



## Article

# Dryland Ecological Restoration Research Dynamics: A Bibliometric Analysis Based on Web of Science Data

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**Abstract:** Previous research on ecological restoration mainly includes three fields: water ecology, soil ecology, and atmospheric ecology, and the most abundant is in the field of soil ecology, among which the most abundant is in dryland ecological restoration. Research on dryland ecological restoration is very important in ensuring national food security, ecological security, and preventing a return to poverty. However, the previous research results do not clearly present the interconnection between the huge number of existing dryland ecological restoration studies and do not provide a three-dimensional understanding of the whole picture of dryland ecological restoration research from a broader perspective. Research on dryland ecological restoration has received wide attention from scholars at home and abroad, revealing the international research trends in the current field, which will provide a reference for the theory and practice of future dryland ecological restoration research. Using the SCI-E and SSCI databases of the “Web of Science Core Collection” as sample data sources and using CiteSpace optical measurement software, the 2254 literature in the field of international dryland ecological restoration research were systematically analyzed to track the situation and impact of research in this field by countries around the world, scientific research institutions and significant authors, and to analyze the interdisciplinary and research hotspots in this field, which is of great significance for the follow-up research of dryland ecological restoration. The research results show that: (1) The number of publications in international dryland ecological restoration has increased significantly with years and has strong development potential. (2) Journals representing the research frontier have an intense concentration with various journals. (3) The study of dryland ecological restoration belongs to a highly interdisciplinary discipline, while the two disciplines of ecology and environmental science are the pivot nodes of multidisciplinary disciplines. (4) China’s posts and total citations are among the best, but the average citation is low. (5) Dryland ecological restoration and protection is a hot research field at present, and special attention is paid to the dynamic changes and key driving factors of dryland ecological restoration and the full use of machine learning and extensive data mining to solve complex social-ecological problems. The study recommends that related disciplines must strengthen cooperation in the field of dryland ecological restoration, especially the two disciplines of ecology and environmental science, in order to promote the progress of dryland ecological restoration research theory and practice. China should continue to strengthen the investment of scientific research forces to improve the international influence of research in the field of dryland ecological restoration.



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**Keywords:** ecological restoration; drylands; land degradation; land degradation neutrality; biodiversity; desertification

## 1. Introduction

With the continuous development of the global economy and the constant increase of the population, the ecological environment is facing tremendous pressure [1,2]. Especially

with the continuous advancement of industrialization, water pollution, air pollution, soil pollution, and other kinds of ecological and environmental pollution events are occurring at a high incidence, which seriously affects and hinders the survival and development of human beings. In addition to the transformation of economic growth, ecological restoration has also been put on an influential agenda. The problem of environmental restoration was first proposed by British scholars in the 1980s [3], mainly referring to the use of appropriate interventions or means to restore the damaged ecological environment and restore the original characteristics and functions of the ecological environment, as far as possible to alleviate the trend of environmental environment deterioration [4], belongs to the category of applied environmental disciplines; other countries and scholars have followed up, and after decades of development, international ecological restoration research has accumulated fruitful results.

Previous research on ecological restoration has been summarized into three main environmental fields: First, research in the field of water ecology. Water resources are among the most critical resources for human production and life. Therefore, the restoration of water resources is a vital component of ecological restoration, as Wang and Shangguan [5] believe that water resources are the foundation of human development and civilization. How to rectify the deteriorating environmental environment, prevent soil erosion, and repair and rebuild damaged ecosystems has become the key to the construction of ecological civilization. Zhao et al. [6] propose an optimization framework for sponge city construction, advocate ecological and hydrological restoration in theory, focus on integrating ecological and hydrological approaches to improve the urban hydrological spatial system in terms of technical methods, and take environmental restoration as an essential construction method to enhance the resilience of cities to disasters. Wang and Huang [7] explore the development process of foreign river ecological restoration concepts and engineering technologies, expound the current situation and practice of river environmental restoration in China, and propose conducting research on river environmental restoration based on river characteristics, environmental processes, and river basins. Mao et al. [8] pointed out that the ecological restoration of complex microbiota has become a commonly used sewage treatment technology in enterprises.

Second, research in the field of soil ecology. Soil is the essential natural resource on which humans depend, and soil pollution caused by mineral exploitation and indiscriminate logging of vegetation must be remedied. Several studies on heavy metal contaminated soil's environmental remediation and organically polluted soil are summarized, such as Zhou et al. [9]. It is noted that the environmental remediation of contaminated soil is still in the primary stage. Still, it can be expected that the environmental remediation of polluted soil will become the key to resolve the problem of soil pollution. Yang et al. [10] believe that although this "marginal effect" of the quicksand treatment plot is challenging to eliminate fundamentally, it can be weakened by expanding the area of the treatment plot because it can reduce the area ratio of the edge of the treatment plot to the core part, ensuring that a more significant proportion of the core part can quickly restore the sandy vegetation. Wu et al. [11] suggested that mushroom residue can be invoked as a modifier for manganese slag, which can significantly improve the properties of slag and promote plant growth and repair.

Third, research in the field of atmospheric ecology. Frequent smog around the world is the most prominent example of atmospheric and ecological pollution related to human survival and health, for which many scholars have explored the environmental restoration of the atmosphere, such as Feng [12] in the Yangtze River Delta region "coal to electricity transmission" effect evaluation, and the atmospheric and ecological restoration have been explored. The results show that the larger the tax, the more pronounced the environmental governance effect, but the Yangtze River Delta region will relatively reduce the corresponding economic indicators. Lu et al. [13], pointing out that air pollution is one of the environmental crises facing humanity, proposed that urban greening plants can be selected according to their ability to repair air pollution, which is a meaningful way and means

to reduce air pollution. He et al. [14] proposed that atmospheric remediation techniques such as “phytoremediation as the mainstay, spray repair, catalytic decomposition repair, and microbial decomposition repair as a supplement” can be used to purify atmospheric pollutants. Overall, there are more and more research results in the field of soil ecology, among which the most research results are in dryland ecological restoration. In addition, it can be seen from the research in the three ecological fields that the research on ecological restoration involves multidisciplinary intersections such as environmental science, ecology, soil science, geology, and water resources science.

From the limited previous literature review on the ecological restoration of drylands, it is clear that drylands generally refer to arable land without irrigation facilities and relying mainly on natural precipitation to grow dry crops, including arable land without irrigation facilities and relying only on flood diversion and silt irrigation. Research on ecological restoration of drylands is very important in ensuring national food security, ecological security, and preventing a return to poverty. However, previous research results do not clearly present the interconnections among the huge number of existing dryland ecological restoration studies and do not provide a three-dimensional understanding of the whole picture of dryland ecological restoration research from a broader perspective. As an essential quantitative analysis method of literature, CiteSpace can effectively describe the overall development of a discipline or research field [15–17] and has been widely used to measure the performance of various research fields. At the same time, the knowledge graph can combine information visualization technology with traditional bibliometric analysis to generate different types of knowledge graphs through data mining, information processing, scientific measurement, graph drawing, etc., and display more intuitive information for researchers [18–20]. Therefore, this study explores the current status of international research on dryland ecological restoration based on the Web of Science database using CiteSpace software, and traces the frontiers of research in this field. Specifically, we tracked the research trends and impacts in the field of dryland ecological restoration by countries, research institutions, and major authors around the world and analyzed the interdisciplinary intersections and research hotspots in this field, which is of great importance for the subsequent research on dryland ecological restoration.

## 2. Materials and Methods

### 2.1. Data Sources

This paper used the “Web of Science Core Collection” as the literature retrieval platform and selects the Science Citation Index Expanded (SCI-E) and Social Science Citation Index (SSCI) databases, and the search period was 2009–2021. Considering the concentration and accuracy of the literature, the search strategy was set to TI = (“ecological restoration” or “drylands” or “land degradation” or “land degradation neutrality”) AND language: (English) AND document type: (Article).

The title in document retrieval is the title of the retrieval article, and the theme is to retrieve the article by retrieving the theme of each article. In the retrieval process, in order to simplify, most of the documents are retrieved by the method of theme or keyword. If you know the full name of the document, you can quickly and accurately retrieve the document by way of its title, which can avoid retrieving a large number of miscellaneous and useless articles and finally determine the sample size of 2254 documents. The retrieved file record download was saved as a plain text file in the format “Full Record and Cited References” as a sample of the data analyzed in this article.

### 2.2. Methods

CiteSpace software is one of the most effective analytical tools in bibliometric analysis [21,22] and is a Java application for literature analysis visualization developed by Chen Chaomei, a Chinese scholar at Drexel University in the United States [23]. This article uses version 5.8 R3.

CiteSpace software's collaborative network analysis, co-existential network analysis, and other statistical analysis capabilities can help scholars objectively understand the current status of the target research field in terms of time, research institutions and members, research keywords, and highly cited literature [24,25]. To meet the requirements of using these functions, this article set the software parameters as follows:

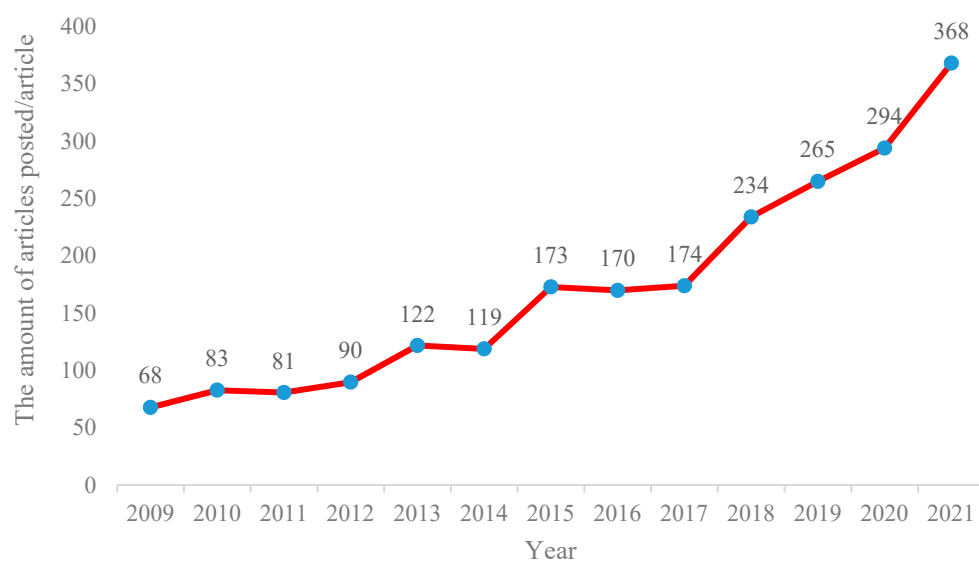
- (1) Time slicing was 2009–2021, and the year of each slice (Years Per Slice) = 1.
- (2) Node types select Study Honor, Institution, Country, Keyword, Category, Reference, Cited Author, and Cited Journal, respectively.
- (3) On Selection Criteria, set to default.
- (4) On the trim settings, "Pathfinder" and "Pruning sliced networks" were selected for most of this article, and only "Pruning the merged network" was set for keyword co-occurrence analysis. The others continued to be the default settings.

### 3. Results and Analysis

#### 3.1. Analysis of the Basic Characteristics of Literature

##### 3.1.1. Amount of Text

Changes in the volume of literature published are an essential indicator of research in a particular field [26,27] in the time range 2009–2021 (statistics as of 20 January 2022, cannot represent the entire year of data, so the 13 articles published in 2022 were deleted). The number of publications in the field of international dryland ecological restoration (Figure 1) has increased, showing that this field has received widespread attention from scholars and has strong development potential.



**Figure 1.** Statistics on the number of publications in the field of ecological restoration of international drylands from 2009 to 2021.

As shown in Figure 1, there have been three breakthroughs in the number of articles in the field of dryland ecological restoration in 2009–2021. The first time was in 2013, when the number of articles published exceeded 100 for the first time. Previously, the number of articles published was prolonged, and after 2009, it began to grow steadily, and the research results gradually increased. The second time was in 2018 when the number of articles published exceeded 200 for the first time, and since then, the number of articles published has proliferated, until the third time, in 2021, when the number of articles published that year exceeded 300 for the first time, and it is expected that the number of articles published will continue to grow after that. An average of 172 papers were published annually between 2009 and 2021.

### 3.1.2. Main Source Journals

By analyzing the international research on dryland ecological restoration, a total of the top 10 journals with citation frequency and intermediary centrality (Table 1), it can be found that these journals have the characteristics of a broad research field and a high concentration of articles.

**Table 1.** Mainly co-cited journals.

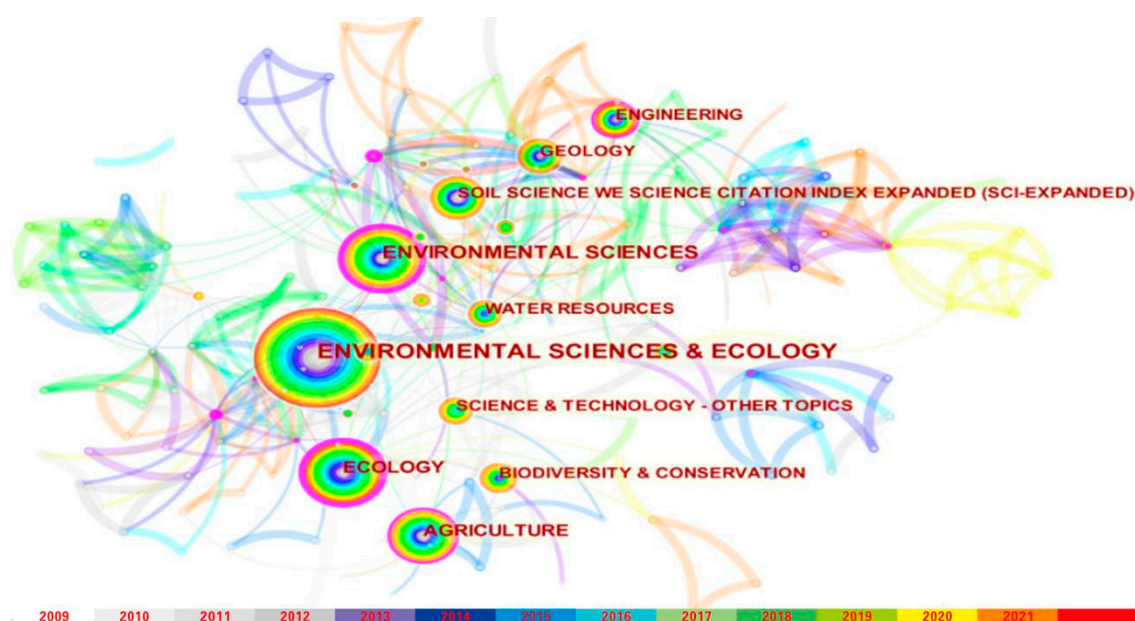
A Total of Cited Journals	Citations/Times	A Total of Cited Journals	Intermediary Centrality	Citations/Times
Science	971	Science of The Total Environment	0.05	6897
Nature	682	Environmental Science & Policy	0.05	4527
Journal of Arid Environments	634	Climatic Change	0.05	5627
Restoration Ecology	620	SCIENCE	0.04	26,194
Proceedings of The National Academy of Sciences of The United States of America	608	Land Use Policy	0.04	6386
Land Degradation & Development	589	Landscape Ecology	0.04	5717
Science of The Total Environment	530	Applied Geography	0.04	3705
Journal of Applied Ecology	488	Soil & Tillage Research	0.04	3951
Ecological Applications	482	New Phytologist	0.04	3532
ECOLOGY	464	World Development	0.04	2389

From Table 1, it can be found that the top three journals with a total of cited frequencies are Science, Nature, and Journal of Arid Environments, and the three journals lead the international frontier of dryland ecological restoration research. The top three journals with high mediation centers are Science of the Total Environment, Environmental Science & Policy, and Climatic Change. The most robust mediation centre is 0.05, indicating that related research in dryland ecological restoration is generally published in these three journals. At the same time, it shows that there is not a complete correspondence between journals with a high volume of publication and high citation.

### 3.2. Interdisciplinary Analysis

In the process of knowledge development in the past few decades, emerging fields and technologies have all involved and promoted the deconstruction and reconstruction of the structural relationships of related disciplines, thus making interdisciplinary research generally regarded as a path of scientific and technological innovation [28]. To explore the interdisciplinary state in the field of dryland ecological restoration, the study builds a multidisciplinary network based on the Web of Science database with the help of the multidisciplinary co-occurrence analysis map (Figure 2).

It can be found from Figure 2 that the disciplines involved in the study of dryland ecological restoration mainly include environmental science and ecology, environmental science and ecology, agriculture, soil science, geology, engineering, water resources, biodiversity and conservation, and science and technology, and are highly cross-cutting. Among them, environmental science and ecology, environmental science, and ecology have many publications. From the perspective of centrality, the centrality of ecology is the highest at 0.29, and the centrality of ecological science is 0.23, indicating that these two disciplines have the most in the field of dryland environmental restoration research, and the connection with other disciplines is relatively close, which is the hub node of multidisciplinary domains.



**Figure 2.** Co-occurrence map of disciplines in the WOS database.

### 3.3. Analysis of Major Research Countries, Scientific Research Institutions, and Authors

#### 3.3.1. The Main Research Countries

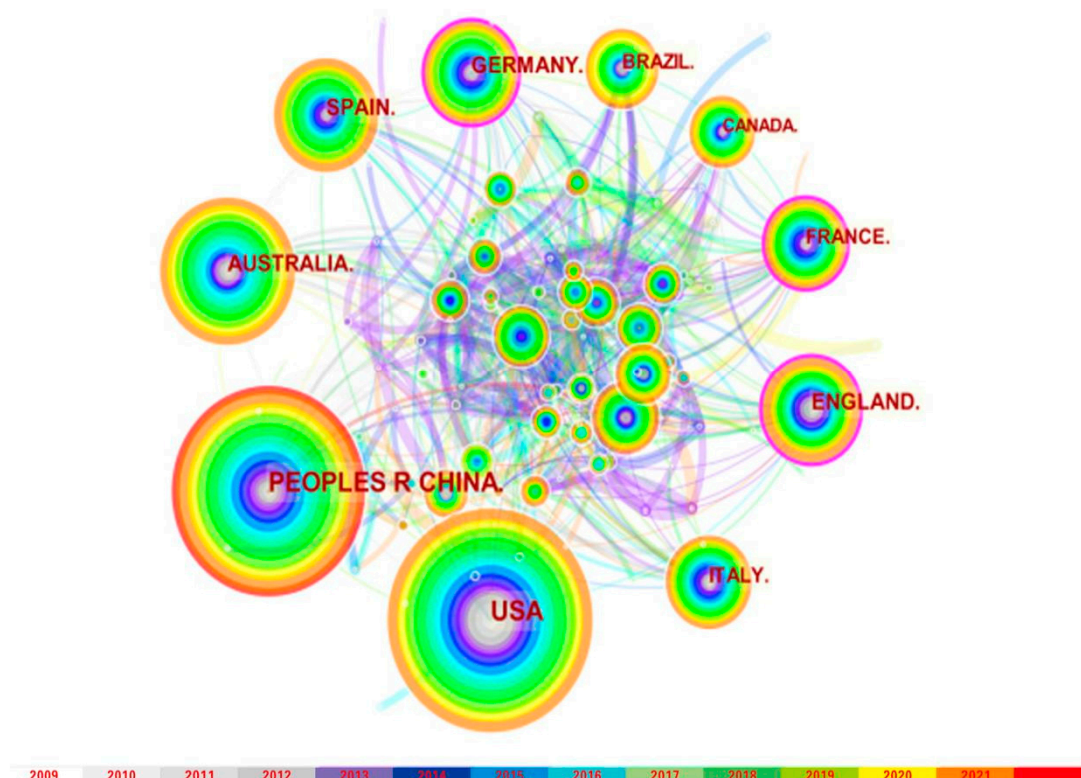
The number of articles, total citations, and average citations of the top 10 countries in the field of dryland ecological restoration research in the international community are shown in Table 2.

**Table 2.** The top 10 countries in dryland ecological restoration research.

Countries	Number of Published Papers/Article	Total Citations/Time	Average Citations/Time
China	583	12,554	21.53
America	517	15,336	29.66
Australia	208	7525	36.18
Germany	181	4910	27.13
Spain	180	7079	39.33
United Kingdom	169	5949	35.20
Italy	123	3227	26.24
France	123	2929	23.81
Brazil	109	3243	29.75
Canada	87	3906	44.90

From Table 2, it can be seen that in terms of the number of articles published, the number of articles published in the top nine countries exceeded 100. China's number of articles published was 583, ranking first. The United States published 517 papers and ranks second only to China. The top three countries are the United States, China, and Spain in terms of total citation indicators. Canada had the highest average citations of 44.90 of the top 10 countries, followed by Spain (39.33) and Australia (36.18). It can also be seen that although China has the most significant number of posts among the 10 countries, the average number of citations is the lowest (21.53 times).

The study also used the Collaborative Network Atlas to continue exploring the situation of dryland ecological remediation research volumes in countries, as shown in Figure 3.



**Figure 3.** Collaborative network map of the nation in dryland ecological restoration research.

The outer ring colour of the node formed in Figure 3 represents the number of posts published as of 20 January 2022 (the same below), which is consistent with the results of Table 2. That is, the dryland ecological restoration research is mainly based in 10 countries; China, the United States, Australia, Germany, Spain, the United Kingdom, Italy, France, Brazil, and Canada. European countries have studied the field a lot, with 5 out of the top 10 countries having studied it: Germany, Spain, the United Kingdom, Italy, and France.

### 3.3.2. The Main Scientific Research Institutions

The number of articles published, total citations, and average citations of the top 10 scientific research institutions in the field of dryland ecological restoration research in the world are shown in Table 3.

**Table 3.** The top 10 dryland research institutes in terms of ecological restoration.

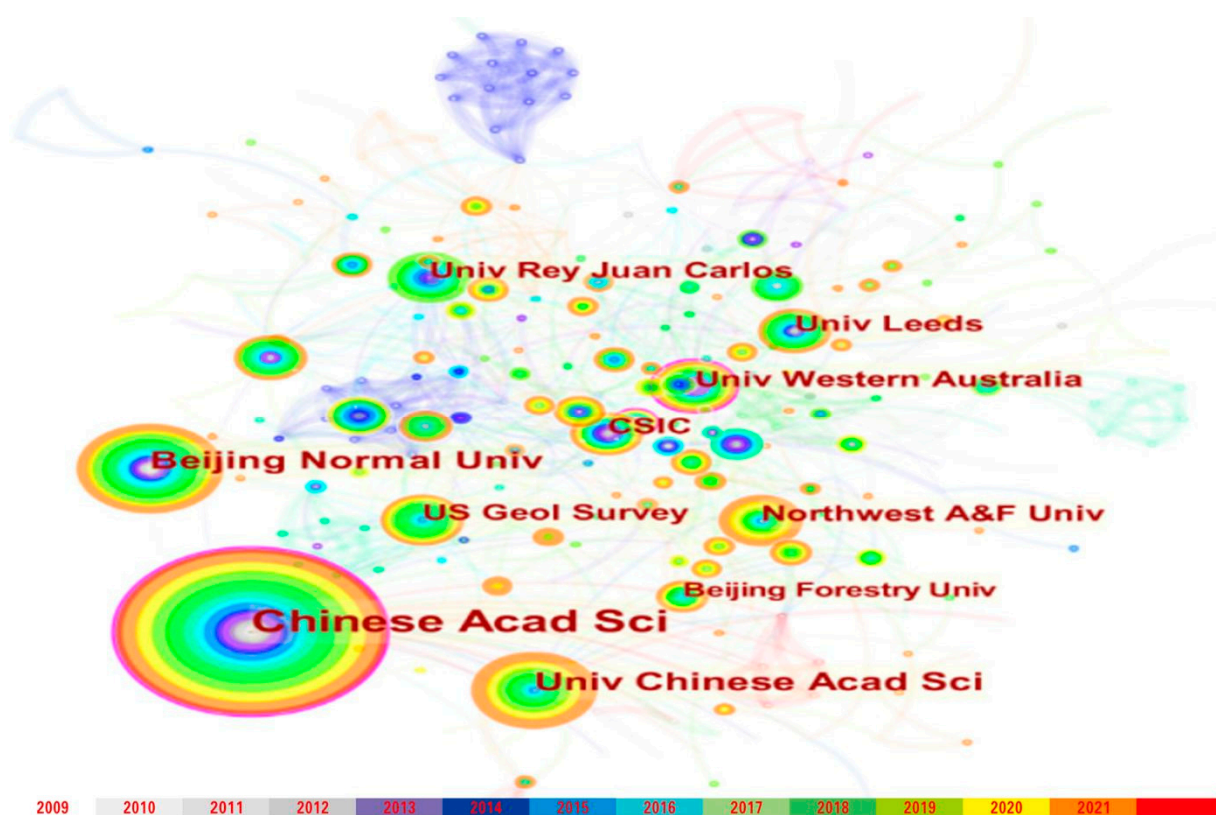
Scientific Research Institutions	Countries	Number of Published Papers/Article	Total Cited Quantity/Time	Average Cited Quantity/Time
Chinese academic of science	China	217	5074	23.38
Univ Chinese Acad Sci	China	89	1487	16.71
Beijing Normal Univ	China	73	1988	27.23
Univ Western Australia	Australia	39	1143	29.31
Univ Leeds	United Kingdom	38	1260	33.16
US Geol Survey	United States	37	935	25.27
Univ Rey Juan Carlos	Spain	37	2799	75.65
Northwest A&F Univ	China	37	837	22.62
CSIC	Spain	36	1726	47.94
Beijing Forestry Univ	China	31	539	17.39

From Table 3, it can be found that the average number of articles published by the top 10 scientific research institutions in the world is 63.4, but there are only three scientific research institutions that exceed the average number of articles. They are all in China,

namely the Chinese Academy of Sciences, the University of Chinese Academy of Sciences, and Beijing Normal University. Regarding the number of articles published, the Chinese Academy of Sciences ranked first with 217 articles. Also publishing more than 50 articles are the University of the Chinese Academy of Sciences and Beijing Normal University. The top three scientific research institutions are the Chinese Academy of Sciences, Rey Juan Carlos University, and Beijing Normal University in terms of the total citation index. In terms of average citations, among the top 10 scientific research institutions, the Spanish Rey Juan Carlos University has the highest average of 75.65 times, followed by the Spanish Council of Higher Research with 47.94 times, and the third place is the University of Leeds in the United Kingdom (33.16 times).

Whether it is the number of articles published, the total number of citations, or the average citation, China's scientific research institutions are in the top few, and the scientific research potential is excellent. At the same time, it should be emphasized that although the number of articles published by the University of Rey Juan Carlos in Spain is only 37, the total number of citations has reached 2799 times (second only to the Chinese Academy of Sciences), with an average of 75.65 citations, ranking first among 10 scientific research institutions. The Spanish Council of Higher Scientific Research, also from Spain, has only 36 articles with 1726 citations. Still, the average number of sources is as high as 47.94 times, second only to the Rey Juan Carlos University, ranking second among the top 10 scientific research institutions, showing Spain's extensive influence in dryland ecological restoration research.

The study also used collaborative network atlases to continue exploring the extent of dryland ecological restoration research loads in various research institutions, as shown in Figure 4.



**Figure 4.** Collaborative network map of scientific research institutions in dryland ecological restoration research.

It can be found from Figure 4 that among the research institutions for dryland ecological restoration, universities are the mainstay, and the proportion is relatively high.

Among them, 7 of the top 10 scientific research institutions in terms of article volume are universities: the Chinese Academic of Science, University Chinese Academic Science, Beijing Normal University, University Western Australia, University Leeds, US Geological Survey, University Rey Juan Carlos, Northwest A&F University, CSIC, and Beijing Forestry University.

### 3.3.3. Main Author

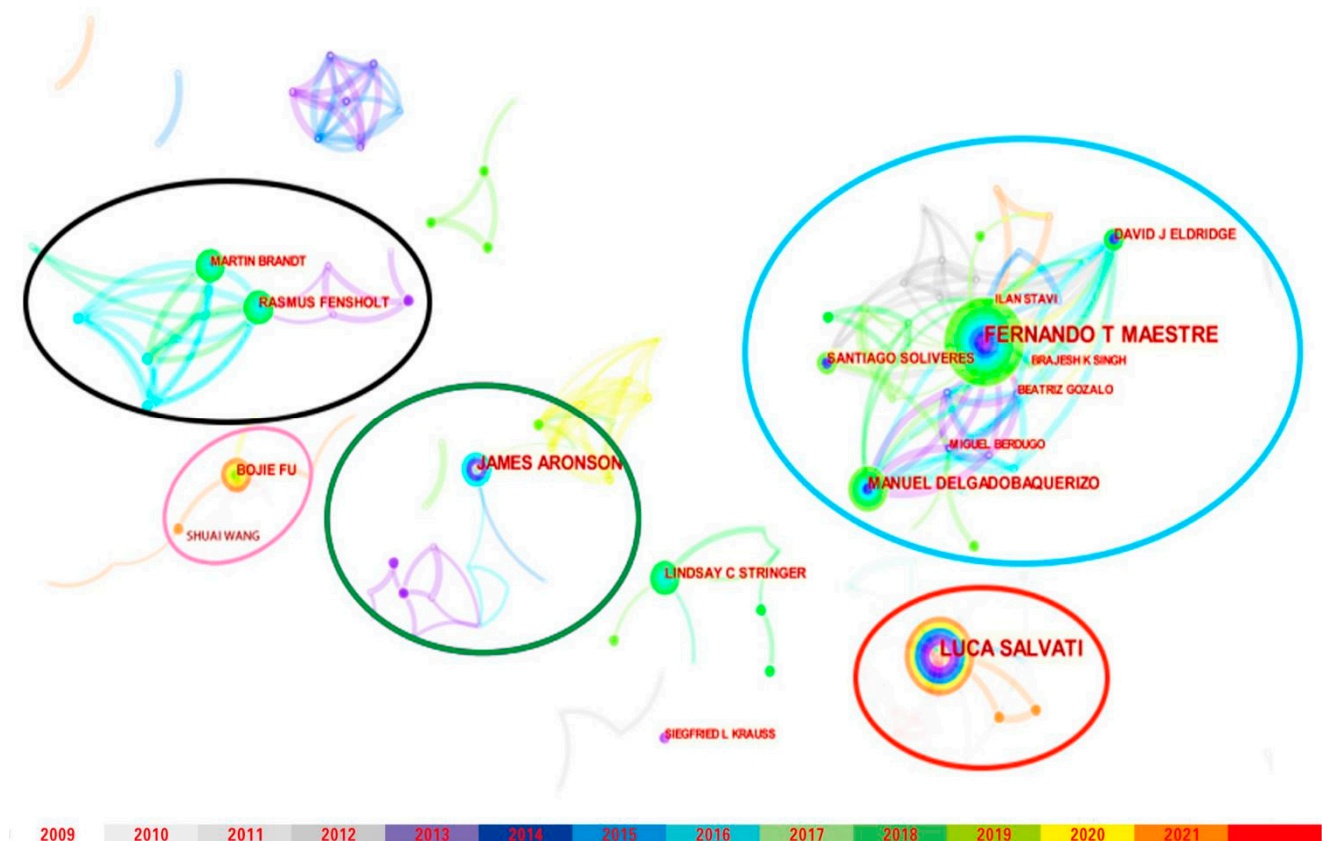
The characteristics of the 10 major authors and their teams in the field of international research on ecological remediation in drylands are shown in Table 4 and Figure 5.

**Table 4.** The top 10 authors in dryland ecological restoration research.

Author	Number of Published Papers/Article	Author's Institution	Countries
Fernando T. Maestre	39	Universidad Rey Juan Carlos	Spain
Luca Salvati	35	Agricultural Research Council—Research Centre for Plant-Soil System	Italy
James Aronson	21	Centre d'Ecologie Fonctionnelle et Evolutive	France
Manuel Delgado-Baquerizo	15	Hawkesbury Institute for the Environment	Australia
David J. Eldridge	12	Centre for Ecosystem Science, School of Biological, Earth and Environmental Sciences, University of New South Wales	Australia
Lindsay C. Stringer	11	Sustainability Research Institute, School of Earth and Environment, University of Leeds,	UK
Rasmus Fensholt	11	Department of Geosciences and Natural Resource Management, University of Copenhagen	Denmark
BOJIE FU	11	State Key Laboratory of Urban and Region Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Science, University of Chinese Academy of Science, Joint Center for Global Change Studies	China
Santiago Soliveres	11	Área de Biodiversidad y Conservación, Departamento de Biología y Geología, Física y Química Inorgánica y Analítica, Universidad Rey Juan Carlos	Spain
Martin Brandt	9	Department of Geosciences and Natural Resource Management, University of Copenhagen, Copenhagen, Denmark	Denmark

From Table 4, it can be found that as far as the principal authors are concerned, Spain's Fernando T Maestre and Italy's Luca Salvati dominate the rankings, reaching more than 30 articles each, which is more than three times the number of articles published by Martin Brandt from Denmark, in 10th place. The remaining authors are mainly from France, Australia, the United Kingdom, Denmark, and China.

As far as the research team is concerned, the international dryland ecological restoration research has formed five distinct author groups with significant research team effects and more prominent research results. This conclusion can be drawn from a collaborative network diagram (Figure 5) of the dryland ecological remediation study authors.



**Figure 5.** Collaborative network map of authors in dryland ecological restoration research.

Each node in Figure 5 represents an author; the larger the node indicates the greater the number of articles for that author. The connection between nodes indicates the cooperation between authors, and the thicker the link indicates, the closer the affiliation. The author collaboration network in Figure 5 consists of 559 authors and 777 pooled threads, demonstrating the many researchers and extensive collaboration in international dryland ecological remediation research. The collaborators and research areas of the five essential research teams are as follows:

- (1) The research team (blue circled area) with Fernando T. Maestre as the core published many articles, reaching 39 articles. Fernando T. Maestre has a closer connection with authors such as Manuel Delgado-Baquerizo and David J. Eldridge, but according to the colour of the relationship between the nodes, it can be seen that cooperation between the three mainly occurred in 2013, 2016, and 2018. There are also partnerships between Fernando T. Maestre's research team and Santiago Soliveres, but most occurred before 2012. Fernando T. Maestre's research team focuses on drylands and ecosystems' carbon cycles and versatility [29–32].
- (2) The research team (brown circle area) with Luca Salvati as the core published many articles, reaching 35 articles. Luca Salvati's research team focuses on land degradation risks [33–37] and desertification risks [38]. Luca Salvati's research team published five papers in 2015, but no articles were published in 2018 and 2019. In the author's collaborative network map, it can also be found that the outer circle colour of the node formed is orange, indicating that the Luca Salvati research team has been active in the past two years, which is consistent with the actual situation of four articles published in 2021 and two articles in 2022, which shows that the Luca Salvati research team will continue to explore the field of dryland ecological restoration in the future.

- (3) The research team led by James Aronson (green circle area). Although James Aronson's research team published 21 papers, it has not published any papers since 2020. James Aronson's research team focuses on ecological restoration [39–41].
- (4) The Chinese research team (pink circle area) with BOJIE FU as the core published 11 articles. The BOJIE FU research team focuses on ecosystem services [42,43], ecological restoration, and drylands [44,45].
- (5) Rasmus Fensholt and Martin Brandt's research team (black circle area). Although the number of articles published by the research team is not much, there are more connections between nodes formed, the cooperation network is more mature and independent, and the relationship is close. The team's research included long-term dynamic monitoring of dryland biomass [46], land degradation and remediation [47], and carbon storage [48], but found that the team had not published a paper since 2019.

### 3.4. The Literature Cited for Analysis

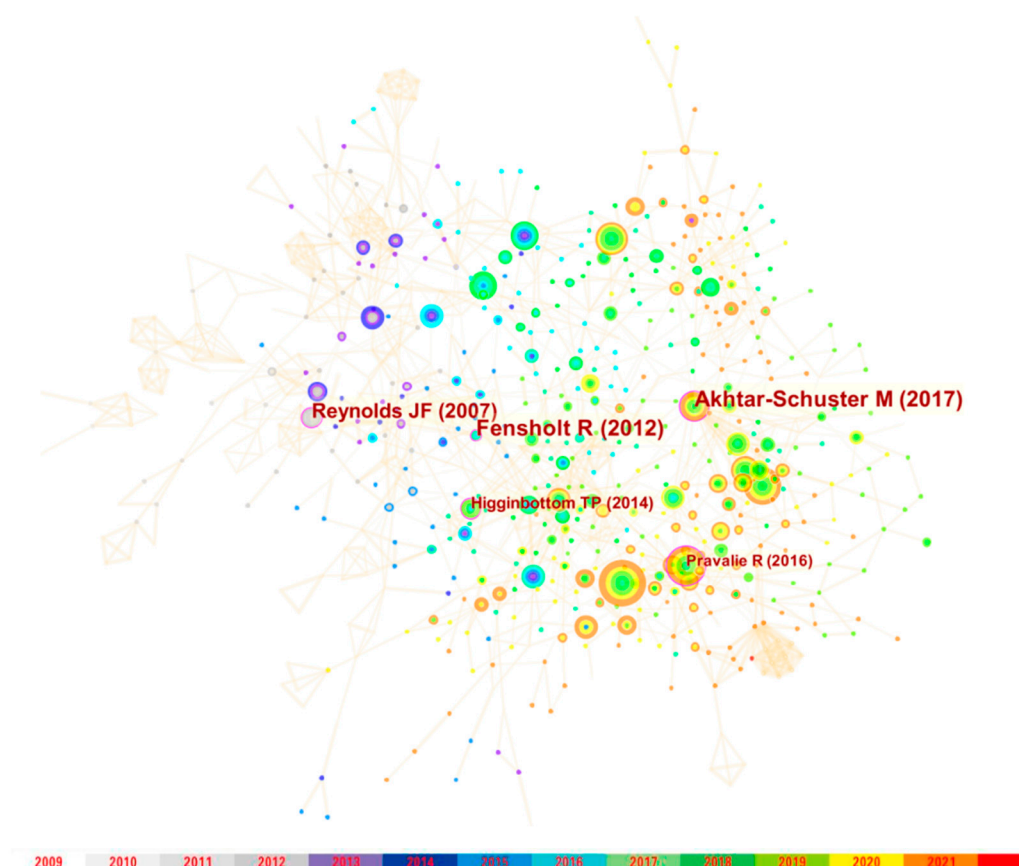
Co-citation refers to the fact that two or more papers are cited by one or more documents simultaneously, which is a research method to measure the degree of relationship between literature. To a certain extent, the number of citations in the literature can reflect the hot spots and trends of research, and the number of literature sources can also reflect the importance of the article. Therefore, the exploration literature has been cited, which is very helpful for exploring the dynamics of dryland ecological restoration research. According to the centrality of the co-cited literature, the top five literatures are shown in Table 5 and Figure 6.

**Table 5.** High-frequency co-cited literature in dryland ecological restoration research.

Total Number of Citations	Centrality	Year	Countries	Literature Title
34	0.16	2017	Germany	Unpacking the Concept of Land Degradation Neutrality and Addressing Its Operation through the Rio Conventions
18	0.15	2007	America	Global Desertification: Building a Science for Dryland Development
11	0.15	2012	Denmark	Greenness in Semi-Arid Areas across the Globe 1981–2007—an Earth Observing Satellite Based Analysis of Trends and Drivers
20	0.12	2014	United Kingdom	Assessing Land Degradation and Desertification Using Vegetation Index Data: Current Frameworks and Future Directions
49	0.11	2016	Romania	Drylands Extent and Environmental Issues. A Global Approach

As shown from Table 5, in a central order, the countries of the top three authors are Germany, the United States, and Denmark. Among them, the most prominent is 0.16, which is from the 2017 German scholar Akhtar-Schuster M's "Unpacking the Concept of Land Degradation Neutrality and Addressing Its Operation through the Rio Conventions", which mainly explores land degradation neutrality, desertification, and sustainable land management.

As can be seen from Figure 6, in the high-frequency co-cited literature in the central order, second only to the article by German Akhtar-Schuster M. is "Global Desertification: Building a Science for Dryland Development" published by Reynolds JF in 2007; the study mainly reviewed the function of dryland ecosystems and explored the problem of desertification. At the same time, a development paradigm for drylands was proposed. The centrality of the remaining three documents is also stronger at 0.15, 0.12, and 0.12, and it can be seen from the title of the literature that "desertification" has been a topic of ongoing concern for scholars for at least 10 years.



**Figure 6.** Map of high-frequency co-cited literature in dryland ecological restoration research [49–53].

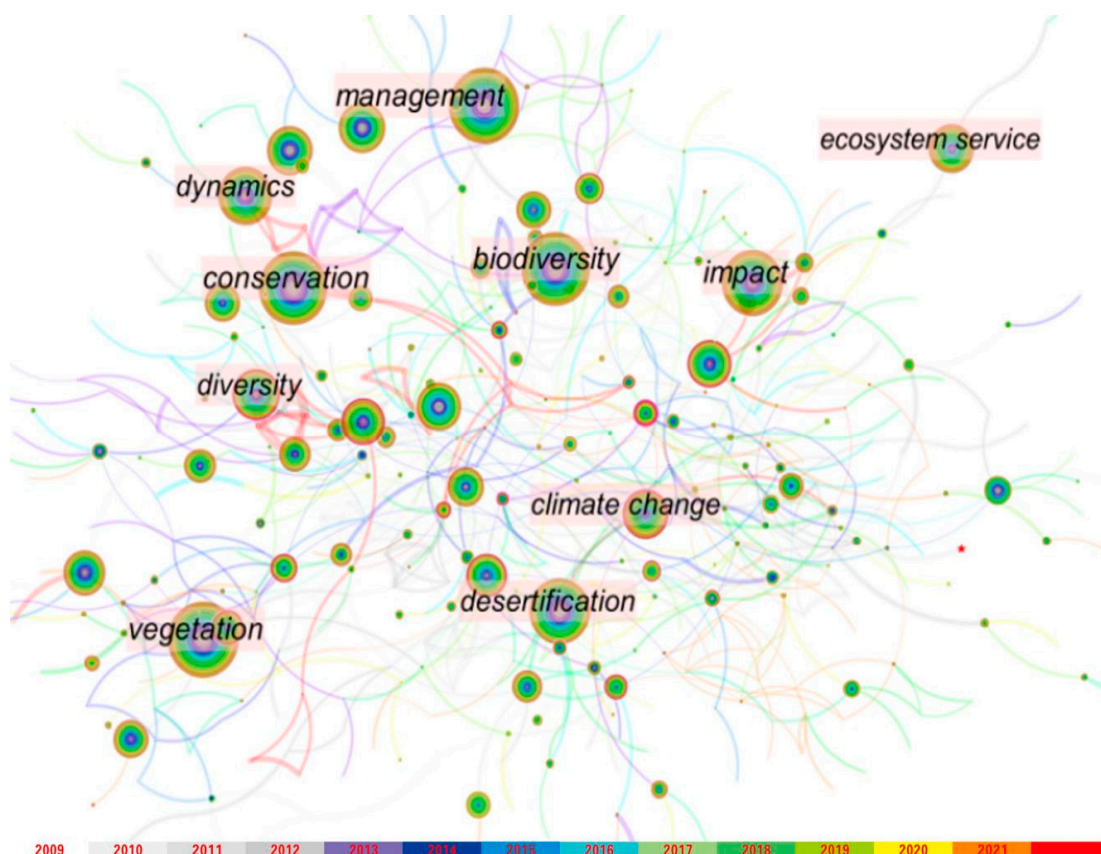
### 3.5. Research Hotspot Analysis

#### 3.5.1. Keywords Are Present

The keywords reflect the author's research direction and scientific research interests [54,55]. Since the leading research content of the article is highly condensed, others can quickly browse the keywords of the article to obtain adequate information such as research objectives, research content, research methods, and views held by the author [56,57]. Therefore, analyzing the frequency of keywords in the literature is the key to discussing the research hotspots in a particular field and their development and changes [58,59].

Using the keyword co-occurrence analysis function of CiteSpace software, the study drew a keyword co-occurrence network map for dryland ecological restoration research and measured the main research hotspots in this field (Figure 7). Through the threshold setting, Figure 7 only showed keywords with a frequency greater than or equal to 148 times. Each node in the graph represents a keyword, and the larger node indicates that the keyword appears more frequently. Similarly, the width of the wire indicates the frequency with which keywords appear together, and the thicker line indicates a higher frequency between two keywords.

From Figure 7, it can be seen that keywords with a frequency greater than or equal to 148 times are ranked in the top 10. Specifically, management (242 times), vegetation (230 times), impact (217 times), conservation (201 times), biodiversity (186 times), climate change (172 times), desertification (167 times), dynamics (165 times), diversity (151 times), and ecosystem service (148 times) have become virtual nodes in the network because of their high frequency.

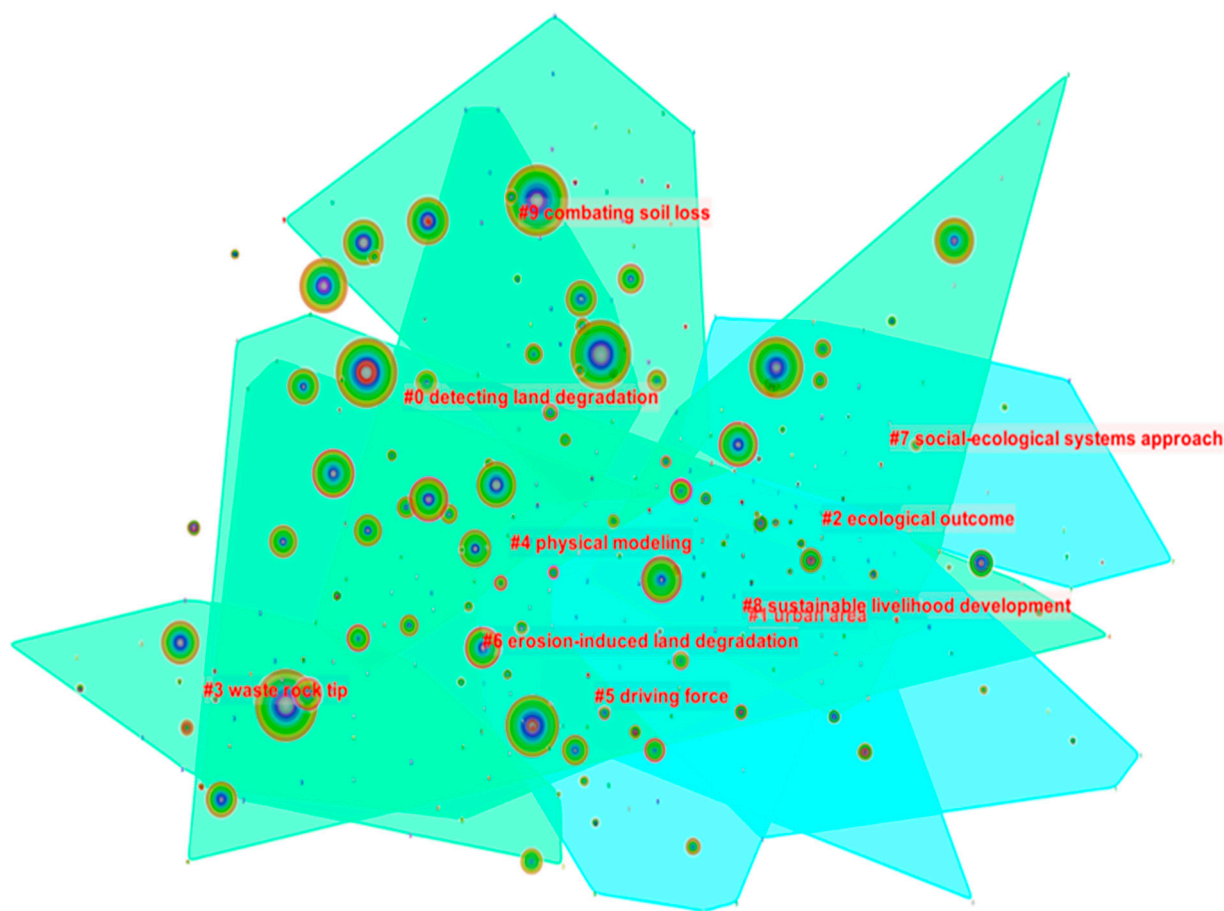


**Figure 7.** A visualization of the keyword co-occurring network in dryland ecological restoration research.

These critical nodes cover several central aspects of international dryland ecological restoration research: first, it can be found that scholars carry out dryland ecological restoration research around the starting point of “how to manage” and “impact” and “protection”; second, the research directions that scholars are mainly concerned about are “biodiversity”, “climate change”, “desertification”, “diversity” and “ecosystem services”; third, the emergence of “dynamics” keywords. This may indicate that scholars are concerned with the dynamic change of dryland ecological restoration or the driving force research that promotes the evolution of dryland environmental restoration.

In order to facilitate the exploration of which keywords are more closely related, the keywords of dryland ecological restoration research are clustered, as shown in Figure 8.

As can be seen from Figure 8, the keywords of dryland ecological restoration research are clustered into 10 categories, namely detecting land degradation, urban area, environmental outcome, waste rock tip, physical modelling, driving force, erosion-induced land degradation, social-ecological systems approach, sustainable livelihood development, and combating soil loss. The order is from 0 to 9. The smaller the number, the more keywords are included in the cluster. Each cluster is composed of multiple closely related keywords; the cluster details are now exported through the report, as shown in Table 6. In this network, it is necessary to pay attention to the average profile value of clustering, which identifies the quality of clustering results. It is generally believed that when the average contour value of clustering is more significant than 0.5, the clustering is reasonable; when the average clustering value is greater than 0.7, the clustering is convincing.



**Figure 8.** Cluster map of key words in dryland ecological restoration research.

**Table 6.** Details the top 10 clusters of dryland ecological restoration research.

Serial Number	Cluster Name	Average Profile Value	Keywords
#0	detecting land degradation	0.907	detecting land degradation; land degradation assessment; human-induced land degradation; NDVI3G soil moisture; using residual trend analysis
#1	urban area	0.917	urban area; spatial relationship; northern shaanxi china; scale mismatches; estuary watershed restoration
#2	ecological outcome	0.892	ecological outcome; biodiversity persistence; human-modified tropical landscape; abiotic factor; vascular plant
#3	waste rock tip	0.928	waste rock tip; organic carbon dynamics; paddy field; northeast china; century model
#4	physical modeling	0.862	physical modeling; freshwater lens formation; wasa-sed model; hyporheic restoration; restoring ecological service
#5	driving force	0.944	driving force; spatial assessment; methane microseepage; ch4 sink; potential land degradation
#6	erosion-induced land degradation	0.826	erosion-induced land degradation; acacia salignas soil legacy; plant species-area relationship; evenness cover; faunal system
#7	social-ecological systems approach	0.832	social-ecological systems approach; socioeconomic processes-chinas experience; puget sound usa; estuary restoration; landscape level

Table 6. Cont.

Serial Number	Cluster Name	Average Profile Value	Keywords
#8	sustainable livelihood development	0.913	sustainable livelihood development; wild food plant; toxoplasma gondii; navigating challenge; using spartina alterniflora
#9	combating soil loss	0.845	combating soil loss; sustainable soil-water relationship; non-linear boundary; re-orienting ecological restoration; interdisciplinary historical vegetation mapping

From Table 6, it can be found that the average contour values of the top 10 clusters in the dryland ecological restoration study are more significant than 0.7, indicating that the clustering results presented are convincing. This also confirms the correctness of the survey to choose dryland environmental restoration as the title of the article, such as #0 clustering: detecting land degradation, which mainly contains the following: detecting land degradation; land degradation assessment; human-induced land degradation; NDVI3G soil moisture; using residual trend analysis. It can be seen that themes related to monitoring and assessment of land degradation, anthropogenic-induced land degradation, normalized vegetation index, and residual trend analysis are all roughly the same, and similarly, the themes under the other nine clustering tags are all roughly the same.

### 3.5.2. Keyword Prominence

CiteSpace provides the function of burst detection, which is mainly used to detect situations where there is a significant change in the number of references in a certain period. Emergent detection is considered an indicator of highly active research fields, which can explore emerging trends and fleeting trends and provide a precise visual analysis of the duration of research hotspots in domestic and foreign academic circles. The higher the intensity of keyword prominence, the more pronounced the research orientation, which is the node that needs to be paid attention to in research. The study used CiteSpace's burst function to plot the intensity of a total of 25 keywords from 2009 to 2022, as shown in Figure 9. Among them, Strength indicates the power of the sudden start, Begin indicates the year of the sudden start, End indicates the year of the premature termination, and the "red part" is the year of the keyword prominence.

From Figure 9, it can be found that, first, during the period 2009–2022, the keyword with the highest intensity of the burst was "conservation". The Strength value reached 6.08. The start of the explosion was in 2012, and the end of the shot was in 2013. Its practical background is that at the end of 2011, the United Nations Environment Programme "Towards a Green Economy" report was published and pointed out that the green economy could significantly reduce environmental risks and ecological scarcity, advocating that human beings should protect existing resources. Thus, resource protection received a new round of attention, but due to the immature technology of land degradation restoration and resource protection at the time, and because humans were unaware of how much harmful impact resource consumption had on the environment, scholars' enthusiasm quickly faded after a year.

Secondly, the keywords "science", "desertification", "population", "river restoration", "governance", "region", and "heavy metal" have attracted much attention, and the intensity of the emergence is greater than 4, but with the continuous refinement and maturity of dryland ecological restoration research, in addition to the "heavy metal" keyword, attention to the remaining keywords has declined.

## Top 25 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2009 - 2022
science	2009	4.77	2009	2016	
desertification	2009	4.34	2009	2011	
gi	2009	3.77	2009	2013	
soil	2009	3.7	2009	2010	
fire	2009	3.52	2010	2016	
population	2009	5.77	2011	2016	
sensitivity	2009	3.75	2011	2014	
poverty	2009	3.63	2011	2014	
africa	2009	3.11	2011	2016	
conservation	2009	6.08	2012	2013	
river restoration	2009	4.53	2013	2016	
infiltration	2009	3.4	2014	2015	
resilience	2009	3.2	2014	2017	
governance	2009	4.34	2015	2016	
adaptation	2009	3.25	2015	2017	
china	2009	3.15	2015	2016	
region	2009	4.51	2016	2017	
perspective	2009	3.61	2016	2018	
ecosystem multifunctionality	2009	3.65	2017	2019	
vegetation restoration	2009	3.95	2019	2020	
rehabilitation	2009	3.63	2019	2020	
tree	2009	3.35	2019	2022	
heavy metal	2009	4.05	2020	2022	
river basin	2009	3.71	2020	2022	
land use change	2009	3.59	2020	2022	

Figure 9. Emergence of keywords in dryland ecological restoration research (2009–2022).

Finally, the keywords “tree”, “heavy metal”, “river basin”, and “land-use change” have maintained a high intensity of prominence and great attention since 2019. In the context of global climate change, forest ecosystems and watershed systems have been entrusted with heavy responsibilities, requiring rich metal treatment and land-use methods to be improved accordingly. As a result, researchers have paid more attention to related research, and the frequency of keywords has increased.

## 4. Discussion

The Institute of Dryland Ecological Restoration involves more disciplines and is more cross-cutting [60,61]. Therefore, it is recommended that related disciplines should strengthen cooperation and communication, especially the two disciplines of ecology and environmental science, which are multidisciplinary pivotal nodes, to promote the progress of dryland ecological restoration research theory and practice. The average number of citations of research results in the field of dryland ecological restoration in China is very low. It is critical to continue investing in research power and expanding international influence. The future research hotspot in the field of dryland ecological restoration is still

how to protect resources, ecology, biodiversity, and reduce the impact of climate change and desertification for the purpose of promoting research on the dynamic changes and key driving factors of dryland ecological restoration.

Regarding the research tool itself, although the CiteSpace software used in this paper has been widely used in bibliometric research, there are still some problems, such as the failure to distinguish between the first author and the corresponding author of the document. The use of machine learning can realize interdisciplinary modelling of dryland ecological restoration, which will provide essential ideas for systematically solving complex social, environmental restoration problems [62,63]. Therefore, in the future, we will consider incorporating methods such as machine learning and extensive data mining into the research in dryland ecological restoration. Of course, the study was based on a bibliometric analysis of objective bibliographic data, and the results were stable and reliable and generally unaffected by empiricism. Therefore, the research conclusions of this paper have specific theoretical value and reference significance for grasping the research dynamics and progress in the field of dryland ecological restoration.

## 5. Conclusions

The study used the SCI-E and SSCI databases of the Web of Science Core Collection as the sample data source, and mapped the knowledge map of international dryland ecological restoration research with the help of CiteSpace visualization software. The basic characteristics of the literature, disciplinary crossover, major research countries, major scientific research institutions, major authors, literature co-citations, and research hotspots were systematically and informatively analyzed.

First, the basic characteristics of the literature: The number of publications in the field of dryland ecological restoration is increasing and has a strong potential for development. The journals *Science*, *Nature*, and *Journal of Arid Environments* lead the frontier of dryland ecological restoration research. Relevant research results are generally published in *Science of the Total Environment*, *Environmental Science & Policy*, and *Climatic Change*. The research on dryland ecological restoration involves more disciplines and is more cross-cutting. Two of the more involved disciplines are ecology and environmental science. The third, the country; China has the largest number of publications, but it is not outstanding in terms of both total citations and average citations. Fourth, scientific institutions; the top three research institutions in terms of number of publications are all in China, except for Beijing Normal University, which has more total citations, but the rest of China does not dominate in terms of total citations or average citations. Fernando T. Maestre (Spain) and Luca Salvati (Italy) have the highest number of publications and the greatest impact. The research on ecological restoration in drylands has initially formed five research teams with significant effects, mainly on drylands, land degradation, desertification, and ecological restoration. Sixth, the total citations of the literature; “Desertification” is a topic that has always been of concern to scholars. The most significant co-citation is the article “Unpacking the concept of land degradation neutrality and addressing its operation through the Rio Conventions” by Akhtar-Schuster M, a German scholar. Seventh, the research hotspots; scholars have focused on the dynamics of dryland restoration and the drivers of its evolution in terms of “how to manage” and “the impacts” and “conservation”. The main research directions are “biodiversity”, “climate change” and “desertification”. The keyword “conservation” appears with the highest intensity, indicating that humans are paying more attention to the conservation of existing resources.

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## References

- Li, X.; Tao, X. The development path of China's green economy based on international environmental and economic relations. *Asia Pac. Econ.* **2011**, *15*, 138–140.
- Zhang, F. Development problems faced by resource-based regions and their solutions. *China Soft Sci.* **2011**, *6*, 1–9.
- Chen, Y. *Research on Environmental Performance Auditing Issues*; Southwestern University of Finance and Economics: Chengdu, China, 2006.
- Sui, Y.; Sun, D.; Li, S.; Xu, Y.; Wu, J. Conservation and restoration of coastal ecosystems in Dongying City under the background of carbon storage changes. *J. Ecol.* **2021**, *41*, 8112–8123.
- Wang, F.; Shangguan, Z. Soil and Water Conservation Ecological Restoration and Ecological Civilization Construction. *China Soil Water Conserv. Sci.* **2013**, *11*, 119–124.
- Zhao, Y.; Cai, T.; Sun, R.; Ni, Z.; Zhang, T. A review of the research progress of sponge cities: From hydrological process to ecological restoration. *J. Ecol.* **2019**, *39*, 4638–4646.
- Wang, W.; Huang, D. Research progress of river ecological restoration at home and abroad. *Water Ecol.* **2012**, *33*, 142–146.
- Mao, S.; Shi, M.; Luo, J. Indicator system and method for sustainability evaluation of sewage treatment technology based on ecological restoration. *J. Cent. South Univ. For. Technol.* **2021**, *41*, 146–157.
- Zhou, Q.; Wei, S.; Diao, C. The basic principle and research progress of ecological restoration of polluted soil. *J. Agric. Environ. Sci.* **2007**, *2*, 419–424.
- Yang, H.; Lu, Q.; Wu, B.; Zhang, J.; Sun, D. Study on ecological restoration effect of desertified land in Gonghe Basin, Qinghai. *China Soil Water Conserv. Sci.* **2006**, *2*, 7–12.
- Wu, J.; Chen, Y.; Du, L.; Ou, Q.; Zhang, Q. Comparison of four modifiers in woody phytoremediation of manganese slag. *J. Cent. South Univ. For. Technol.* **2020**, *40*, 150–159.
- Feng, Z. *“Three West” Region—Yangtze River Delta Region “Coal Transfer to Power Transmission” Effect Evaluation and Atmospheric Ecological Restoration*; Dongbei University of Finance and Economics: Dalian, China, 2018.
- Lu, M.; Li, Y.; Qi, X. Comparison of phytoremediation ability of atmospheric SO<sub>2</sub> pollution. *J. Shandong Inst. Archit. Eng.* **2003**, *4*, 44–46.
- He, J.; Deng, J.; Zeng, C.; Chen, X. Analysis of Atmospheric Restoration Effect Based on Different Seasons. *Guangdong Chem. Ind.* **2020**, *47*, 76–78.
- Xia, R.; Yang, J. Analysis and Prospect of Interdisciplinary Research on Linguistic Distance Based on CiteSpace. *Foreign Lang.* **2021**, *2*, 90–96.
- Luo, K.; Zhang, Y.; Li, Z. An investigation of the changes in the academic field of public health incident research in China: Visual analysis based on CiteSpace knowledge graph (2000–2019). *News Univ.* **2021**, *507*, 22–39.
- Bai, X.; Wang, J. A review of neuroscientific methods in foreign library and information science based on emotional space. *Inf. Sci.* **2021**, *39*, 185–192.
- Li, X. Research status and hotspot mining of metrology scientific research in my country based on knowledge graph. *Metrol. Test. Technol.* **2019**, *46*, 95–98.
- Pei, M. Information visualization analysis of “Human Resource Development in China” based on bibliometrics. *China Bus. Rev.* **2021**, *6*, 168–170.
- Wang, D.; Yang, H.; Tian, Z.; Sun, X.; Zhou, Z.; Zhu, Q.; Guan, Y.; Wang, H. Scientific knowledge map and visualization analysis in the field of objectification of tongue characteristics of traditional Chinese medicine. *World Sci. Technol.-Mod. Tradit. Chin. Med.* **2021**, *23*, 3032–3040.

21. Qiu, S.; Pan, L.; Hou, J. Hotspots and Frontier Evolution of International Preschool Education Research in the 21st Century: Quantitative and Visual Analysis Based on the Five Most Influential Preschool Education Periodicals in SSCI. *Presch. Educ. Res.* **2014**, *6*, 10–20.
22. Qiu, J. Analysis and Application of Knowledge Visualization Based on CiteSpace—A Case Study of International Attendance Behavior. *Inf. Sci.* **2018**, *36*, 139–144.
23. Lei, X. *Research on Adult Learning Psychology under the Background of Learning Society: Retrospect and Prospect*; Zhejiang University of Technology: Hangzhou, China, 2017.
24. Ji, Q.; Huang, W.; Min, Y.; Fu, G. Research hotspots and trends of ecological livability based on bibliometrics. *J. Ecol.* **2019**, *39*, 3392–3399.
25. Han, C.; Wang, J.; Wang, G. Bibliometric analysis of Chinese grass and animal husbandry research based on CiteSpace. *Grass Ind. Sci.* **2021**, *38*, 976–991.
26. Schj, N.P.; Thomsen, I.K.; Berg, J.P.; Jonge, H.D.; Kristensen, K.; Christensen, B.T. Turnover of organic matter in differently textured soils: I. Physical characteristics of structurally disturbed and intact soils. *Geoderma* **1999**, *89*, 177–198.
27. Xiao, H.; Wu, J.; Sun, J. Significance and role of academic journal dose-response index (JMI). *J. Ed.* **2017**, *29*, 340–344.
28. Xu, H.; Yin, C.; Guo, T.; Tan, X.; Fang, S. Review of Interdisciplinary Research. *Libr. Inf. Serv.* **2015**, *59*, 119–127.
29. Maestre, T.; Escolar, D.; Guevara, M.L.; Quero, J.; Lazaro, D.; Ochoa, B.; Gozalo, G. Changes in biocrust cover drive carbon cycle responses to climate change in drylands. *Glob. Chang. Biol* **2013**, *19*, 3835–3847. [[CrossRef](#)] [[PubMed](#)]
30. Fernando, T.; Maestre, J.L.; Quero, N.; Gotelli, A.E.; Victoria, O. Plant Species Richness and Ecosystem Multifunctionality in Global Drylands. *Science* **2012**, *335*, 214–218.
31. Maestre, F.T.; Delgado-Baquerizo, M.; Jeffries, T.C.; Eldridge, D.J.; Singh, B.K. Increasing aridity reduces soil microbial diversity and abundance in global drylands. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 15684–15689. [[CrossRef](#)] [[PubMed](#)]
32. Maestre, F.T.; Solé, R.; Singh, B.K. Microbial biotechnology as a tool to restore degraded drylands. *Microb. Biotechnol.* **2017**, *10*, 1250–1253. [[CrossRef](#)] [[PubMed](#)]
33. Salvati, L.; Zitti, M. Assessing the Impact of Ecological and Economic Factors on Land Degradation Vulnerability through Multiway Analysis. *Ecol. Indic.* **2009**, *9*, 357–363. [[CrossRef](#)]
34. Salvati, L.; Bajocco, S.; Ceccarelli, T.; Zitti, M.; Perini, L. Towards a process-based evaluation of land vulnerability to soil degradation in Italy. *Ecol. Indic.* **2011**, *11*, 1216–1227. [[CrossRef](#)]
35. Salvati, L.; Zitti, M. The Environmental “Risky” Region: Identifying Land Degradation Processes Through Integration of Socio-Economic and Ecological Indicators in a Multivariate Regionalization Model. *Environ. Manag.* **2009**, *44*, 888–898. [[CrossRef](#)] [[PubMed](#)]
36. Luca, S.; Alberto, M.; Sofia, B.; Roberta, G.; Margherita, C. Socioeconomic development and vulnerability to land degradation in Italy. *Reg. Environ. Chang.* **2011**, *11*, 767–777.
37. Salvati, L.; Bajocco, S.; Ceccarelli, T.; Luigi, P. Amplifying (or Reversing) the Territorial Disparities in Land Vulnerability to Soil Degradation: The Case of Italy. *Prof. Geogr.* **2013**, *65*, 647–663. [[CrossRef](#)]
38. Salvati, L.; Mavrikis, A.; Colantoni, A.; Mancino, G.; Ferrara, A. Complex Adaptive Systems, soil degradation and land sensitivity to desertification: A multivariate assessment of Italian agro-forest landscape. *Sci. Total Environ.* **2015**, *521*, 235–245. [[CrossRef](#)]
39. James, A.; Pedro, H.S.; Brancalion, G.D.; Ricardo, R.; Rodrigues, V.L.; Marcelo, T.; José, M.D.; Torean, S.G.; Antnio, C.G.D.M.; Paulo, Y.; et al. What Role Should Government Regulation Play in Ecological Restoration? Ongoing Debate in So Paulo State, Brazil. *Restor. Ecol.* **2011**, *19*, 690–695.
40. Aronson, J. The Ecological Restoration Alliance of Botanic Gardens: A New Initiative Takes Root. *Restor. Ecol.* **2015**, *22*, 713–715. [[CrossRef](#)]
41. Aronson, J.; Alexander, S. Steering Towards Sustainability Requires More Ecological Restoration. *Nat. Conserv. Ao Rev. Bras. Conserv. Ao Nat.* **2013**, *11*, 127–137. [[CrossRef](#)]
42. Luo, Y.; Lu, Y.; Fu, B.; Zhang, Q.; Li, T.; Hu, W.; Comber, A. Half century change of interactions among ecosystem services driven by ecological restoration: Quantification and policy implications at a watershed scale in the Chinese Loess Plateau. *Sci. Total Environ.* **2018**, *651*, 2546–2557. [[CrossRef](#)] [[PubMed](#)]
43. Stefani, D.; Fu, B.; Zhao, W. Evaluating the use of fire to control shrub encroachment in global drylands: A synthesis based on ecosystem service perspective. *Sci. Total Environ.* **2018**, *648*, 285–292.
44. Lü, D.; Gao, G.; Lü, Y.; Xiao, F.; Fu, B. Detailed land use transition quantification matters for smart land management in drylands: An in-depth analysis in Northwest China. *Land Use Policy* **2019**, *90*, 350–356. [[CrossRef](#)]
45. Pan, N.; Wang, S.; Liu, Y.; Li, Y.; Fu, B. Rapid increase of potential evapotranspiration weakens the effect of precipitation on aridity in global drylands. *J. Arid. Environ.* **2021**, *186*, 409–414. [[CrossRef](#)]
46. Tian, F.; Brand, M.T.; Liu, Y.; Verger, A.; Tagesson, T.; Diouf, A.A.; Rasmussen, K.; Mbow, C.; Wang, Y.; Fensholt, R. Remote sensing of vegetation dynamics in drylands: Evaluating vegetation optical depth (VOD) using AVHRR NDVI and in situ green biomass data over West African Sahel. *Remote Sens. Environ.* **2016**, *177*, 265–276. [[CrossRef](#)]
47. Fensholt, R.T.; Rasmussen, K.; Kaspersen, P.; Huber, S.; Horion, S.; Swinnen, E. Assessing Land Degradation/Recovery in the African Sahel from Long-Term Earth Observation Based Primary Productivity and Precipitation Relationships. *Remote Sens.* **2013**, *5*, 664–686. [[CrossRef](#)]

48. Martin, B.; Jean-Pierre, W.; Jerome, C.; Torbern, T.; Rasmus, F. Satellite passive microwaves reveal recent climate-induced carbon losses in African drylands. *Nat. Ecol. Evol.* **2018**, *2*, 827–835.
49. Reynolds, J.F.; Smith, D.; Lambin, E.F.; Turner, B.L.; Mortimore, M.; Batterbury, S.J.; Downing, T.E.; Dowlatabadi, H.; Fernández, R.J.; Herrick, J.E.; et al. Global Desertification: Building a Science for Dryland Development. *Science* **2007**, *316*, 847–851. [[CrossRef](#)]
50. Fensholt, R.; Langanke, T.; Rasmussen, K.; Reenberg, A.; Prince, S.; Tucker, C.; Scholes, R.J.; Le, Q.B.; Bondeau, A.; Eastman, R.; et al. Greenness in semi-arid areas across the globe 1981–2007—An Earth Observing Satellite based analysis of trends and drivers. *Remote Sens. Environ.* **2012**, *121*, 144–158. [[CrossRef](#)]
51. Akhtar-Schuster, M.; Stringer, L.C.; Erlewein, A.; Metternicht, G.; Minelli, S.; Safriel, U.; Sommer, S. Unpacking the concept of land degradation neutrality and addressing its operation through the Rio Conventions. *J. Environ. Manag.* **2017**, *195*, 4–15. [[CrossRef](#)] [[PubMed](#)]
52. Higginbottom, T.P.; Symeonakis, E. Assessing Land Degradation and Desertification Using Vegetation Index Data: Current Frameworks and Future Directions. *Remote Sens.* **2014**, *6*, 9552. [[CrossRef](#)]
53. Pravalie, R. Drylands extent and environmental issues. A global approach. *Earth-Sci. Rev.* **2016**, *161*, 259–278. [[CrossRef](#)]
54. Sun, H. Author Keyword Co-occurrence Network and Empirical Research. *J. Intell.* **2012**, *31*, 63–67.
55. Li, G.; Li, L.; Mao, J.; Ye, G. The author co-authored an empirical study on the similarity of research interests in the network. *Libr. Inf. Serv.* **2015**, *59*, 75–81.
56. Yin, Q. *Research on Keyword Extraction Method of Chinese News Web Pages Based on Cluster Analysis*; Hefei University of Technology: Hefei, China, 2009.
57. Feng, Z. *An Intelligent Search Method for Scientific and Technological Articles*; Sun Yat-sen University: Guangzhou, China, 2010.
58. Pan, L.; Wang, S. Hotspots and Frontier Topics of Educational Research in the Past Ten Years—Based on Quantitative Analysis of Keyword Co-occurrence Knowledge Graph of Literatures Published in Eight Pedagogical Periodicals from 2000 to 2009. *Educ. Res.* **2011**, *32*, 47–53.
59. Yang, H. Hotspots and Frontiers of Higher Education Research in my country: Quantitative and Visual Analysis of Keyword Co-occurrence Based on Documents Included in CSSCI Database from 2004 to 2014. *Fudan Educ. Forum* **2015**, *13*, 46–56.
60. Yin, G. Research on the ecological restoration effect of the fallow grass project in the dry land in front of Tarbahtai Mountain in Tacheng area. *Grass-Feed. Livest.* **2016**, *5*, 70–73.
61. Zhang, Z. *Observation of Greenhouse Gas Emission Fluxes from Dryland Ecosystems in the Central Sichuan Hilly Region*; Southwest Agricultural University: Chongqing, China, 2004.
62. Xu, F.; Li, J.; Chu, X.; Man, Y. A study of daily PM<sub>2.5</sub> simulation based on MODIS data and multi-machine learning method. *China Environ. Sci.* **2022**, *42*, 2523–2529.
63. Liu, H.; Xu, F.; Bao, H.; Xu, W.; Yan, X.; Lu, H.; Xu, C. Application of machine learning classification algorithm in rainfall-type landslide forecasting. *J. Appl. Meteorol. Sci.* **2022**, *33*, 282–292.