



Evolution of research topics on the Tibetan Plateau environment and ecology from 2000 to 2020: a paper mining

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Abstract

The Tibetan Plateau works as an important environmental and ecological barrier for the Asian continent. The researches on Tibetan environment and ecology are becoming extensive, but there is no systematic summary of research hotspots and trends in this field. Here, we analyzed 9180 publications retrieved from the WOS and CNKI during 2000~2020. The characteristics of publication, keywords with a 5-year interval and co-occurrence analysis were carried out so as to reveal the evolution and development trends of topics. The results show that articles increase dramatically since 2012. Except for common concerns like evolution, climate change, and precipitation, diversity was been studied more by Chinese scholars, while the USA, Germany, UK, and Australia researchers focused more on adaptability, basin western Tibet, lake, barley, and ore-related themes, respectively. Besides, China closely collaborated with the USA, Australia, and Germany in topics of evolution, climate change and degradation, precipitation, and diversity. The institutions located in Chinese different economic regions focused on different research keywords, such as vegetation, growth, trace elements, and geochemistry. The CAS contributed the most articles with 4254, showed advantages both in quantity and quality. Few articles were published by researchers affiliated to Free University of Berlin but with higher citations. It is the only one institute outside of China in the top 20. Main research hotspots include climate change, geology, and diversity. In future researches, ecological management and rehabilitation of mining area and tailings ponds, waste disposal, and changes of soil and water quality are worthy of attention and funding.

Keywords Tibetan Plateau · Ecology · Environment · Bibliometric · Hotspots

Introduction

Tibetan Plateau, which averages 4000 m above sea level and has an area of approximately 2.5×10^6 km², is the highest and most extensive plateau in the world (Kang et al. 2010). It is known as the Water Tower of Asia due to the existence of the largest number of glaciers outside the polar regions (Yao et al. 2012). Almost all major rivers in Asia originated from there and these rivers servers for nearly 1.4 billion

people (Bibi et al. 2018). Besides, the Tibetan plateau has an important effect on local and global climate through thermal forcing mechanisms (Duan and Wu 2005; Kang et al. 2010). At the same time, Tibetan Plateau changes are considered to be an indicator of global warming effects due to the high sensitivity of the Tibetan plateau to climate change (Bibi et al. 2018). Furthermore, Tibetan Plateau, acting as an environmental and ecological barrier (Yao et al. 2017), has an important effect on ecological security in Asia (Sun et al. 2012). Although being called the third pole of the world, Tibetan plateau has been neglected for a long time compared to the Arctic and Antarctic regions (Qiu 2008). With climate change and increased human activity, the Tibetan Plateau faces increasing resources and environmental risks and pressure, such as glacier retreat (Jiang et al. 2019), grassland, meadow, and permafrost degradation (Xie et al. 2018; Ling and Pan 2019; Ren et al. 2020). These problems seriously threaten regional ecological security. Therefore, it is urgent to strengthen protection of the Tibetan Plateau. Though

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more and more studies have been conducted on the Tibetan Plateau with the efforts of all sectors of society in recent years, such as climate and environmental change based on ice core records (Tian and Tian 2019), species diversity (Zhang et al. 2020a, b), soil properties (Wang et al. 2020), etc., there is no systematic summary of research hotspots and trends in this field. On the one hand, changes in hot spots and research trends can provide references for researchers to select topics; on the other hand, new research directions in this field can be found so as to increase investment and policy support. Thus, it is great of importance to summarize the evolution of topics and reveal the research hotspots and development trends.

This work made a bibliometric analysis of 9180 publications retrieved from the Web of Science (WOS) Core Collection and China National Knowledge Infrastructure (CNKI) searched up to September 16, 2020, with strings (Qinghai-Xizang or Qinghai-Tibet* or Tibet*) and (environment* or ecolog*) during 2000–2020. General characteristics, including annual outputs, categories, journal distribution, as well as productive countries and institutions were analyzed. Besides, social network was used to uncover the cooperation relationship between different countries and institutions. Furthermore, a co-occurrence analysis of keywords was carried out to discover the evolution of research themes.

Material and methods

Bibliometric

Bibliometric, the term firstly proposed by Pritchard in 1969, is an effective approach that could be used for uncovering various publication characteristics with the application of mathematics and statistical method, such as document types, countries, important institutions, and productive authors (Pritchard 1969). As a tool of quantitative analysis in literature reports, it has been applied to many fields to discover research hotspots and frontiers as well as to predict future research directions (Wilson 2006). Citation analysis and content analysis are commonly used in above two processes, respectively (Zhong et al. 2016).

Social network analysis

Social network analysis is a method to find collaborative relationship between actors via a visual way (Zhong et al. 2016). The most frequently used software includes HistCite, Gephi, VOSviewer, Pajek, CiteSpace, and UCINET (van Eck and Waltman 2010; Chen and Song 2019; Zhang et al. 2019; Yue et al. 2020; Zhang et al. 2020a, b). In network graph, the nodes' size represents the importance of article, country, institution, or author, while the thickness of lines

between nodes represents the connection among them (Shi et al. 2020). In this study, HistCite, VOSviewer, and CiteSpace were mainly used to facilitate bibliometric analysis and information visualization.

Impact factor and H-index

Since the term “impact factor” (IF) was coined by Garfield, E. and Sher, I. H. (Garfield and Sher 1963), it has been a widely used index to evaluate the influence of a journal, as well as author's impact and paper's quality. A journal's IF depends on the total number of citations and publications in the current year (Garfield 2006; Shasha et al. 2020). The authoritative IF is published by Thomson Reuters in its' Journal Citation Reports (JCR) every year. Besides, H-index is another important indicator to characterize the researchers' output, which is proposed by Hirsh in 2005. It was defined as that H papers in N_p papers published by a researcher are cited at least H time per paper, while the others are cited less than H time per paper (Hirsch 2005; Ma et al. 2020). It is a simple and useful evaluation for researchers' scientific contributions. Moreover, the global citation score (GCS) and local citation score (LCS) obtained from HistCite were also adopted to evaluate the journals, institutions, and countries in this study.

Source of data

In this study, (Qinghai-Xizang or Qinghai-Tibet* or Tibet*) and (environment* or ecolog*), in which asterisk (*) is a wildcard to ensure related words, such as “Tibetan,” “ecology,” and “ecological,” could be comprised, were used as Topical Subject (including titles, abstracts, author keywords, and keywords plus) to search relevant publications from 2000 to 2020 in WOS Core Collection (including Science Citation Index Expanded (SCIE), Social Science Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), Conference Proceedings Citation Index-Science (CPCI-S), and Emerging Sources Citation Index (ESCI)) and CNKI database.

Results and discussion

General characteristics of literature reports

A total of 9180 records were searched in this study. The number of different literature types is shown in Table 1 below. The periodical article, accounting for 80.82% of all of the publications, is the most document type, followed by proceeding paper (6.90%), dissertation (5.03%), review (3.90%), and news item (2.29%). These five document types occupy more than 98%, while others account for no

Table 1 Document types information of literature from 2000 to 2020

Document type	Records	Percentage (%)
Article	7419	80.82
Proceedings paper	633	6.90
Review	281	3.06
Editorial material	35	0.38
Data paper	14	0.15
Book review	9	0.10
Letter	7	0.08
Meeting abstract	6	0.07
Chronology	4	0.04
Correction	4	0.04
Book chapter	4	0.02
Retracted publication	2	0.04
Reprint	1	0.01
News item	210	2.29
Dissertation	462	5.03
Others	89	0.97

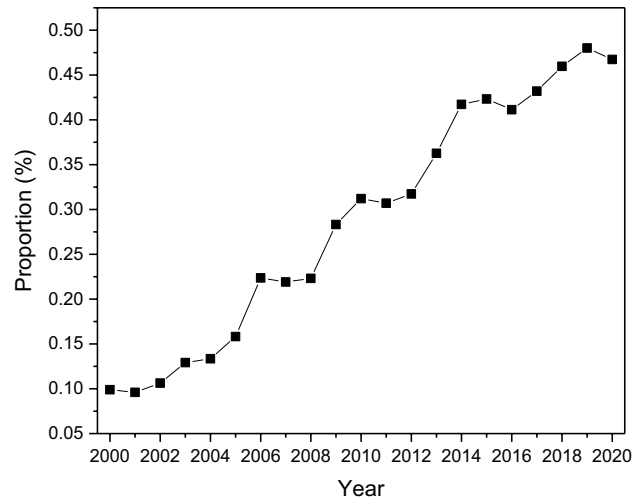


Fig. 2 Proportion of Tibetan Plateau researches in environmental and ecology

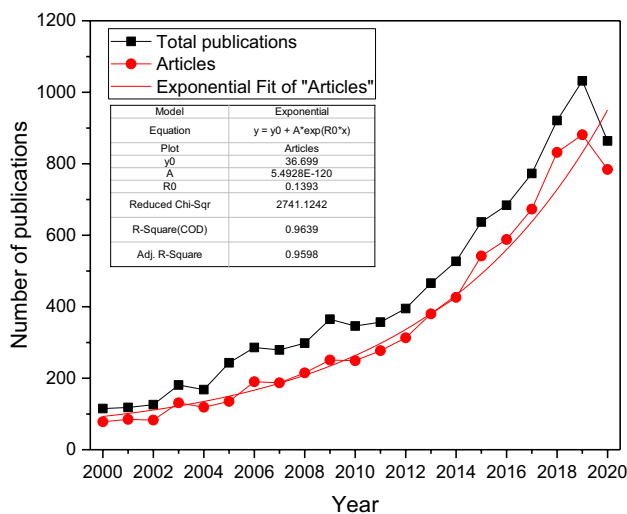


Fig. 1 Publications trends during 2000–2020

more than 0.5%, respectively. Therefore, our analysis in subsequent study mainly focuses on periodical articles due to its' highly representativeness of the overall data, as shown in Fig. 1. The relationship between the number of articles and year can be described by an exponential equation, in which a high correlation coefficient ($R^2 = 0.95$) was observed. The fit curve indicates that the number of articles in this field will maintain a high rate growing. It can also be inferred from Fig. 2, in which we made a statistic about proportion on the Tibetan Plateau in all environment and ecology related researches.

Language information on periodical articles during 2000–2020 is shown in Table 2. English is the most used language in studied articles, accounting for 83.00%. Although ranking second place with 16.86%, the number of articles in Chinese is still far fewer than that in English. And the rests, including Russian, French, Spanish, German, Italian, Polish, and Portuguese, totally occupy not more than 0.2%. Hence, English still remains an advantage place in this field.

National/regional contribution and cooperation

The periodical articles attributed to different countries were analyzed based on their postal address. There are 117 countries identified and the geographic distribution of them is shown in Fig. 3, in which the size of circle represent the number of articles published by their researchers. Besides, the top 20 productive countries in related field are shown

Table 2 Language information of articles from 2000 to 2020

Language	Records	Percentage (%)
English	6158	83.00
Chinese	1251	16.86
Russian	2	0.03
French	2	0.03
Spanish	2	0.03
German	1	0.01
Italian	1	0.01
Polish	1	0.01
Portuguese	1	0.01

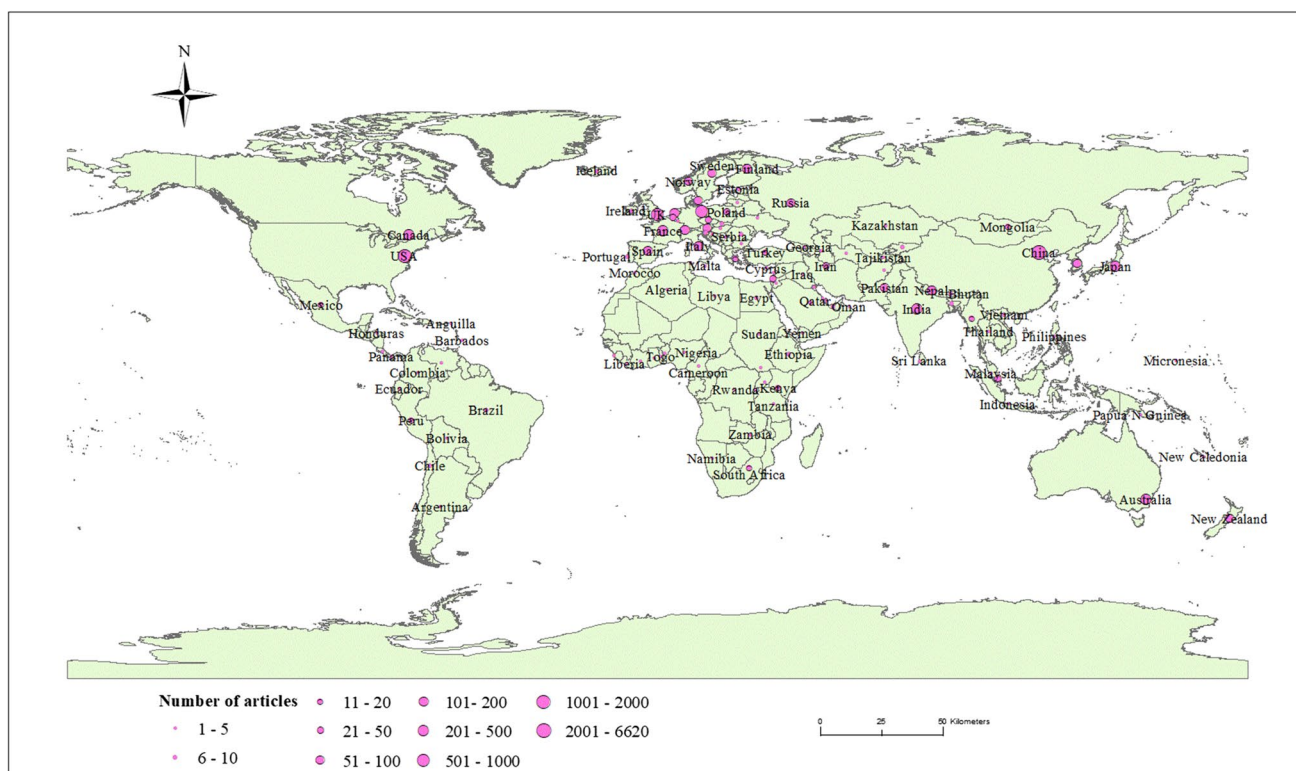


Fig. 3 The distribution of articles published by different countries during 2000–2020

in Table 3. Articles originated from China are the most, accounting for 89.15%, followed by the USA (16.42%), Germany (6.09%), UK (4.29%), Australia (2.79%), and Canada (2.71%). Only these 6 countries published more than 200 articles during 2000–2020. And the publication trends detail of above countries is presented in Fig. 4. The number of articles published by Germany, UK, Australia, and Canada keeps stable during all studied periods, while articles originated from the USA increase slowly after 2005. At the same time, the number of articles published by Chinese scholars could be divided into four stages. In the first stage, the number of articles less than 150 and kept stable before 2005. Then, there was a relatively rapid increase from 2006 to 2011 with entry into force of the Tokyo Protocol in 2005. Since 2012, the researches related to Tibetan ecology and environment has increased sharply, this may be attributed to the fact that the concept of “a beautiful China” was put forward for the first time at the 18th National Congress of the Communist Party of China, which emphasizes putting the construction of ecological civilization in a more prominent position, thus attracting more attention to relevant fields. Subsequently, the implementation of the Paris Agreement in 2016 further promoted relevant researches. While the sudden drop in the number of articles in 2020 may be due to the COVID-19 pandemic, which caused work stoppages and school suspension, affected research outputs. Thus, research outputs are closely related to policies and emergencies.

The top 5 keywords in papers affiliated to above countries were analyzed to reveal the differences in research focus among them, and the results are shown in Table 4. In these keywords, evolution is the most been mentioned, especially in articles from the USA and UK. The second is climate change, which appeared in five country’s research keywords (except Canada) and ranked high in every country. Precipitation was mainly researched by China, the USA, and Australia. Moreover, Germany and the UK paid more attention to monsoon, while China and Australia also focused on the keyword temperature. In terms of the differences in research fields, diversity was been studied more by Chinese scholars, while the USA focused more on adaptability, other countries such as Germany, the UK, and Australia focused on basin Western Tibet, lake, and barley, respectively. In particular, Canada paid more attention to the arid environment, hypoxia, and ore-related researches. On the other hand, the most frequently studied geological ages are the late Miocene and Holocene, the former was the focus of the USA and the latter was the focus of Germany and the UK.

The cooperation relationship of the top 20 productive countries is shown in Fig. 5. The most productive country, China, collaborated with more than 10 countries. And the cooperation relationship between China and the USA is especially close, which is indicated by a thick line between them. That means China and the USA play important roles in this field. Besides, there are 5 countries, including France,

Table 3 Top 20 productive countries during 2000–2020

Country	Records	Percentage (%)	LCS	GCS
China	6614	89.15	14,593	93,999
USA	1218	16.42	4053	33,598
Germany	452	6.09	2862	12,552
UK	318	4.29	1255	10,075
Australia	207	2.79	410	4628
Canada	201	2.71	392	3573
Japan	184	2.48	802	6008
India	150	2.02	229	3669
France	131	1.77	401	4028
Switzerland	91	1.23	337	3453
Netherlands	88	1.19	338	2483
Italy	77	1.04	152	1889
Nepal	71	0.96	115	1201
Finland	68	0.92	207	1429
Spain	63	0.85	93	1729
Sweden	54	0.73	191	1403
Russia	52	0.70	57	785
Denmark	45	0.61	149	1820
New Zealand	45	0.61	171	1416
Austria	44	0.59	226	1404

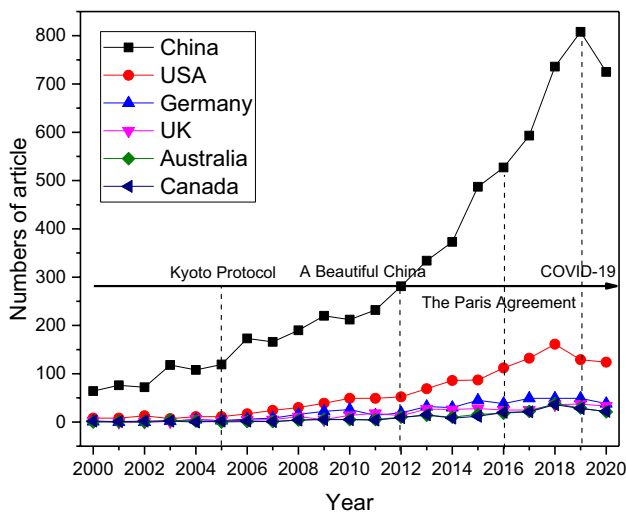


Fig. 4 Publication trend of top 6 productive countries

Table 4 Top 5 keywords from different countries’ articles

Countries	Keywords (in descending order)
China	Climate change, evolution, temperature, diversity, precipitation
USA	Evolution, climate change, precipitation, adaptation, late Miocene
Germany	Climate change, basin western Tibet, evolution, Holocene, summer monsoon
UK	Evolution, climate, Holocene, Asian monsoon, lake
Australia	Temperature, climate change, evolution, precipitation, barley
Canada	Arid environment, hypoxia, zircon, evolution, mafic rocks

Germany, Switzerland, UK, and Canada, which show relatively strong links with others. It also can be found that some countries like Russia, Austria, and India have less cooperation with others. Although it shows plenty of cooperation between the top 20 countries, there is still more space to promote the collaboration relationship in this field.

To identify the cooperation emphasis between China and different countries, keywords in the papers jointly published by China and the USA, China and Germany, and China and Australia were analyzed, due to the relatively close cooperation relationship (as shown in Fig. 5). It can be seen from Table 5, evolution is the keyword for cooperation between China and the USA or Australia, while climate change is the keyword for cooperation between China and the USA or Germany. In addition, China also worked on the topic of degradation with the USA, on the topic of grassland and sensitivity with Australia, and on the topic of precipitation and diversity with Germany.

Institute contribution and cooperation

The top 20 productive institutions are shown in Table 6. It is worthy to note that only one institution, Free University of Berlin, is affiliated to Germany. The rest institutions are all affiliated to China. Furthermore, the top 11 productive institutions, which have published more than 100 articles, are affiliated to China. The Chinese Academy of Sciences (CAS) has published 4254 articles, which is far more than the sum amount of article from other institutions (3137). Furthermore, it also shares the highest LCS and GCS at the same time. The CAS is the most important institution in this field whether in quantity or quality. Except for the CAS, Lanzhou University is also active in this field, which has published 657 articles and shares a relatively high LCS and GCS. Although the Free University of Berlin published no more than 100 articles, its publications rank the third with 972 LCS, which indicates a relatively high quality of articles. There are some institutions that publish more articles but share fewer of LCS and GCS. That is to say, the quality of articles published by these institutions may need to be improved. As shown in Fig. 6, main institutions are distributed in Beijing, Jiangsu province

Fig. 5 The cooperation network of top 20 productive countries

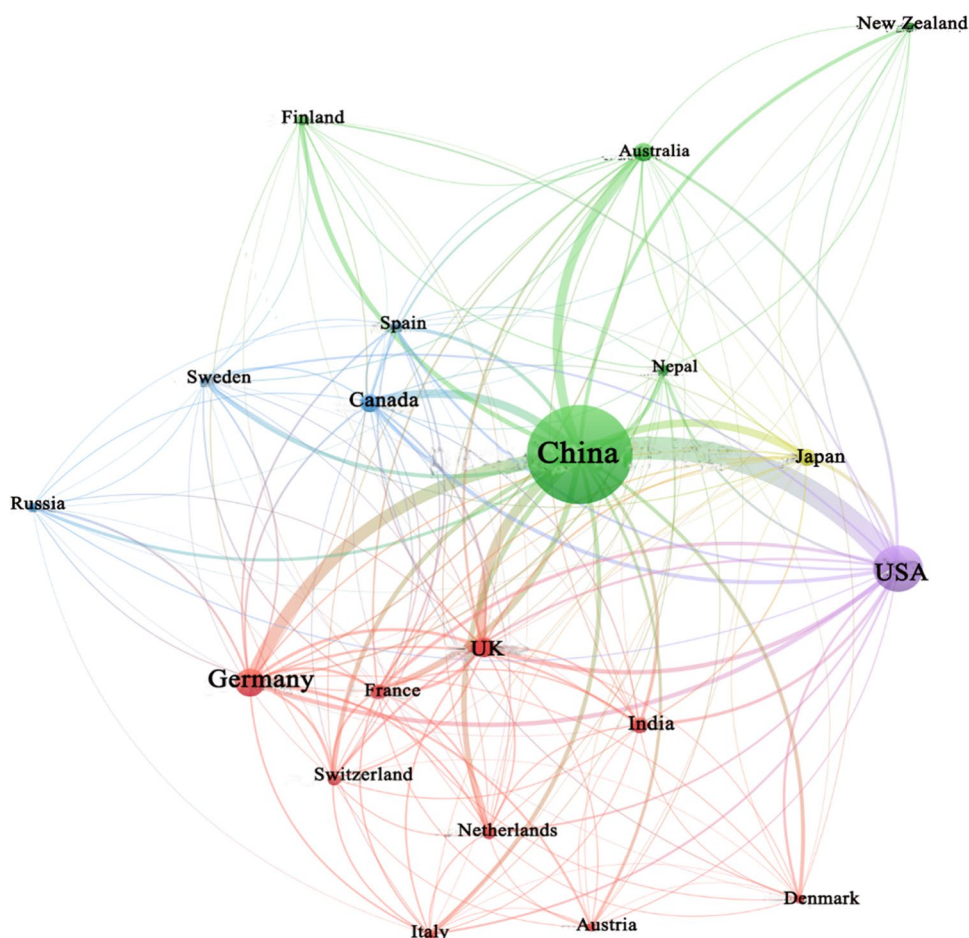


Table 5 Cooperation keywords between different countries

Countries	Cooperation keywords (in descending order)
China and USA	Evolution, climate change, nitrogen
China and Australia	Evolution, grassland, susceptibility
China and Germany	Climate change, precipitation, diversity

and Gansu province. This mainly depends on the number of universities and institutes, which are closely related to the level of local economic development. While Gansu province with few universities shares a relatively high contribution, this may be due to that Lanzhou University collaborates closely with the CAS, which can be verified in Fig. 7. It also can be found that the CAS cooperated with almost every institution ranked in the top 20. Except for Lanzhou University, China University of Geoscience is another one that has close cooperation relationship with the CAS. Cooperation relationships between other institutions are not so frequent, which can be inferred from thin link lines between them. Therefore, cooperation can also be stronger among different institutions.

The keywords in papers belonging to different economic regions of China are shown in Table 7. It can be found that institutions (except for that in Northeast China) have many common concerns, including climate change, evolution, diversity, and temperature. In particular, the order of keywords concerned by institutions in East China and West China is highly consistent, while the focuses of central institutions are different from the east and west only in priorities. In addition, eastern institutions pay more attention to precipitation, western institutions are more concerned with vegetation, and the keyword for institutions in the central region is growth. Institutions in Northeast China focus more on trace elements and geochemistry, which has a big difference from other regional institutions.

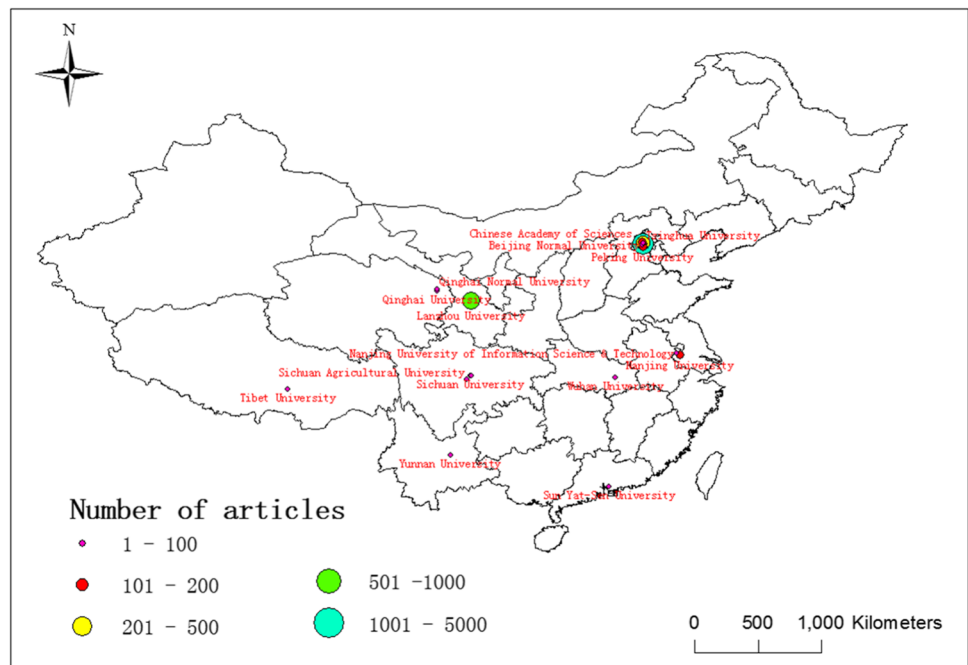
Subjects and journals analysis

There are 20 categories in CNKI database and 209 categories in WOS database recognized respectively (listed in Tables 8 and 9). In CNKI database, most articles belong to Environmental science and Resource Utilization subject (37.64%), while the number of articles in other subjects is less than

Table 6 Top 20 productive institutions during 2000–2020

Institutions	Records	Percent (%)	TLCS	TGCS
Chinese Academy of Sciences	4254	57.34	11,923	71,838
Lanzhou University	657	8.86	2732	12,162
China University of Geosciences	374	5.04	784	5837
Beijing Normal University	245	3.30	491	4043
Peking University	237	3.19	866	7162
Nanjing University	219	2.95	759	4047
Chinese Academy of Geological Sciences	202	2.72	361	3957
Sichuan University	139	1.87	310	1822
Qinghai University	132	1.78	288	1694
Nanjing University of Information Science & Technology	100	1.35	93	1270
Wuhan University	100	1.35	201	1227
Qinghai Normal University	96	1.29	57	311
China Earthquake Administration	94	1.27	120	1200
Chengdu University of Technology	87	1.17	133	893
Tsinghua University	79	1.06	105	1074
Free University of Berlin	78	1.05	972	2442
Sichuan Agricultural University	77	1.04	46	511
China Agricultural University	76	1.02	163	1184
Sun Yat-Sen University	74	1.00	70	711
Yunnan University	71	0.96	178	1163

Fig. 6 The geographic distribution of top 20 productive institutions



100. In WOS database, most of articles, occupy 27.13%, are categorized as Environmental Science & Ecology, which is followed by Geology (26.01%) and Geosciences-Multi-disciplinary (22.62%). Environmental Sciences (19.50%)

and Physical Geography (11.70%) rank the fourth and fifth, respectively. The other subjects are less than 10%. The following content mainly analyzed WOS database due to inconsistent in subject classification between WOS and CNKI.

Fig. 7 The cooperation network of institutes

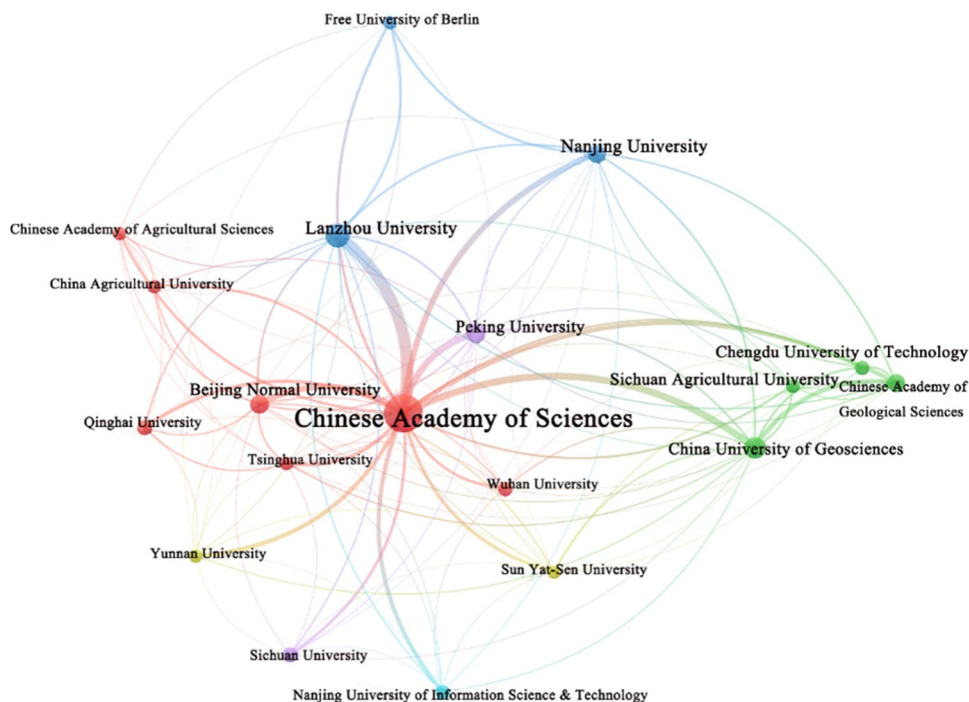


Table 7 Top 5 keywords from different economic regions of China

Regions	Provinces	Keywords (In descending order)
Eastern	Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan, Taiwan, Hong Kong, Macau	Climate change, evolution, temperature, precipitation, diversity
Northeastern	Heilongjiang, Jilin, Liaoning	Trance element, climate change, geochemistry, temperature, dynamics
Central	Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan	Evolution, diversity, climate change, temperature, growth
Western	Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang	Climate change, evolution, temperature, diversity, vegetation

The variation of the top 5 most productive subjects at a period of 5-year interval is shown in Fig. 8. As it shows, the top three subjects are always Geology, Geosciences-Multidisciplinary, and Environmental Sciences & Ecology, and articles belong to these categories keep a steady growth. While the fourth and fifth subjects are variable during 2000–2010 and keep stable after 2010. Of the top five subjects, Environmental Sciences & Ecology and Environmental Sciences increase rapidly during 2015–2019 and rank in the first place with 916 articles and the third place with 690 articles, respectively. This indicates that the problem of environment and ecology in the Tibetan plateau has attracted more attention in recent years.

More than 25% of articles related to the Tibetan environment and ecology are published in the top 20 journals, as listed in Table 10. One hundred and thirty-six articles are published in PALAEOGEOGRAPHY PALAEOCLIMATOLOGY PALAEOECOLOGY, which is the most

productive journal. And SCIENCE OF THE TOTAL ENVIRONMENT and PLOS ONE follow closely with 134 articles and 130 articles, respectively. Moreover, SCIENCE OF THE TOTAL ENVIRONMENT shows the highest IF with 6.551 and PLOS ONE shows the highest H-index with 268. Figure 9 presents the publication trends of the top three journals during 2000–2020. It can be found that the number of articles published in these journals is no more than 10 before 2012. After 2012, the number of articles begins to increase in a wave way, especially the amount of article in SCIENCE OF THE TOTAL ENVIRONMENT grows dramatically and keeps more than 30 articles published per year in last 3 years, while the amount of article in PLOS ONE shows a decline after 2015. In terms of journals’ distribution, the number of articles published in each journal occupies a small percentage of less than 3%, which shows that it is dispersive in our studied field. In order to reflect the changes of attention on the Tibetan Plateau researches, we analyzed

Table 8 Subjects in CNKI database during 2000–2020

Subjects	Records	Percent (%)
Environmental science and Resource Utilization	405	37.64
Reform of the economic system	88	8.18
Animal husbandry and Veterinary Medicine	85	7.90
Biology	83	7.71
Agricultural economy	83	7.71
Geology	65	6.04
Macroeconomic management and sustainable development	64	5.95
Meteorology	48	4.46
Travel	47	4.37
Physical geography and mapping	38	3.53
Railway transportation	31	2.88
Resource science	31	2.88
Agricultural basic science	30	2.79
Forestry	26	2.42
Industrial economy	25	2.32
Administrative law and local rule of law	21	1.95
Crop	20	1.86
Physical geography	19	1.77
Industrial general technical equipment	19	1.77
Road and water transportation	19	1.77

Table 9 Top 20 productive subjects in WOS database during 2000–2020

Subjects	Records	Percent (%)
Environmental Sciences & Ecology	1721	27.13
Geology	1650	26.01
Geosciences, Multidisciplinary	1435	22.62
Environmental Sciences	1237	19.50
Physical Geography	742	11.70
Ecology	603	9.51
Science & Technology-Other Topics	532	8.39
Meteorology & Atmospheric Sciences	487	7.68
Multidisciplinary Sciences	455	7.17
Plant Sciences	378	5.96
Geochemistry & Geophysics	359	5.66
Agriculture	351	5.53
Engineering	263	4.15
Water Resources	246	3.88
Genetics & Heredity	241	3.80
Evolutionary Biology	225	3.55
Paleontology	199	3.14
Zoology	197	3.11
Soil Science	185	2.92
Biochemistry & Molecular Biology	183	2.89

the proportion in different level journals quartile rankings by JCR, as shown in Fig. 10. It can be found that the proportion of papers published in journals ranking Q2, Q3, and Q4

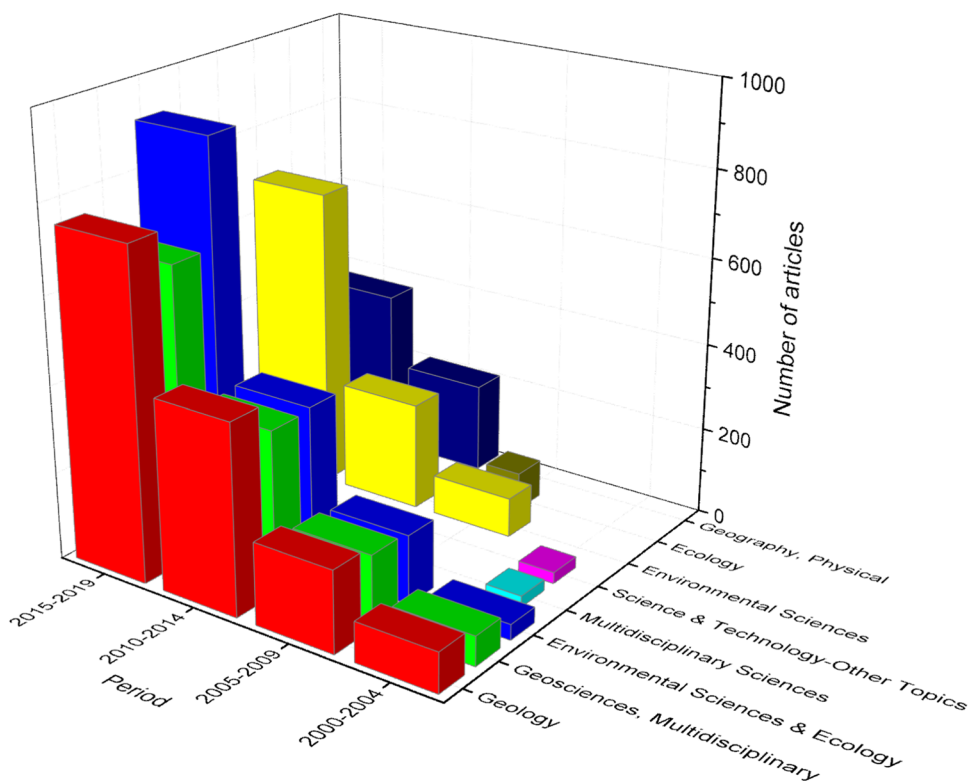
was relatively stable, while papers published in Q1 journals showed increase trend before 2015, and then stable at about 40%. It indicates that the study of Tibetan ecological and environment is of great importance in the research field.

Keywords and co-occurrence analysis

There are 3874 keywords used in Tibetan environment- and ecology-related researches during 2000–2020. And the increasing tendency towards keywords per year is presented in Fig. 11. It can be seen that the number of keywords shows fast growth of time except 2020 which is affected by the COVID-19 pandemics that resulted in a decline in article outputs (Fig. 1). It means that the research on Tibetan environment and ecology is becoming more popular and covering more scopes. But we also find that 66.13% (2562) of these keywords are used less than 5 times, and only 18.40% (713) of them are used more than 10 times. A large number of keywords used a few times may indicate that related researches are dispersive and lack continuity (Chuang et al. 2007). Moreover, it implies that the mainstream researches on Tibetan environment and ecology still focus on a few fields.

The variations in ranking and percentage of the top 30 most frequently used keywords with a 5-year interval is listed in Table 11, which provide us some clues about the research hotspots in a way (Xie et al. 2008). Except for searching strings (qinghai-xizang or Qinghai-tibet* or tibet*), the top 30 most used keywords during 2000–2020

Fig. 8 Variation of top 5 subjects during 2000–2020



are mainly the following research fields: climate, geological, diversity, model, and soil. Of these topics, plateau climate is the most eye-catching direction, while climate change is a relatively new theme and the research on it has soared

since it emerging in 2005, this phenomenon may be affected by the formation of the Kyoto Protocol, which calls on all countries to take climate change seriously (Zheng et al. 2020a, b). In terms of the methods, a test of isotope from

Table 10 Top 20 productive journals during 2000–2020

Journal	Records	Percent (%)	LCS	GCS	IF (2019)	H-index
Palaeogeography Palaeoclimatology Palaeoecology	136	2.1	830	3257	2.833	134
Science of The Total Environment	134	2.1	224	1711	6.551	205
PLoS One	130	2.0	0	2436	2.74	268
Scientific Reports	119	1.9	0	1542	3.998	149
Quaternary International	103	1.6	492	1710	2.003	93
Journal of Asian Earth Sciences	92	1.5	186	1355	3.059	107
Science Bulletin	88	1.4	376	1983	—	—
Acta Petrologica Sinica	81	1.3	68	673	1.265	71
Quaternary Science Reviews	79	1.2	876	3801	3.803	164
Journal of Mountain Science	72	1.1	66	270	1.55	25
Remote Sensing	71	1.1	19	594	4.509	81
Journal of Geophysical Research-Atmospheres	66	1.0	45	1694	3.821	—
Acta Geologica Sinica-English Edition	64	1.0	92	431	1.973	—
Chinese Journal of Geophysics-Chinese Edition	63	1.0	55	572	0.811	49
Science China-Earth Sciences	63	1.0	148	801	3.242	74
Science In China Series D-Earth Science	55	0.9	288	1400	—	—
Environmental Earth Sciences	53	0.8	105	570	2.18	98
Journal of Geographical Sciences	52	0.8	96	581	2.851	38
Ecology and Evolution	51	0.8	75	342	2.392	47
Ecological Indicators	50	0.8	105	900	4.229	97

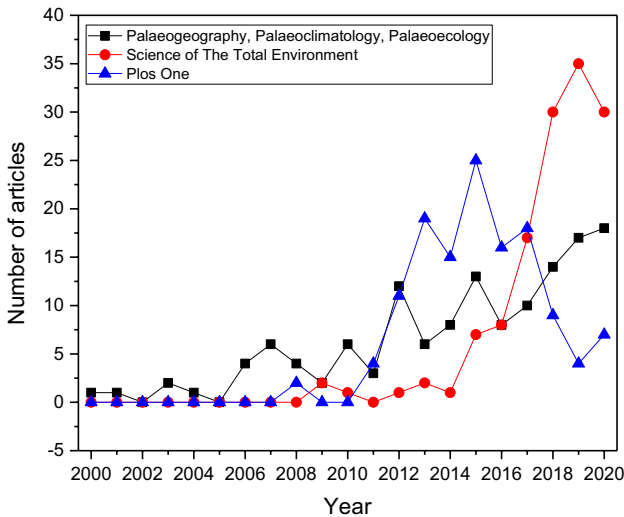


Fig. 9 The publication trend of top 3 journals during 2000–2020

sediment samples is the most mentioned, especially for a remote age (Liu et al. 2013). It can be proved by the related keywords (carbon) ranked from 108th during 2000–2004 to 38th during 2005–2009 and kept slightly increasing during 2010–2014. Besides, plateau geological change is another hot topic, including the impacts of Tibetan Plateau uplift on environment and climate, and the evolution of plateau geomorphology during different geologic ages. But it can be found that the research on plateau uplift presents a decline tendency in recent years, especially after 2015. Like climate change, diversity in the Tibetan Plateau is a topic emerging in 2005, which grows rapidly and ranks by the front. This area comprises several directions, such as microbial diversity, plant diversity, and genetic diversity. The frequency of

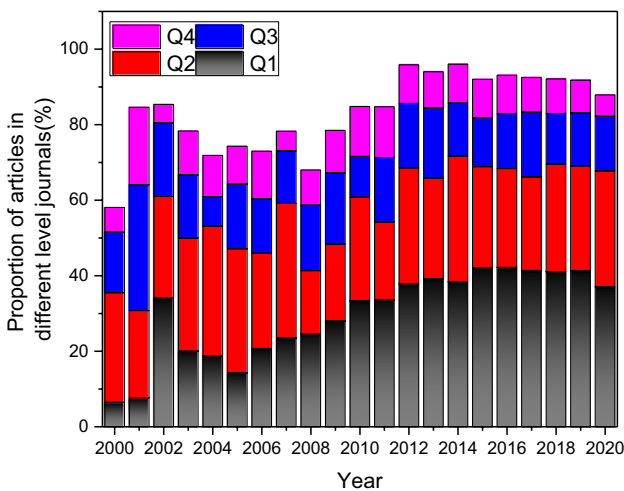


Fig. 10 Variation of articles in different level journals during 2000–2020

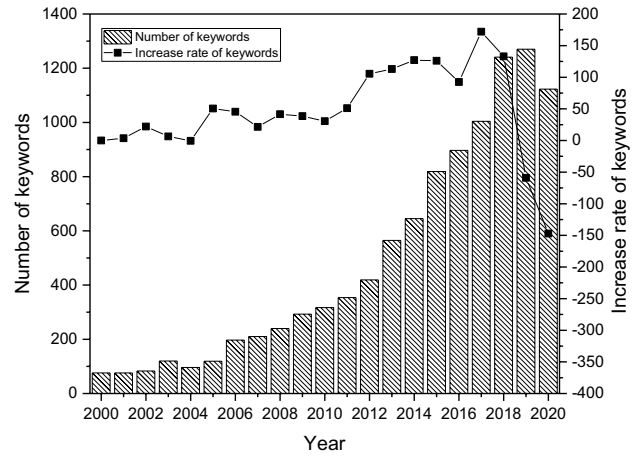


Fig. 11 The variation of keywords number during 2000–2020

diversity and plant varies in a small range indicating that research on this field keeps stable. As for soil, it involves microbial, soil organic carbon, soil nutrient, soil moisture, and other soil properties. Mathematic model is an effective method to predict experimental results; it has also been used for above research fields and ranks basically steady. Moreover, grassland and basin are two geomorphologies that attract more attention. Holocene is the most mentioned geological age.

Hotspots and future direction

Research hotspots

The variation of top 30 keywords during different periods with a 5-year interval is shown in Fig. 12, which reflects the evolution of topics during different period to some content. As it shows, climate change, geology, and diversity are three main hotspots in this field. Monsoon and temperature are two most frequently mentioned words in the study of climate change, while Pleistocene and Holocene are two of the most studied epochs in geologic researches. And the most studied themes in diversity are biodiversity and ecologic diversity.

As for geographic position, the most involved are Himalaya, southern Tibet, and western Tibet. While in above areas, plateau and basin are the first landform to be studied, and lake, alpine meadow, grassland, and forest are studied as time goes on.

As far as research objects, sediment, precipitation, and vegetation are always important objects in different studied periods, while volcanic rock and permafrost are only appearing in the first stage. At the same time, population growth and its impacts on ecologic diversity are hotspots in the first three stages. Furthermore, researches on carbon

Table 11 The changing trends of top 30 keywords during 2000–2020

Keywords	<i>R</i> (%)					
	2000–2020	2000–2004	2005–2009	2010–2014	2015–2019	2020
Tibetan plateau	3257 (39.54)	168 (22.55)	347 (28.35)	704 (39.18)	1672 (45.56)	366 (45.64)
Climate change	930 (11.29)	4 (0.54)	43 (3.51)	190 (10.57)	562 (15.31)	131 (16.33)
China	777 (9.43)	34 (4.56)	70 (5.72)	179 (9.96)	421 (11.47)	72(8.98)
Evolution	516 (6.26)	28 (3.76)	69 (5.64)	128 (7.12)	226 (6.16)	65 (8.10)
Climate	434 (5.27)	28 (3.76)	39 (3.19)	114 (6.34)	207 (5.64)	46 (5.74)
Temperature	404 (4.90)	12 (1.61)	35 (2.86)	98 (5.45)	208 (5.67)	51 (6.36)
Diversity	327 (3.97)	—	35 (2.86)	55 (3.06)	192 (5.23)	46 (5.74)
Precipitation	327 (3.97)	5 (0.67)	27 (2.21)	66 (3.67)	192 (5.23)	37 (4.61)
Environmental change	301 (3.65)	9 (1.21)	44 (3.59)	95 (5.29)	131 (3.57)	24 (2.99)
Vegetation	282 (3.42)	6 (0.81)	31 (2.53)	68 (3.78)	149 (4.06)	31 (3.87)
Plateau	280 (3.40)	15 (2.01)	36 (2.94)	65 (3.62)	153 (4.17)	15 (1.87)
Pattern	271 (3.29)	4 (0.54)	20 (1.63)	62 (3.45)	143 (3.90)	42 (5.24)
Variability	256 (3.11)	4 (0.54)	18 (1.47)	69 (3.84)	132 (3.60)	33 (4.11)
Impact	254 (3.08)	2 (0.26)	10 (0.82)	42 (2.34)	161 (4.39)	38 (4.74)
Model	214 (2.60)	11 (1.48)	20 (1.63)	51 (2.84)	102 (2.78)	32 (3.99)
Record	211 (2.56)	18 (2.42)	34 (2.78)	64 (3.56)	84 (2.29)	11(1.37)
Sediment	211 (2.56)	2 (0.26)	23 (1.88)	58 (3.23)	95 (2.59)	34 (4.24)
Dynamics	209 (2.54)	—	13 (1.06)	44 (2.45)	114 (3.11)	38 (4.74)
Carbon	201 (2.43)	2 (0.85)	15 (1.23)	49 (2.73)	97 (2.64)	38 (4.74)
Growth	197 (2.39)	3 (1.28)	25 (2.04)	41 (2.28)	96 (2.62)	32 (3.99)
Grassland	189 (2.29)	—	14 (1.14)	33 (1.84)	117 (3.19)	25 (3.12)
Soil	188 (2.28)	1 (0.13)	11 (0.90)	40 (2.23)	111 (3.02)	26 (3.24)
Response	187 (2.27)	4 (1.70)	10 (0.82)	29 (1.61)	116 (3.16)	28 (3.49)
Uplift	178 (2.16)	12 (5.11)	24 (1.96)	45 (2.50)	78 (2.13)	19 (2.37)
Plant	175 (2.12)	4 (1.70)	15 (1.23)	37 (2.06)	101 (2.75)	18 (2.24)
Basin	174 (2.11)	7 (2.98)	17 (1.39)	40 (2.23)	84 (2.29)	26 (3.24)
Holocene	174 (2.11)	5 (2.13)	17 (1.39)	48 (2.67)	82 (2.23)	22 (2.74)
Biodiversity	170 (2.06)	—	12 (0.98)	37 (2.06)	98 (2.67)	23 (2.87)
Alpine Meadow	168 (2.04)	—	22 (1.80)	35 (1.95)	93 (2.53)	18 (2.24)
Adaptation	167 (2.03)	—	11 (0.90)	34 (1.89)	94 2.56)	28 (3.49)

R (%): records and percent of keywords in different period

and soil begin in 2005 and are outside the top 30 in the third stage. Then, they become hotspots again in the fourth stage. In addition, researches on water, trace elements, and soil/grassland/meadow degradation are starting to gain momentum in the fourth stage.

In terms of research methods, isotope detection along with modeling are the most frequently used at present researches.

Future direction

The Tibetan plateau has an important influence on local and surrounding climate due to the special geographical environment. It is also an ideal area for studying climate changes in the world. Thus, climate change will continue to be an important theme in related researches, while geological change is one of important reasons of climate change,

and variation of diversity is an indicator of climate change. Hence, climate change, geology, and diversity are still important components in future researches.

Besides, the Tibetan Plateau is rich in mineral resources, with 65 metal deposits in Tibet alone. With the development of local mineral resources, pollution caused by industrial enterprises cannot be ignored. We think ecological management and rehabilitation of mining area and tailings ponds will be an important research direction in the future.

Moreover, another direction worthy of attention is the environmental problems caused by development of tourism, such as the treatment of travel rubbish (especially plastic) and the prevention and control of pollution along traffic line and in tourism areas (especially soil and water quality change). It can also be evidenced by the burst of keywords such as water, soil, and trace elements in the fourth stage in Fig. 12.

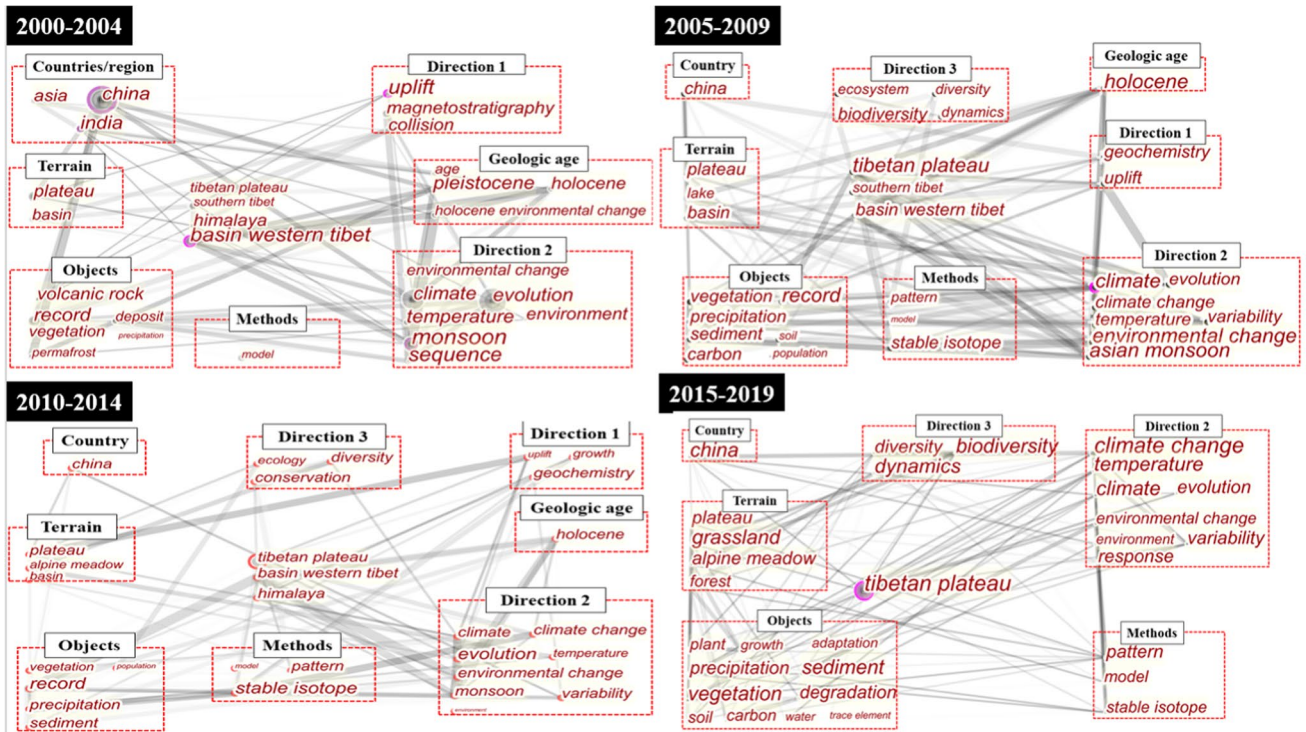


Fig. 12 The variation of top 30 keywords during different periods

Conclusions

We systematically summarize the hotspots and development trends on Tibetan environment and ecology researches. Bibliometric method is used for analyzing the characteristics of articles, which is retrieved from WOS and CNKI database during 2000–2020. The results reveal that researches on Tibetan environment and ecology have been attractive in recent years, and the number of articles in this field keeps fast increasing, especially after 2012. English is still the most used language, accounting for 83.00%. Besides, China plays the most important role in related research. Articles from China soar after 2005, consisting with the increasing tendency of total articles. Articles from the USA show slowly increasing and from other countries keep stable at the same time. Except for common concerns such as evolution, climate change, and precipitation, diversity is more studied by Chinese scholars, while the USA focuses on adaptability, and other countries such as Germany, UK, and Australia focus on basin western Tibet, lake, and barley respectively. In particular, Canada paid more attention to arid environment, hypoxia, and ore-related researches. In cooperation relationship, evolution is the keyword for cooperation between China and USA or Australia, while climate change is the keyword for cooperation between China and USA or Germany. In addition, China also works on the topic of degradation with

USA, on the topic of grassland and sensitivity with Australia, and on precipitation and diversity with Germany.

As the most productive country, Chinese institutions located in different economic regions focus on different research emphasizes. The eastern institutions pay more attention to precipitation, while western institutions are more concerned with vegetation, and the keyword for institutions in the central region is growth, while institutions in Northeast China focus more on trace elements and geochemistry. Among all institutions, the CAS contributes the most articles with 4254 and shows advantage place whether in quantity or quality. Besides, Lanzhou University also performs well in our study. In addition, Free University of Berlin has published fewer articles but with higher citations. It is the only one from a country outside of China ranked in top 20 institutes.

PALAEOGEOGRAPHY PALAEOCLIMATOLOGY PALAEOECOLOGY, SCIENCE OF THE TOTAL ENVIRONMENT and PLOS ONE are the most productive periodical journals, especially for SCIENCE OF THE TOTAL ENVIRONMENT, and the amounts of articles in them increases dramatically since 2012. The subjects of Environmental Sciences & Ecology and Environmental Sciences also increase rapidly during 2015–2019. Besides, the number of articles published in the journal ranking in the first quartile by JCR increase as time go. All of these

indicate that the researches on environment and ecology in Tibetan Plateau have attracted more attention.

Co-occurrence analysis reveals that geology, climate change, and diversity have always been the focuses of researchers. In above areas, sediment, precipitation, monsoon, and vegetation are the most mentioned objects. Modeling and isotope detection methods are widely used in relevant progress. In addition, ecological management and rehabilitation of mining area and tailings ponds, water and soil quality changes in tourism areas and along traffic line, and waste (especially plastic) disposal are worthy of attention and research investment in future researches.

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Declarations

Ethical approval This paper does not involve human and animal research.

Consent to Participate All authors were participated in this work.

Consent to Publish All authors agree to publish.

Competing interests The authors declare no competing interests.

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