Research Trends and Focus on the Deserts of Northern China: A Bibliometric Analysis During 1986–2020

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With the economic progress and scientific development since the 1980s, research on deserts in China has advanced remarkably. Many research outputs have been published, especially in recent years. However, a systematic review and quantitative analysis of these publications has been lacking. Here, we conducted a comprehensive bibliometric analysis of the main deserts in China in order to characterize the trends and temporal changes in publications. Because the first publication was found in 1986, we searched all publications from 1986 to 2020. We found that annual publication output increased exponentially, especially after 2012, and that the Tengger Desert, the Taklimakan Desert, and the Horqin Sandy Land were the most intensively studied areas. Earth science, involving environmental science and ecology, geology, and agriculture were the major research fields. In addition, *Journal of Arid Land*, *Chinese Science Bulletin*, and *Catena* were the journals with the largest number of publications. The Chinese Academy of Sciences produced the largest number of publications, wherein, Li X R, Zhao X Y, and Zhang Y M were the three most productive authors. Noticeably, "climate change" has become a frequent topic since 2010, indicating that more attention has been paid to climate change and alleviating anthropogenic disturbances in desert areas in China. Although Chinese authors contributed the most publications, the average number of citations per publication for Chinese authors was relatively low. Our results highlight that authors should continue to improve the number of citations of their publications and pay more attention to the interactions between climate change and desertification in the deserts research of Northern China in the futures.

Keywords: sandy land, arid area, Northern China, bibliometrics, publications, citations

INTRODUCTION

Due to economic development and governmental support, research on deserts in China has made tremendous progress over the past 30 years (Wang, 2009; Li et al., 2017). As one of the largest sandy regions in the world, desert lands in Northwestern China cover approximately 1,721,200 km^2 and account for 17.93% of China's total area (State Forestry Administration, 2015). Characterized by severe sandstorms and extreme water shortage, Northwestern China has encountered serious ecological and environmental stresses, such as the increasing desertification and frequent sand and dust storms (Zhu, 1985). Since the 1950s, the Chinese government has promoted a series engineering solutions to stabilize sands, such as the protective system of the Shapotou section of the Baotou-Lanzhou Railway (Li et al., 2017) and the Three-North Shelter Forest Program (Bao et al., 2018). At that time, the main goal of research on deserts in China was to provide guidance and suggestions for sand-stabilization engineering (Wang et al., 1999). It was only after China's reform and opening up in the 1980s that scientific research and publications have become a focus of this research field (Wang et al., 1999; Li et al., 2017). In addition, increased exchange and cooperation with other countries has prompted relevant institutions and researchers to publish in international journals (Wang et al., 1999).

Due to continuous efforts, the environmental and ecological issues in desert areas in Northern China have been significantly mitigated in recent years (Chen et al., 2019). At the same time, global change has emerged as a hotly debated topic across the world in the past 2 decades (Puigdefábregas, 1998; Franklin et al., 2016). It also may be a major disturbance to deserts that should be considered in research on deserts in Northern China (Yang et al., 2021). Therefore, research on deserts in China has entered a new stage, and a systematic review at this time could provide meaningful insight into future work for this research field (Shi et al., 2007; Yang et al., 2021). Although there have been a few reviews on this topic, such as Wang, (2009), none has included research from the most recent 10 years. Moreover, most reviews were narrative and qualitive, and lacked quantitative analysis using modern bibliometric methods.

The conditional qualitative reviews are narrative and suffer from some important limitations. One is the subjectivity and the lack of transparency inherent in this approach. A second limitation of narrative reviews is that they become less useful as more information becomes available, especially in a time with information explosion (Wallin, 2005). As the progress of computer technology, quantitative reviews represented by bibliometric analysis has become a powerful tool to conduct systematic and transparent reviews of a specific research field by processing a large number of publications (Borgman and Rice, 1992; Bornmann and Mutz, 2015). This methodology provides detailed information on the annual outputs, temporal evaluation of key words, dominant research areas, marked journals, and the institutions and authors involved in the research (Wallin, 2005; Aria and Cuccurullo, 2017). Bibliometric analysis also provides ways of exploring the potential relationships between publications and can reveal emerging trends in research (Liu

et al., 2011; Michael Hall, 2011). The major differences between bibliometric analysis and traditional narrative review are that bibliometric analysis is more quantitative and less subjective (Bornmann and Mutz, 2015). In an era of information explosion and dramatic increase of publications (Michels and Schmoch, 2012; Pautasso, 2012), bibliometric analysis is becoming more and more important for drawing systematic conclusions (Wallin, 2005; Neff and Corley, 2009; Zhang and Chen, 2020). Bibliometric analysis of the advancement of a particular field of scientific research is also called "the science of science" (Zhang and Chen, 2020).

To review the entire landscape, understand the development progress and predict its future research trends of the scientific research on deserts in China, we conducted a comprehensive bibliometric analysis on publications and citations. Specifically, we ask the following three questions: 1) What are the characteristics and patterns in desert research in China in the past 30 years? 2) What is the temporal evolution of research areas and topics? 3) What are the strategies for future work in this research field?

# DATA COLLECTION AND ANALYSIS

Data Collection

We conducted a bibliometric collection on 20 May 2021 using topic search (TS) based on the Science Citation Index Expanded (SCI-E) database in "Web of Science Core Collection." We selected SCI-E database because it provides comprehensive coverage of the most important and influential research outputs across the world.

We selected the eight main deserts and four so-called sandy lands in China as our search terms (See details **Figure 1**). These twelve deserts are ordered as followings: the Taklimakan Desert, the Gurbantunggut Desert, the Badain Jaran Desert, the Tengger Desert, the Kumtag Desert, the Qaidam Desert, the Kubuqi Desert, the Ulan Buh Desert, the Mu Us Sandy Land, the Hunshandake Sandy Land, the Horqin Sandy Land and the Hulunbuir Sandy Land. Hence, we retrieved the following outputs in detail: TS = [Taklimakan or Gurbantunggut or "Badain Jaran" or Tengger or Kumtag or (Qaidam and Desert) or (Hobq or Kubuqi) or "Ulan Buh" or ("Mu Us" and Desert) or (Hunshandake or Otindag) or Horqin or ((Hulunbuir or "Hulun Buir") and (Desert or "Sandy land"))]. Because deserts are not distributed in all parts of some target areas, such as in the Qaidam Basin and the Hulunbuir grassland, we had to constraint our search strings to "desert" or "sandy land." The document types in our research included articles, books, reviews and letters, but we did not include meeting abstracts, book reviews, and corrections.

The earliest study in the SCI-E database was from 1986, and thus we searched all publications between 1986 and 2020. A total of 2,600 documents were identified, and the three most productive research regions were the Tengger Desert (597 documents), the Taklimakan Desert (590 documents), and the Horqin Sandy Land (499 documents) (**Figure 2A**). However, less publications were founded for the Kubuqi Desert, the Ulan Buh
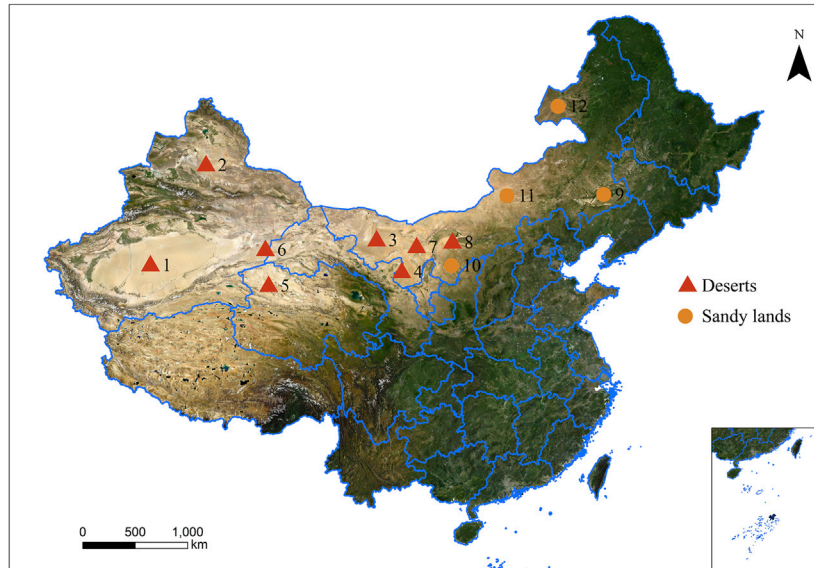
FIGURE 1 | Geographic distribution of the main deserts (including eight deserts and four so-called sandy lands) in Northern China which were selected as search terms in the bibliometric analysis. 1: the Taklimakan Desert; 2: the Gurbantunggut Desert; 3: the Badain Jaran Desert; 4: the Tengger Desert; 5: the Qaidam Desert; 6: the Kumtag Desert; 7: the Ulan Buh Desert; 8: the Kubuqi Desert; 9: the Horqin Sandy Land; 10: the Mu Us Sandy Land; 11: the Otindag Sandy Land; 12: the Hulunbuir Sandy land.
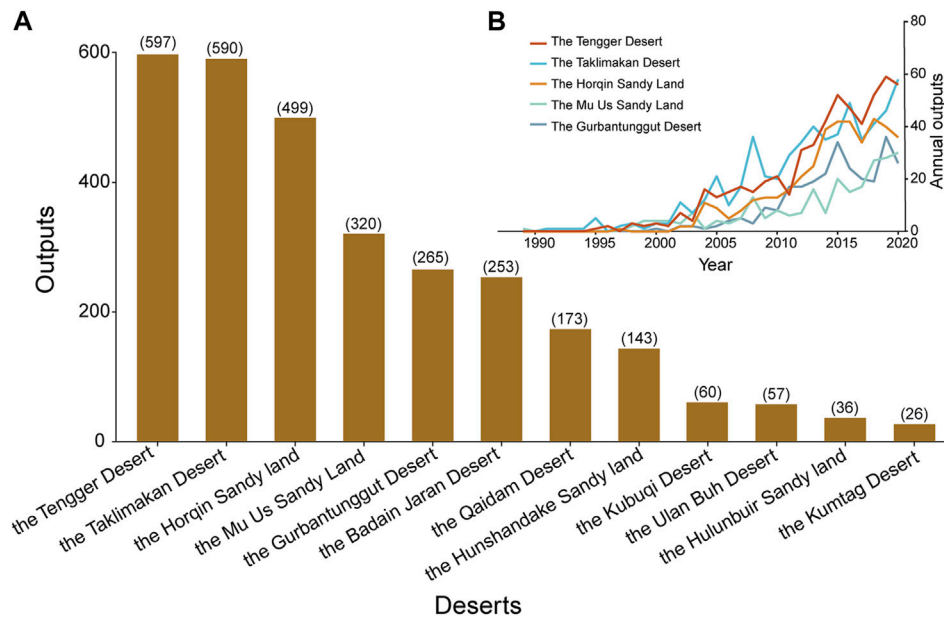
FIGURE 2 | Outputs published for the main deserts in China from 1986 to 2020 on the SCI-E database. **(A)** Total outputs for the 12 main deserts. The outputs numbers are listed in parentheses. **(B)** Annual outputs for the five most productive deserts.

Desert, the Hulunbuir Sandy Land, and the Kumtag Desert. The annual outputs for the Taklimakan Desert had significant increase after 2006, and the annual outputs for the Tengger Desert and the Horqin Sandy Land increased quickly from 2012 (**Figure 2B**). The most common publication type was research article, which accounted for 98.5% of the total

outputs, and the remaining publications types included reviews (1.33%) and letters (0.1%).

Data Analysis

To evaluate the research on deserts in China since 1986, we conducted our bibliometric analysis in the following five

FIGURE 3 | Annual outputs and average citations per output of the research on deserts in China from 1986 to 2020 in the SCI-E database. The red line is the predicted exponential model of annual outputs.

FIGURE 4 | The 10 most productive areas of the research on deserts in China. The output numbers are listed in parentheses.
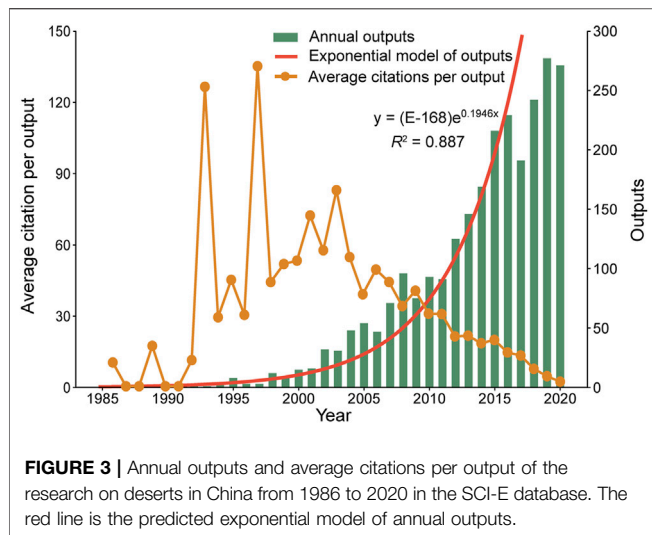
components: temporal evolution of annual outputs, main research areas, temporal evolution of keywords, marked journals, dominant institutions, and most productive authors.

Outputs and citations are the two main metrics that represent publication quantity and quality, respectively. Average number citations per output was used to show the average numbers for one paper cited by others in the local database (Zhang and Chen, 2020). To identify the most productive countries, we classified outputs by the nationality of their corresponding authors. International cooperation rate (ICR) for publications was measured as the proportion of papers whose authors come from at least two countries and was used to describe the cooperation patterns of one country with other countries (Bouabid et al., 2016). In addition, a concept map based on correspondence analysis in bibliometrics was used to show the clusters of research topics (Cuccurullo et al., 2016). Marked journals was assigned by the number of publications they carried on the subject based on Bradford's law for bibliometric analysis (Gong et al., 2019).

We used the *bibliometrix* R package (Aria and Cuccurullo, 2017) to perform data mining and analysis. This package provides powerful and comprehensive tools for bibliometric analysis and has been widely used (Rodríguez-Soler et al., 2020; Niknejad et al., 2021). We used the *ggplot2* R package (Wickham, 2016) to visualize the results.

RESULTS AND DISCUSSION

Temporal Evolution of Annual Publications

After the first publication in SCI-E database in 1986, the annual output of research on deserts in China increased exponentially (**Figure 3**) with an average annual growth rate of 9.45%. Specifically, we divided the annual output into three rising periods: 1) ready-to-grow period: steady with slight rising from 1986 to 2000 with 58 publications totally; 2) steady growth period: publications were risen to 563 during 2001–2010, with an average annual growth rate of 87%; 3)
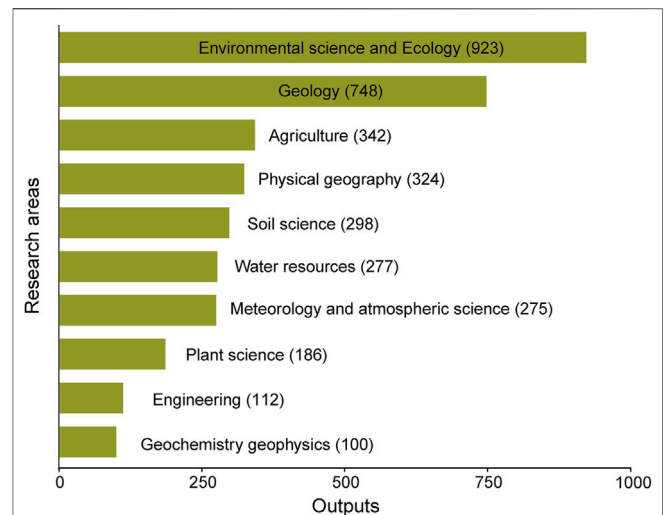
explosive growth period: there were 1,957 publications from 2011 to 2020, with nearly 200 papers published per year. The remarkable growth occurred after 2012, during which time 71.8% of the total outputs were published. This dramatic increase followed the global trend of increasing academic publications in recent years (Mu et al., 2016; Zia, 2021). At the same time, it coincided with the remarkable growth of scientific research in China in the past 10 years. For example, Zhang and Chen (2020) found that almost 90% of the outputs about the Chinese Loess Plateau were published between 2006 and 2018. Dong et al. (2020) concluded that more than 40% of all publications about the Qinghai-Tibetan Plateau were published between 2013 and 2018. Therefore, the most likely explanation for this explosive increase in research output on deserts in China is due to the rapid economic development and increased support (e.g., more funding) from the Chinese government for scientific research (Dong et al., 2020). At the same time, it indicated that more attention have been paid to the environmental and ecological research on desert areas in Northern China. From this trend, it can be predicted that the annual publications of the research on deserts in China will continuous to increases in the next few years.

In contrast to the continuous growth in annual output, the average citations per output showed a fluctuant trend (**Figure 3**). The similar increasing trend for the average citations per output to the annual outputs were found during 1985–2003. This might be explained that researchers started to pay more attention to scientific research on deserts in this period, leading to a synchronous growth between outputs and citations under the circumstance that a relative small number of publications exists. The remarkable decrease in citations occurred after 2004, whereas annual production of publications increased rapidly during this period. One reason for the declining citation rate despite the increasing publication rate is that researchers had too abundant references to cite. Due to lags in publishing time, later outputs usually had lower citations while older outputs gradually lose

TABLE 1 | The 15 most frequent words within two main time periods (i.e., 1986 to 2010 and 2011–2020).

Frequent words (1986–2010)	Occurrences	Frequent words (2011–2020)	Occurrences
Taklimakan Desert	209	Sandy land	498
Sandy land	125	Taklimakan Desert	394
Sand dunes	117	Soil moisture	385
Northern China	104	Soil water	370
Soil water	103	Northern China	324
Soil moisture	96	Sand dunes	307
Tengger Desert	95	Grain size	259
Loess Plateau	91	Horqin Sandy Land	257
Grain size	83	Tengger Desert	243
Badain Jaran Desert	72	**Climate change**	**242**
Biological soil crusts	68	Semi arid	240
Soil organic carbon	63	Badain Jaran Desert	214
Dust storm	62	Biological soil crusts	207
Horqin Sandy Land	61	Tibetan Plateau	207
Summer monsoon	60	Wind erosion	179

Notes: Bold font indicated that climate change has become a frequent word since 2010.
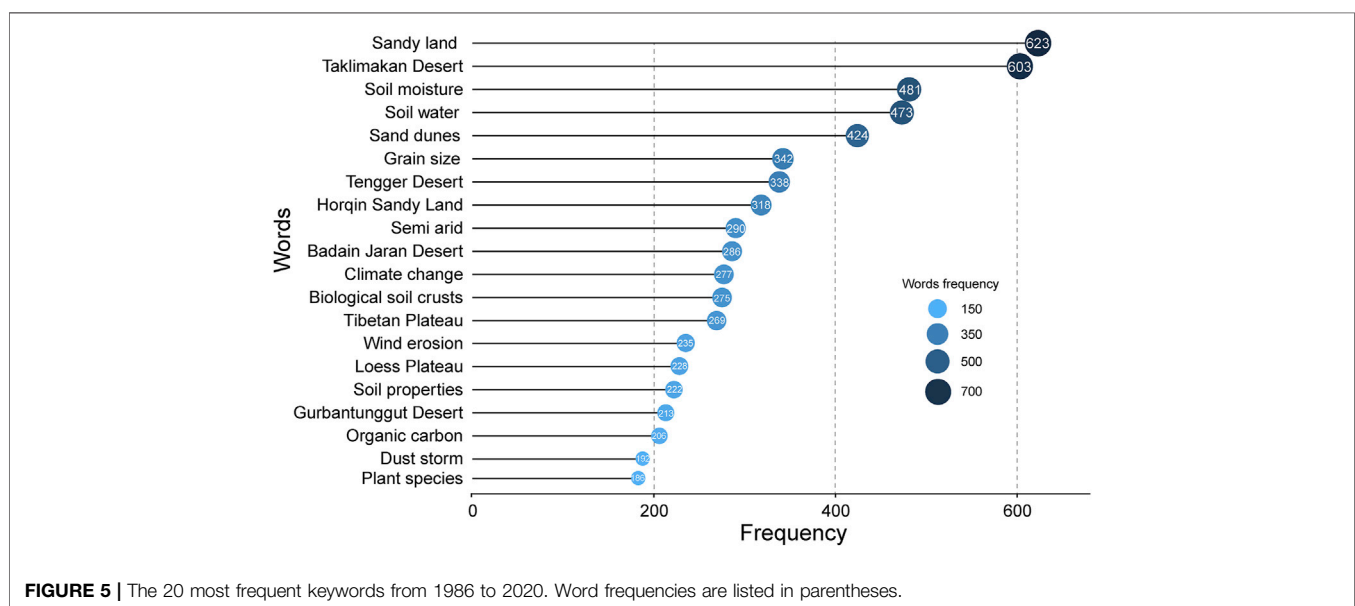
FIGURE 5 | The 20 most frequent keywords from 1986 to 2020. Word frequencies are listed in parentheses.

their influence as they are replaced by more recent publications (Zhang and Chen, 2020). Therefore, what should be noted is that our analysis showed only the current citations of newly published papers and could not show their peak number of citations. Altogether, because of the continuing growth of outputs in desert research in China, it's not surprising that the average number of citations per output decreased gradually.

Dominant Research Areas

Analysis of research areas can help to reveal the core subjects responsible for increasing productivity in the research field (Zhang and Chen, 2020). By analyzing the contents using Clarivate Analytics in Web of Science, each publication can be assigned to at least one research area. Based on the classification of the Web of Science research areas, the total number of research

areas increased from 9 in 2000 to 32 in 2020. The 10 most productive areas were environmental sciences and ecology (accounting for 35.5%), geology (28.8%), agriculture (13.2%), physical geography (12.5%), soil science (12.5%), water resources (10.7%), meteorology and atmospheric science (10.6%), plant science (7.15%), engineering (4.31%), and geochemistry geophysics (3.85%) (**Figure 4**). This reveals that the research on deserts on China were mainly focused on earth sciences, although they covered a wide range of other research areas such as paleontology, energy fuels, business economics, nutrition dietetics, remote sensing, and archaeology. Some of the research of China's deserts in the area of energy fuels concerned resource exploitation and petrochemical industry (Wang et al., 2008); business economics area involved the trade of livestock and Chinese herbal medicine (Song et al., 2021); remote sensing

TABLE 2 | The 18 core journals publishing work on China's deserts classified by Bradford's law and their corresponding output numbers and citations.

Journals with most outputs	Outputs	Citations
Journal of Arid Land	109	363
Chinese Science Bulletin	74	1,669
Catena	64	1,320
Environmental Earth Sciences	59	506
Journal of Arid Environments	56	3,255
Journal of Geophysical Research: Atmospheres	53	3,563
Geomorphology	49	1,590
Atmospheric Environment	44	1,408
Palaeogeography Palaeoclimatology Palaeoecology	44	1803
Quaternary International	44	1,184
Arid Land Research and Management	39	307
Science of the Total Environment	39	628
Journal of Asian Earth Sciences	38	549
Plos One	37	475
Scientific Reports	37	430
Aeolian Research	32	584
Ecological engineering	32	664
Plant and Soil	30	1,466

Notes: Citations were measured by calculating the numbers of citations each paper was cited by other papers in the local database.
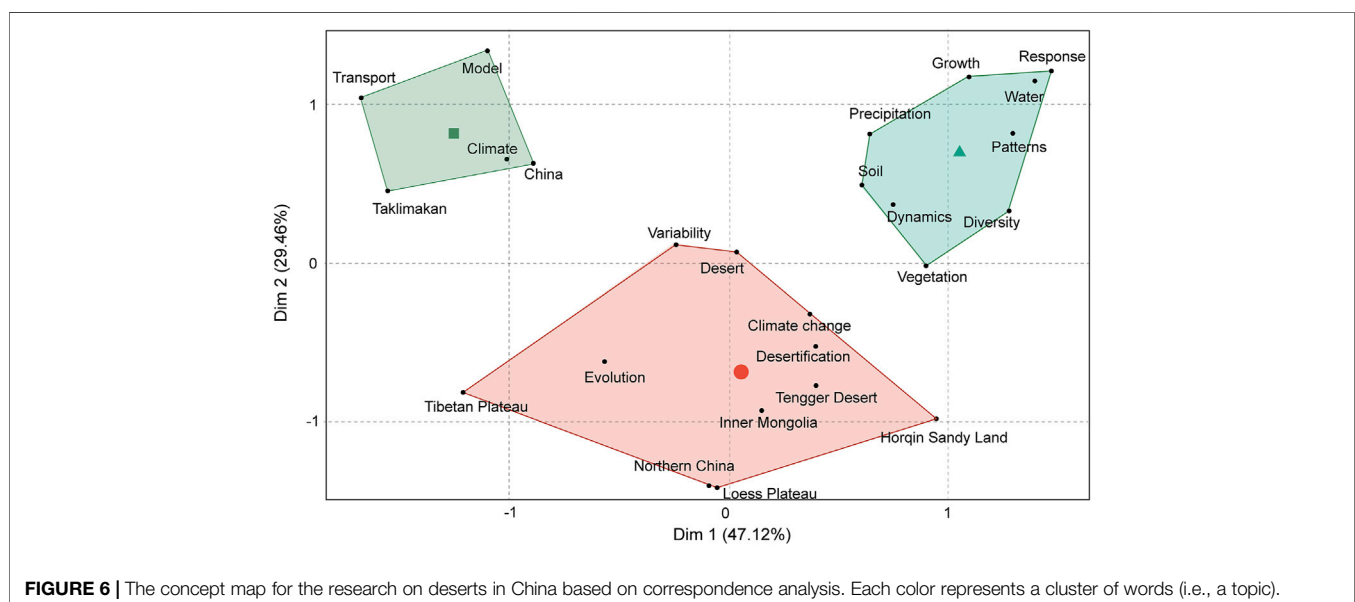
area regraded the use of geographic information system, remote sensing and machine learning method to evaluate and regulate the environment in the desert lands in Northern China (Xu et al., 2011; Filonchyk et al., 2018).

Due to limitations of water and nutrients availability and the scare of vegetation, desert lands are considered as one of the most ecologically fragile regions in the world. Hence, environment and ecology is usually an important focus for scientific research in this field (Wang et al., 1999; Li et al., 2018). It was confirmed by our results that the research area of environmental sciences and ecology accounting for 35.5% of the total publications for the

research on deserts in China. Ecological restoration and environmental protection have always been important tasks in the regulation of desert areas in Northwestern China (Wang, 2009; Li et al., 2017). Meanwhile, ecological engineering construction in Northwestern China in the past 30 years has also driven a substantial amount of scientific research (Li et al., 2009; Chen et al., 2019). For example, based on the protective system of the Shapotou section of the Baotou-Lanzhou Railway, researchers analyzed the soil water carrying capacity of vegetation and the model for sand fixation by revegetation in aeolian desert areas where precipitation levels are less than 200 mm (Li et al., 2014). In addition, the research of the engineering practices for ecological restoration in the Horqin Sandy Land identified and parameterized various ecological models and techniques for the ecological restoration of desertified grassland (Zuo et al., 2012; Miao et al., 2015). Vice verse, research work in these areas could provide a scientific basis for decision-making by the government to formulate restoration policies, and technical guidance for the ecological restoration industry (Wang et al., 1999).

Temporal Evaluation of Frequent Keywords and Topic Clusters

Frequent keywords analysis can provide vital information about research trends and reveal new research directions (Xie et al., 2008; Sun et al., 2012; Zhang and Chen, 2020). Besides our search terms (e.g., Taklimakan Desert, Tengger Desert, Horqin Sandy Land, Badain Jaran Desert etc.), the most frequent keywords were related to "sand" and "soil," including "sandy land," "sand dunes," "soil properties," and "soil organic carbon," with the frequencies of 623, 424, 222 and 206, respectively (**Figure 5**). At the same time, "water" was another frequent keyword and was associated with "soil moisture," "soil water," and "semi arid," with the frequencies of 481, 473 and 290, respectively. These results indicated that construction projects aimed to stabilize sand dunes

FIGURE 6 | The concept map for the research on deserts in China based on correspondence analysis. Each color represents a cluster of words (i.e., a topic).

TABLE 3 | The 10 most productive countries and their corresponding international cooperation rate (ICR), as measured by publications.

Corresponding author's country	Outputs	Percentage (%)	ICR	The rank of ICR
China	2,198	84.60	0.263	9
Japan	123	4.73	0.585	6
United States	83	3.19	0.627	3
Germany	36	1.39	0.611	5
United Kingdom	26	1.00	0.731	1
Korea	22	0.85	0.409	8
Israel	20	0.77	0.550	7
France	12	0.46	0.667	2
Iran	10	0.38	0.200	10
Canada	8	0.31	0.625	4

and improve soil and water conditions are still a major focus of research on China's deserts (Su and Zhao, 2003; Li et al., 2007; Zou et al., 2010; Zhang and Zhao, 2015). In addition to these terms, "biological soil crusts" was also a frequent keyword with a frequency of 275. As a key biotic component of desert ecosystems, biological soil crusts can help maintain soil stability, influence soil hydrological processes, fix carbon and nitrogen, and promote the establishment of vascular plants and microorganism communities (Zhang et al., 2007; Li et al., 2010; Colica et al., 2014). The role of biological soil crusts in desert lands has been recognized and highly valued in recent years (Li et al., 2018), and even artificial crusts have been developed and applied to stabilize sandy dunes and in ecological restoration of arid and semi-arid ecosystems (Bu et al., 2017; Zhao et al., 2021).

Compared to the period of 1986–2010, the frequent keywords showed several changes during 2011–2020 (**Table 1**). The rank of "sand dunes" fell to sixth in period of 2011–2020 from the third during 1986–2010, despite that

the frequency increased from 117 to 307. We also found the "dust storm" disappeared from the 15 most frequent keywords list in the period of 2011–2020. The above findings likely reflect that the mitigation of environmental issues resulted by Chinese government's great efforts such as the Three-North Shelter Forest Program (Wang et al., 1999; Bao et al., 2018; Chen et al., 2019). However, with the global warming intensification, we found that the keyword "climate change" ranked into the top 10 with the frequency up to 242 between 2011 and 2020 (**Table 1**). The widespread focus on climate change in this research field was confirmed by the concept map of topics shown in **Figure 6**. The total research outputs can be clustered into three main topics, with the largest cluster focusing on "desert" and "desertification" and the other two clusters focusing on "water" and "climate," respectively. These results indicated that more attention has been paid to the potential impacts of climate change on desert areas in Northern China (Shi et al., 2007; Dong et al., 2014; Zeng et al., 2016). For example, the climate transition from warm-dry to warm-wet in Northwestern China has been hotly debated in recent years (Yang et al., 2021). Altogether, climate change, combined with desertification, will remain an important research topic relevant to deserts in China.

In addition, it should be noted that the "Tibetan Plateau" became one of the 15 most frequent keywords in the period of 2011–2020 with more than two hundreds frequencies. As the "third pole of the world," the Tibetan Plateau distributes alpine meadow and other kinds of grasslands, but why here became to a hot area relating to desert research? We explained this by that the land degradation and even desertification has been occurring in the Tibetan Plateau especially the region near the Qaidam Basin because of the grassland conversion to croplands, overgrazing, global warming and so on (Cao et al., 2004; Huang et al., 2020).
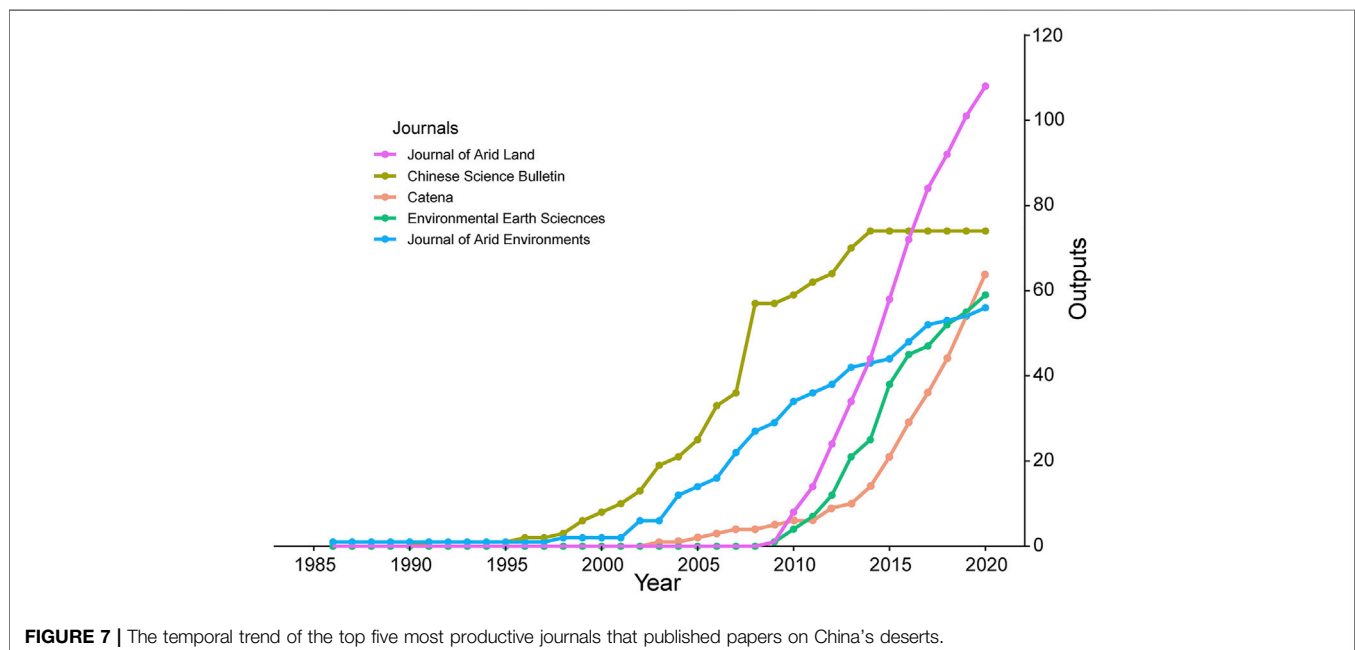
FIGURE 7 | The temporal trend of the top five most productive journals that published papers on China's deserts.

TABLE 4 | The top 10 countries whose outputs had the largest number of citations and their corresponding average number of citations per output.

Country	Total citations	Average output citations	The rank of average output citations
China	39,602	18.02	8
Japan	3,744	30.44	7
United States	3,710	44.70	3
Germany	1,380	38.33	5
United Kingdom	1,203	46.27	1
France	547	45.58	2
Korea	381	17.32	9
Canada	313	39.12	4
Israel	300	15.00	10
Italy	219	36.50	6

TABLE 5 | The 20 most productive institutions publishing research on China's deserts.

Institution	Outputs	Percentage (%)
Northwest Institute of Eco-Environment and Resources, CAS	434	16.7
University of Chinese Academy of Sciences	398	15.3
Lanzhou University	309	11.9
Xinjiang Institute of Ecology Geography, CAS	274	10.5
Institute of Earth Environment, CAS	116	4.46
Institute of Geology Geophysics, CAS	111	4.27
China Meteorological Administration	110	4.23
Institute of Geographic Sciences Natural Resources Research, CAS	102	3.92
Beijing Normal University	100	3.85
Beijing Forestry University	76	2.92
Shenyang Institute of Applied Ecology, CAS	74	2.85
Nanjing University	73	2.81
China University of Geosciences	67	2.58
Peking University	60	2.31
Institute of Botany, CAS	59	2.27
Chinese Academy of Forestry	56	2.15
Northwest A&F University	52	2.00
China Agricultural University	42	1.62
Institute of Atmospheric Physics, CAS	42	1.62
Inner Mongolia Agricultural University, IMAU	38	1.47

Marked Journals

The number of journals covering desert research on China has also increased significantly, and more journals were involving in this field. Before 2000, publications were founded in only 45 journals, and the total research outputs have been published in 482 journals now. Based on Bradford's law of bibliometrics (Pope, 1975), the 18 most productive journals were assigned to the core class (**Table 2**). These journals published 880 (33.8%) of the total 2,600 papers. The five most productive journals were *Journal of Arid Land* (109 papers), *Chinese Science Bulletin* (74 papers), *Catena* (64 papers), *Environmental Earth Sciences* (59 papers), and *Journal of Arid Environment* (56 papers). As the most productive journal, *Journal of Arid Land* has exhibited the fastest increase since its establishment in 2009 (**Figure 7**). Meanwhile, *Chinese Science Bulletin*, as a classical journal in this research field, showed almost no increase after changed the

journal title changed to *Science Bulletin* in 2015. Overall, the publications in these marked journals displayed a similarly dramatic increasing trend with the annual outputs showed in **Figure 3**.

The top three journals with the highest citations were *Journal of Geophysical Research*: *Atmospheres*, *Journal of Arid Environments*, and *Palaeogeography Palaeoclimatology Palaeoecology*. Although *Journal of Arid Land* had the largest number of publications, it did not have the highest number of citations. The most likely reason is that papers in *Journal of Arid Land* were mainly published only recently (after 2009), and it takes time for newly published papers to be cited. In summary, the scope of the most productive journals covering desert research on China are about earth science in arid land, involving environmental and ecological management, land degradation and restoration process, ecosystem health and sustainable development, and environmental change.

Dominant Institutions and Competitive Authors

All of the outputs were distributed in 43 countries, and most studies were conducted by Chinese authors (2,198 outputs; 84.6%) (**Table 3**). The other four most productive countries were Japan (4.73%), the United States (3.19%), Germany (1.39%) and the United Kingdom (1.00%). As the deserts are located in China, it's not uncommon that the international cooperation rate for Chinese authors was relatively low (ICR = 0.263; **Table 3**), ranking ninth among the top 10 most productive countries. Despite Chinese authors accounted for the most of outputs, the average number of citations per output for Chinese authors was low (18.02), ranking only eighth among the top 10 countries with the highest number of citations (**Table 4**). The average number of citations to a certain extent could represent the overall research quality and the global influence for a specific field (Mu et al., 2016; Zhang and Chen, 2020). Hence, these results highlight that Chinese researchers should improve the average number of citations of their outputs to expand their global influence.

According to our analysis, 1,653 institutions worldwide have engaged in research on Chinese deserts, and the top 20 most productive institutions contributed 2,595 papers (including

TABLE 6 | The 10 most productive authors and the 10 most highly cited authors for research on China's deserts.

Author	Institution	Outputs	Author	Institution	Citations
Li X R	NIEER	102	Li X R	NIEER	1,578
Zhao X Y	NIEER	90	Wang X P	NIEER	769
Zhang Y M	XIEG	61	Yang X P	ZJU	758
Dong Z B	S N U	57	Sun J M	IGG	731
Zhao H L	NIEER	54	Zhao H L	NIEER	689
Zhang Y Q	BFU	52	Liu L C	NIEER	543
Wang X P	NIEER	51	Zhao X Y	NIEER	529
Li Y	XIEG	46	Lu H Y	NJU	511
Zhang T H	NIEER	46	Zhang T H	NIEER	509
Liu L C	NIEER	42	Dong Z B	SNU	486

Note: NIEER: Northwest Institute of Eco-Environment and Resources, CAS; XIEG: Xinjiang Institute of Ecology and Geography, CAS; SNU: Shanxi Normal University; BFU: Beijing Forestry University; ZJU: Zhejiang University; IGG: Institute of Geology and Geophysics, CAS; NJU: Nanjing University.

collaborative publications). The Chinese Academy of Sciences (CAS) accounted for the largest number of papers (1,477 papers; 56.8%) (**Table 5**). Specifically, Northwest Institute of Eco-Environment and Resources (NIEER, CAS), University of Chinese Academy of Sciences (UCAS), Lanzhou University, and Xinjiang Institute of Ecology Geography (XIEG, CAS) had significantly more publications than other institutions. Most of the dominant institutions were located in the Northwestern region of China.

The analysis of authors revealed the researchers who had more outputs and made important contributions. There were 5,373 authors in total, of whom 3,283 (61.1%) had published only one paper. The 10 most productive authors were all from China and contributed a total of 601 papers (23.1%) (**Table 6**). Li X R, Zhao X Y, and Zhang Y M were the top three most productive authors, and Li X R, Wang X P, and Yang X P were the authors with the highest number of citations. Therefore, Li X R was the author with both the highest number of publications and citations. In

addition, we found that the 10 most highly cited papers in this research work were all published before 2010 (**Table 7**). The citation numbers is usually an important indicator to evaluate the quality of publications (Zhang and Chen, 2020). However, the continuous increase of annul publications in the recent 10 years has resulted in the decline of citations per publication even for the high-quality papers. Therefore, we should take a more rational view to recognize and assess the citation numbers of publications today.

CONCLUSION

Using a bibliometric method, our study was the first to analyze the publications of the research done on deserts in China over the past 30 years. It provided a qualitive and quantitative overview of the past work in this field, and highlighted the future prospects. The results showed that the three desert lands that were the most studied were the Tengger Desert, the Taklimakan Desert, and the Horqin Sandy Land. The number of publications produced annually increased exponentially, especially after 2012. This growth coincided with the general trend in science across the world and in China. In addition, we predict that the number of annual publications will continuous to increase in the next several years.

The research areas of the research on deserts in China are multidisciplinary and focused mainly on earth science, including environmental science and ecology, geology, agriculture, physical geography, soil science, and engineering. Frequent keywords analysis showed that the core topics in this research field included "desertification," "water" and "climate." Climate change has become a major focused since 2010. Traditional the research work of deserts in China focused on desertification and sand-stabilization engineering. However, it has crossed the boundaries and started to be combined with

TABLE 7 | The 10 most highly cited publications for research on China's deserts from 1986 to 2020.

Publication information	Citations
Sun J M, Zhang M Y, Liu T S (2001). Spatial and temporal characteristics of dust storms in China and its surrounding regions, 1960–1999: Relations to source area and climate. Journal of Geophysical Research: Atmospheres, 106: 10,325–10,333	143
Pachur H J, Wünnemann B, Zhang H (1995). Lake Evolution in the Tengger Desert, Northwestern China, during the Last 40,000 Years. Quaternary Research, 44 (2): 171–180	96
Li X R, Wang X P, Li T, et al. (2002). Microbiotic soil crust and its effect on vegetation and habitat on artificially stabilized desert dunes in Tengger Desert, North China. Biology and Fertility of Soils, 35 (3): 147–154	93
Zhang X Y, Gong S L, Zhao T L, et al. (2003). Sources of Asian dust and role of climate change versus desertification in Asian dust emission. Geophysical Research Letters, 30 (24): 2,272	90
Zhang H C, Peng J L, Ma Y Z, et al. (2004). Late Quaternary palaeolake levels in Tengger Desert, NW China. Palaeogeography, Palaeoclimatology, Palaeoecology, 211 (1): 45–58	87
Zhao H L, Zhou R L, Su Y Z, et al. (2007). Shrub facilitation of desert land restoration in the Horqin Sand Land of Inner Mongolia. Ecological Engineering, 31 (1): 1–8	84
Chen J, Li G, Yang J, et al. (2007). Nd and Sr isotopic characteristics of Chinese deserts: Implications for the provenances of Asian dust. Geochimica et Cosmochimica Acta, 71 (15): 3,904–3,914	84
Sun J M (2002). Provenance of loess material and formation of loess deposits on the Chinese Loess Plateau. Earth and Planetary Science Letters, 203 (3): 845–859	81
Su Y Z, Zhao H l. (2003). Soil properties and plant species in an age sequence of Caragana microphylla plantations in the Horqin Sandy Land, north China. Ecological Engineering, 20 (3): 223–235	81
Uno I, Eguchi K, Yumimoto K, et al. (2009). Asian dust transported one full circuit around the globe. Nature Geoscience, 2 (8): 557–560	80

climate change in the past 10 years. It showed that the current main task of the desert research in China is changing to alleviate anthropogenic disturbances and promoting sustainable development.

The three most productive journals were *Journal of Arid Land*, *Chinese Science Bulletin*, and *Catena*. Although its establishment was late, *Journal of Arid Land* has exhibited the fastest increase in the past 10 years and becomes the most productive journals. Northwest Institute of Eco-Environment and Resources (NIEER, CAS), University of Chinese Academy of Sciences (UCAS), Lanzhou University, and Xinjiang Institute of Ecology Geography (XIEG, CAS) contributed larger number of publications than other institutions. Most of these dominant institutions were located in the Northwest region of China. Li X R, Zhao X Y, and Zhang Y M were the three most productive authors, and Li X R, Wang X P, and Yang X P were the authors with the highest number of citations. Although contributed to the most papers (84.6%), the average citations for Chinese authors was relatively low.

As our analysis was based on the SCI-E database in Web of Science, some outputs published in Chinese are not included. Although additional publications in other databases could be supplemented, it could cause a bias regarding other languages. In conclusion, this research provided a new view for the elucidation of the evolution of the research on deserts in China, and developed insights for future work in this filed.

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DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article; further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

Conceptualization, Y-SJ and X-MH; methodology, Y-FS; formal analysis, Y-FS, S-HS, Y-SJ, and X-MH; data curation, Y-FS; writing-original draft preparation, Y-FS and X-MH; writing-review and editing, Y-FS, F-FH, S-HS,Y-SJ, and X-MH; visualization, Y-FS. All authors have read and agreed to the published version of the manuscript.

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