1102	54.3913
Temperature	1	657	22.5
Responses	1	407	44.1912
Future	1	329	33.2963
Conservation	1	291	21.8654
Biodiversity	1	281	132.38
Models	1	252	28.58
Global warming	1	210	31.0444
Prediction	1	207	35.6667
Distributions	1	197	38.7778
Knowledge	2	420	36.9726
Risk perception	2	393	33.0822
Policy	2	390	36.3333
Mitigation	2	356	40.0328
Perceptions	2	278	28.5
Change adaptation	2	247	30.4048
Science	2	242	28.4222
Attitudes	2	239	57.0256
Determinants	2	219	13.4
Experience	2	206	43.5
Climate change	3	3651	33.474
Vulnerability	3	1476	54.8086
Climate change adaptation	3	408	23.5976
Resilience	3	402	28.662
Adaptive capacity	3	314	37.4808
Disaster risk reduction	3	263	41.4
Health	3	224	25.8723
Mortality	3	206	41.5106
Governance	3	205	20.9318
Exposure	3	182	17.0278
Impact	4	601	37.6154
Variability	4	463	28.7215
Agriculture	4	364	53.6724
Scenarios	4	320	33.5
Strategies	4	320	30.06
Food security	4	256	51.6977
Systems	4	192	46.7333
Weather	4	190	31.025
Sustainability	4	159	16.8182
China	4	137	15.3846
Model	5	713	32.9804
Change impacts	5	459	46.7294
Risk assessment	5	367	20.2581
Drought	5	358	27.9844
Precipitation	5	339	25.2063
Projections	5	263	25.6087

Table 12 (continued)

Label	Cluster	Weight < total link strength >	Score < avg. citations >
Trends	5	246	32.9167
Flood risk	5	234	27.42
USA	5	231	75.9388
Water	5	225	20.15

Table 13 Keywords co-occurrence information in “nature risk of climate change”

Label	Cluster	Weight < total link strength >	Score < avg. citations >
Impacts	1	293	62.0189
Variability	1	120	35.52
Future	1	98	19.3889
Temperature	1	98	34.3478
Model	1	79	106.4737
Trends	1	68	41.6471
Impact	1	67	22.1875
Scenarios	1	63	178.8
Africa	1	59	65.5
Drought	1	59	40.0833
Policy	2	122	108.5833
Uncertainty	2	111	78.2609
Science	2	99	51.3529
Knowledge	2	88	41.9231
Risk perceptions	2	78	27.6923
Politics	2	61	65.1667
Public perceptions	2	59	23.5556
Perceptions	2	58	25.75
Beliefs	2	57	25.3636
Risk perception	2	57	13.4286
Climate change	3	867	31.067
Biodiversity	3	164	23.7586
Responses	3	140	62.3333
Conservation	3	139	24.3462
Extinction risk	3	103	18.7143
Change impacts	3	96	135.6667
Distributions	3	77	14.5833
Diversity	3	77	34.7273
Patterns	3	66	22.4545
China	3	62	11.8
Adaptation	4	531	69.8316
Vulnerability	4	435	90.95
Framework	4	164	150.1034
Adaptive capacity	4	148	48.52
Change adaptation	4	88	13.2353
Communities	4	66	53.8182
Canada	4	49	59.625

Table 13 (continued)

Label	Cluster	Weight < total link strength >	Score < avg. citations >
Barriers	4	43	69.7778
Level	4	37	43.1667
Inuit	4	35	139.6
Risk	5	328	47.1579
Management	5	263	83.4314
Resilience	5	194	60.3429
Governance	5	116	161.8571
Climate change adaptation	5	105	43.16
Challenges	5	72	31.4615
Sustainability	5	68	142.75
Capacity	5	51	39.125
Nature-based solutions	5	51	10.1818
Livelihoods	5	46	13.1429
Mitigation	6	87	38.75
Agriculture	6	79	74.75
Strategies	6	79	89.0714
Food security	6	43	52.7143
Scale	6	31	37.5
Energy	6	29	22.1667
Emissions	6	27	4.4286
Forest	6	24	19.8
Power	6	22	76.2
Change mitigation	6	21	5.8

Table 14 Keywords co-occurrence information in "social risk of climate change"

Label	Cluster	Weight < total link strength >	Score < avg. citations >
Climate change	1	3829	35.8274
Risk	1	1893	39.1517
Impacts	1	991	36.5105
Impact	1	508	39.6875
Social vulnerability	1	442	45.1129
Temperature	1	359	32.1636
Health	1	346	34.5818
Risks	1	285	16.5814
Model	1	250	29.5476
Future	1	244	38.3784
Perceptions	2	678	37.6437
Knowledge	2	638	24.1264
Risk perception	2	528	38.3889
Risk perceptions	2	320	57.3636
Communication	2	316	51.5417
Experience	2	316	45.5714
Attitudes	2	310	38.675

Table 14 (continued)

Label	Cluster	Weight < total link strength >	Score < avg. citations >
Gender	2	299	53.9286
Information	2	285	34.9189
Public perceptions	2	281	60.4118
Resilience	3	1074	41.9565
Management	3	985	40.5538
Climate change adaptation	3	509	28.2078
Governance	3	341	56.383
Change adaptation	3	311	11.15
Communities	3	247	27.8824
Capacity	3	241	29.4545
Systems	3	239	20.0606
Conservation	3	211	55
Sustainable development	3	177	40.5185
Variability	4	571	26.875
Agriculture	4	460	36.0492
Strategies	4	408	21.9149
Food security	4	276	22.3333
Perception	4	220	22.8
Environment	4	184	28.2414
Poverty	4	146	105.8571
Dynamics	4	106	88.8571
Natural disasters	4	101	42.6
Social capital	4	101	145.5455
Adaptation	5	2435	36.0865
Vulnerability	5	2088	46.1549
Framework	5	585	58.4583
Drought	5	296	32.6364
Change impacts	5	238	31.3429
Livelihoods	5	203	26.4615
Migration	5	171	28.2308
Social-ecological systems	5	169	59.6818
Rainfall	5	141	36.8095
Environmental-change	5	135	30.3333

Table 15 Keywords co-occurrence information in "economic risk of climate change"

Label	Cluster	Weight < total link strength >	Score < avg. citations >
Model	1	789	32.015
Framework	1	650	56.8049
Scenarios	1	368	58.5862
Precipitation	1	348	22.8182
Trends	1	272	24.3684
Projections	1	263	39
Flood risk	1	258	40.2195
Rainfall	1	250	33.3421
Sea-level rise	1	221	45.9333
Risk assessment	1	179	26.6296
Impacts	2	1336	37.7228
Future	2	423	28.7143
Responses	2	315	89.7955
Land-use	2	276	41.2368
Models	2	253	31.3333
Biodiversity	2	233	15.8571
Conservation	2	220	14
Dynamics	2	150	17.35
Global warming	2	138	17.1852
Security	2	137	40.6842
Risk	3	1707	28.737
Governance	3	214	108.5152
Environment	3	187	22.3226
Insurance	3	170	32.2333
Flood	3	159	36
Climate change impacts	3	156	120.4286
Migration	3	144	31.68
Natural disasters	3	139	30.913
Politics	3	118	21.9444
Benefits	3	108	34.3333
Agriculture	4	619	37.2135
Strategies	4	436	24.1228
Water	4	373	27.1837
Change impacts	4	367	81.2778
Food security	4	367	36.375
Drought	4	366	22.8333
Systems	4	347	19.8478
Risks	4	241	22.3077
Yield	4	151	26.4583
Perception	4	149	11.7895
Management	5	868	52.1538
Uncertainty	5	663	44.3061
Growth	5	293	33.3061
Decision-making	5	182	26.3077
Emissions	5	174	62.5517

Table 15 (continued)

Label	Cluster	Weight < total link strength >	Score < avg. citations >
Economics	5	161	46.3214
Energy	5	153	19.5417
Carbon	5	147	18.52
Costs	5	141	96.6
Integrated assessment	5	138	44

Table 16 Keywords co-occurrence information in "political risk of climate change"

Label	Cluster	Weight < total link strength >	Score < avg. citations >
Knowledge	1	374	34.4706
Risk perception	1	313	56.7872
Attitudes	1	243	34.0303
Polarization	1	209	28.8214
Views	1	208	65.9259
Beliefs	1	201	63.1923
Perceptions	1	188	57.6667
Gender	1	181	81.5
Experience	1	169	45.9583
Risk perceptions	1	160	40.3478
Adaptation	2	607	38.1724
Risk	2	603	34.1176
Vulnerability	2	445	47.5949
Framework	2	183	41.1875
Management	2	146	34.4483
Environment	2	123	20.4762
Conflict	2	99	20.2857
Security	2	88	33.9412
Political ecology	2	85	38.4
Migration	2	79	47.0556
Policy	3	430	37.2429
Politics	3	270	48.6429
Resilience	3	246	31.5333
Mitigation	3	178	38.1034
Governance	3	159	21.1389
Adaptive capacity	3	118	44.8889
Change adaptation	3	100	10
Climate change adaptation	3	94	16.05
Challenges	3	89	30.2667
Cities	3	76	25.5
Science	4	317	47.4314
Communication	4	217	37.2353
USA	4	125	59.3684
Engagement	4	122	20
Uncertainty	4	121	49.9091

Table 16 (continued)

Label	Cluster	Weight < total link strength >	Score < avg. citations >
Perception	4	92	13.6923
Media	4	91	56.0667
Risks	4	84	26.7059
News	4	77	103.5
Framing	4	69	55.3
Climate change	5	1406	37.0348
Impacts	5	201	36.25
Impact	5	139	77.3571
Sustainability	5	110	32.2
Health	5	108	23.7059
Weather	5	94	46
Responses	5	92	85
Model	5	69	21.2857
Decision-making	5	59	26
Climate policy	5	46	26.8889
Risk management	6	36	25.1667
Tourism	6	34	8.8333
UK	6	34	73
Carbon	6	26	22.7143
Public policy	6	22	19.6
Growth	6	20	6.3333
IPCC	6	19	13.2

Table 17 Keywords co-occurrence information in “culture risk of climate change”

Label	**Cluster**	**Weight < total link strength >**	**Score < avg. citations >**
Adaptation	1	123	33.3939
Culture	1	109	32.4815
Adaptive capacity	1	57	30.6
Perception	1	37	28.1667
Indigenous	1	36	92.2
Inuit	1	34	82.4
Experience	1	25	26
Risk perception	1	24	5.6
Traditional knowledge	1	24	62.3333
Community	1	23	19.2
Risk	2	94	21.1724
Management	2	43	46.2143
Perceptions	2	42	16.9091
Framework	2	39	56.2857
Behavior	2	38	22.8
Policy	2	34	25.6
Decision-making	2	25	53.6
Sea-level rise	2	18	28
Governance	2	17	16.8
Responses	2	17	22.4
Climate change	3	192	29.7681
Vulnerability	3	110	36.5517
Impacts	3	33	31.5455
Science	3	32	55.3
Impact	3	30	88.875
Health	3	26	44.5
Politics	3	24	79.2857
Knowledge	3	23	24.3333
Temperature	3	7	35.6667
Resilience	4	47	15.4545
Values	4	37	50.1429
Change adaptation	4	26	6.2857
Sustainability	4	20	27.1667

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Declarations

Conflict of interest The authors declare no competing interests.

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