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Review

Bibliometrics-Based: Trends in Phytoremediation of Potentially Toxic Elements in Soil

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Abstract: Land purity is of central importance to crop production. The accumulation of toxic elements in soil seriously affects crop safety. Phytoremediation is a widely used technology to clean soil pollution because of its low cost, simple implementation, and lack of secondary pollution. This investigation includes data from 4787 articles on phytoremediation of heavy metals in soil from the period between 2008 and 2021, acquired from Web of Science databases. VOSviewer was utilized to conduct statistical analysis of countries (regions), institutions, journals, cited literature, and keywords. According to the statistical data, the use of phytoremediation for cleaning soil with heavy metals has matured in recent years, showing a trend of rapid growth. There were also few collaborative studies on this subject between institutions, and China has the most extensive research in this field and, therefore, has the highest number of publications, followed by India and the United States. Publications from Pakistan are very in-depth and have the highest average number of citations. It was discovered that many researchers are now publishing articles on Environmental Science and Pollution Research. *Chemosphere* was revealed as the most influential journal, whereas *The Journal of Hazardous Materials* was the most cited. In-depth research on keywords such as metal enrichment, super-enrichment plants, phytoremediation, Cd, Pb, etc. have been conducted by many scientists; however, the research content for different countries was different. The review analysis revealed that in the future it will be possible to breed trees with high heavy metal accumulation, or to use transgenic plants and ornamental plants with high tolerance to prevent and control heavy metal pollution in soil. This paper aims to provide references for scholars in this field and to allow them quick access to summarized knowledge on this topic.

Keywords: soil; toxic elements; phytoremediation; Cd; hyperaccumulator; bibliometrics; Web of Science

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Citation: Zhang, Y.-L.; He, G.-D.; He, Y.-Q.; He, T.-B. Bibliometrics-Based: Trends in Phytoremediation of Potentially Toxic Elements in Soil. *Land* **2022**, *11*, 2030. https://doi.org/10.3390/land11112030

Academic Editor: Evangelia Golia

Received: 1 November 2022
Accepted: 10 November 2022
Published: 13 November 2022

1. Introduction

With industrialization, a large amount of residual and potentially toxic elements are being discharged into the environment in the form of flue gas and wastewater residue. These toxins eventually invaded the soil via rainfall, rivers, and other sources [1,2]. Excessive accumulation of potentially toxic elements in soil not only leads to soil degradation and crop reduction, but also affects the human body through the food chain, threatening human life and safety. Phytoremediation of contaminated soil using plants that are potentially able to tolerate toxic elements is the simplest remediation method, and does not produce secondary pollution [3,4]. It is also a field of interest for many scientists, although the research focus and future development trends of this field are rarely reported.

Remediation methods for soil polluted with toxic elements mainly include physical, chemical, and biological remediation [5]. Physical and chemical remediation are mostly not used because of their many disadvantages, such as high cost, irreversible changes in soil properties, and secondary contamination [6]. Phytoremediation is, however, a widely used restoration method as it is cost-effective, economical, environment-friendly, and has sustainable advantages [7,8]. It uses metal-accumulating plants that enrich themselves with potentially toxic elements, thereby restoring the contaminated soil. The remediation process is simple, effective, and has wide applicability on a large scale. Phytoremediation technology is an effective method in the contemporary development of agricultural and industrial integration. The implementation success of phytoremediation depends on the selection of species [9]. Specific plants can absorb high levels of potentially toxic elements into their roots, can tolerate different metals, and can adapt to different environments; therefore, they can repair different kinds of pollution produced by potentially toxic elements under different soil and local conditions [10]. The bibliometric method is different from traditional statistical analysis and can show development trends more intuitively in the form of cluster analysis. At present, there are only a few studies that both follow bibliometric methods while also focusing on the phytoremediation of soil polluted with potentially toxic elements.

Ten years ago, researchers focused on the remediation of potentially toxic elements in soil using different types of chelators to target the activation of specific toxic elements to maximize the effect of plant enrichment [11]. The metabolites produced by *Aspergillus niger* can leach Cd from industrially contaminated soils, and has a high potential for production [12]. At soil pH 5.56, combined treatment with alfalfa and sunflower greatly improves the removal rates of Cd and Cu [13]. In the past five to ten years, researchers began to focus on the screening and cultivation of plants with high enrichment potential for toxic elements. When afforestation was combined with soil remediation, the Jatropha plant absorbed and accumulated large amounts of Cd, Ni, and Zn in its branches and leaves, while Cu, Pb, and Cr were in the roots [14]. The removal rate of As by hybrid Miscanthus cultivation is 97.7% [15]. In the past half-decade, researchers have focused on the development of repair plants from the perspective of molecular biology, or on transgenic plants to reduce the intake of potentially toxic elements in crops to ensure food safety. For example, 7000 Arabidopsis Thaliana mutants were grown in three kinds of toxic-element media. The screening revealed the resistant mutant Athpp9 and the sensitive mutant Atala4, which provides a further reference for the study of phytoremediation in contaminated soil [16]. HhSSB protein transformation in Arabidopsis can increase the stress tolerance of Arabidopsis in response to Cd contamination, thus increasing its accumulation. The use of gene editing and manipulation techniques can improve the efficiency of phytoremediation [17]. Transgenic phytoremediation is still in the developmental stages and has only shown success in Arabidopsis.

In this paper, the Web of Science (WoS) database was used to search literature data. The WoS tool and HistCite citation analysis software were used to conduct network and econometric analyses of keywords such as 'hyper-enriched plants' and 'phytoremediation' [18]. In recent years, with rapid industrialization, soil pollution has become a challenge for different countries, and the remediation methods they use are also different. It is difficult to find a suitable method from the extensive literature when carrying out targeted pollution remediation. Therefore, to facilitate scholars from various countries having a comprehensive understanding of the worldwide research status and trends in this field, in this study, the relevant literature from 2008 to 2021 on phytoremediation of soil with harmful elements was analyzed, and the major research aspects, such as time distribution, literature sources, main research forces, and high-frequency keywords, were summarized. A targeted literature search was conducted to provide a reference for future research in this field.

2. Materials and Methods

2.1. Data Sources

The data in this paper were obtained from the Web of Science core collection database. The WoS database is a comprehensive database (including the SCI, SSCI, and A&HCI3 databases), containing 256 subjects worldwide, more than 12,000 high-impact academic journals, and 170,000 international conference proceedings [19,20]. In this paper, 'phytoremediation' and 'potentially toxic elements in the soil' are used as the main topics to query and analyze the literature published on the Web of Science from 2008 to 2021. The literature types were data papers and review papers, and the retrieval date was 13 June 2022. A total of 4787 relevant research papers were retrieved, and 4787 papers were imported into the HistCite software, including 593 journals, 13,678 authors, and 125,716 references [21].

2.2. Research Technique

Using analysis tools in the Web of Science database (https://www.webofscience.com/wos/woscc/basic-search, accessed on 13 June 2022), Excel 2016, Origin 2021, VOSviewer1.6.18, HistCite2.1, Biblioshiny(https://www.bibliometrix.org/home/ accessed on 13 June 2022), and other software, the main countries, quantitative trends, scientific research institutions, authors, and keywords of the literature from 2008 to 2021 related to phytoremediation of soil potentially contaminated with toxic elements were analyzed quantitatively [22,23].

HistCite software is a software for visualizing the number of citations. The operation process of the HistCite software is simple, the map expression is intuitive, and the analysis is convenient. Its indicators include Local Citation Score (LCS), Global Citation Score (GCS), Total Local Citation Score (TLCS), and Total Global Citation Score (TGCS) [24]. This paper mainly deals with TLCS and TGCS. A high TLCS value of a paper indicates that the paper has a high influence in the research field, which is likely to be a groundbreaking article in the field [25]. A high TGCS indicates the cross-field influence of the article and a higher research value.

VOSviewer Knowledge Graph is a free software for scholars [26]. It combines graphic information and visualization theory with word frequency co-occurrence technology in traditional bibliometrics and has unique advantages in visual display, especially in clustering [27,28].

3. Result

3.1. Distribution of Time

Statistics on the number of papers published in a given period is an important way to judge the development trends and depth of a certain field [29]. For a better intuitive understanding of the global research degree and development trends with respect to phytoremediation of soil with potentially toxic elements, a total of 4787 articles from 2008 to 2021 were acquired from the WoS database.

The time distribution of the retrieved publications is shown in Figure 1. According to the time trend of publication, the publication of articles from 2008 to 2021 can be roughly divided into three stages: the steady stage (annual number of publications $\leq$ 250), the gradual improvement stage (annual number of publications = between 250 and 500), and the rapid development stage (>500 articles published per year).

1. Steady stage (2008–2013)

At this stage, <250 articles were included in the WoS database every year, with an annual increase of <30 articles. However, 235 articles published in 2013 showed a significant increase compared to 152 articles published in 2008, and gradually this field started getting more attention.

2. Gradual improvement stage (2014–2018)

During this stage, the research showed a steady upward trend and the number of published papers increased by 56.3%, from 279 in 2014 to 436 in 2018. People also began to look for new solutions to improve pollution in soil via phytoremediation technology.

3. Rapid development stage (2019–now)

At this stage, the number of articles published every year increased significantly, and by 2020, the number reached 682. Moreover, the number of researchers also increased rapidly and the field began to attract the attention of scholars all across the world.

The publications on phytoremediation of soil polluted with potentially toxic elements in the WoS database are disaggregated by year (2008–2021) (Figure 1). It can be seen that the research in this field has matured on global scale in recent years.

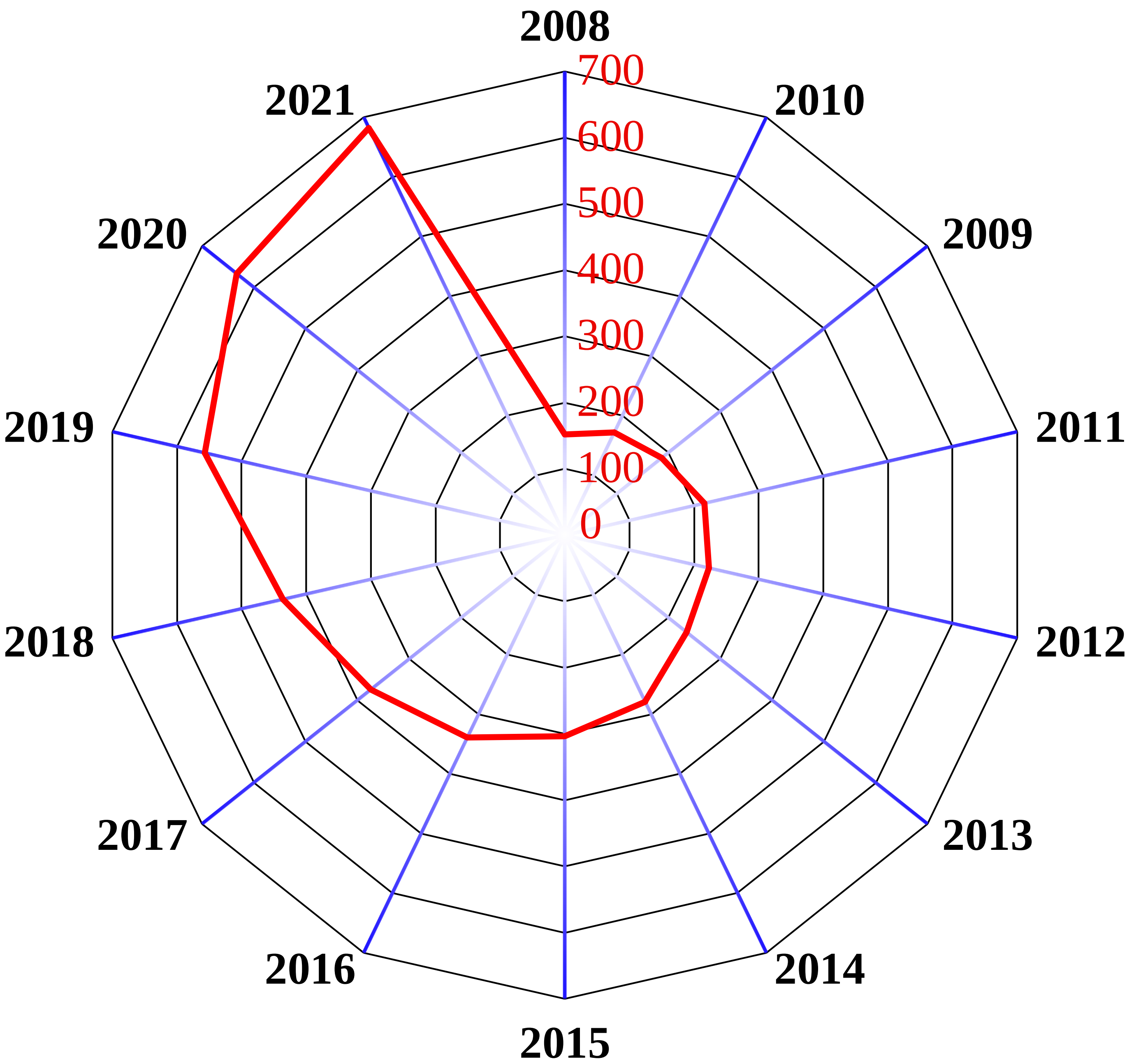

Figure 1. Phytoremediation of soil containing potentially toxic elements from 2008 to 2021.

3.2. Important Sources of Literature

The analysis of the literature level, journal quality, and article quantity published in a certain field at a certain stage can effectively help scholars in that field to understand the current global research focus and developmental trends of that field. Impact factor (IF) is important data in the Journal Citation Report (JCR) of the Institute of Scientific Information (ISI). It is an important index to evaluate the international influence of a journal [30,31].

In this review, research on the phytoremediation of soil's potentially toxic elements was gathered from 597 different journals. The journals were ranked based on the number of articles published on this topic. The top 10 journals by publication volume are shown in (Table 1). The top three journals, *Environmental Science and Pollution Research*, *The International Journal of Phytoremediation*, and *Chemosphere*, published 418, 395, and 325 articles, respectively, accounting for 8.73%, 8.25%, and 6.79% of the retrieved literature, respectively. These numbers indicate that these journals are the main contributors to this field. The journal with the highest IF (10.588) was *The Journal of Hazardous Materials*.

Table 1. Top 10 journals in phytoremediation of soil with potentially toxic elements.

Journal Name	ArticleNum	Proportion	IF2021	TLCS	TGCS
Environmental Science and Pollution Research	418	8.73	4.223	2019	7747
International Journal of Phytoremediation	395	8.25	3.212	1985	6846
Chemosphere	325	6.79	7.086	3517	14,066
Ecotoxicology and Environmental Safety	186	3.88	6.291	1457	5358
Journal of Hazardous Materials	148	3.09	10.588	1824	8537
Science of The Total Environment	135	2.82	7.963	849	4264
Environmental Pollution	124	2.59	8.710	990	4413
Water Air and Soil Pollution	119	2.49	2.520	322	2394
Journal of Environmental Management	106	2.21	6.789	923	3770
Ecological Engineering	72	1.50	4.035	642	2060

According to the citations of different journals, the top three cited journals were *Chemosphere*, *The Journal of Hazardous Materials*, and *Environmental Science and Pollution Research*. *Chemosphere* was most the frequently cited and holds the highest influence in the field of phytoremediation of soil with potentially toxic elements. *The Journal of Hazardous Materials* has the highest average number of cited articles in this field, indicating that the journal has in-depth literature research and the highest quality.

Figure 2 represents the analysis chart of important literature on phytoremediation of soil containing potentially toxic elements. The ordinate is the year of publication, the circle represents the published literature, the number is the publishing journal, and the size of the circle represents the citation frequency. The arrow line represents the citation relationship between the references, among which reference No. 2065 has been cited 2535 times. In 2013, Pakistani scholars conducted a comprehensive discussion on the background and trends of phytoremediation of potentially toxic elements for the first time [32]. Reference No. 1299 also shows that biological metal availability plays a crucial role in the remediation of soil containing potentially toxic elements [33].

3.3. Main Research Strength

3.3.1. Analysis of Publishing Countries

The number of papers included in the WoS database and the citation rate can, to a certain extent, reflect the depth and research level of this topic in different countries. From the beginning of 2008 to the end of 2021, a total of 4789 articles related to the phytoremediation of soil's potentially toxic elements were published in 117 countries. The top 10 countries that published the most articles were China, India, the United States, Pakistan, Spain, Italy, Poland, France, Iran, and Brazil. Of these, 4123 published articles, were associated with China and India, accounting for 86.1% of the world's total research on this topic, including document quantity accounting for >10%. China ranks first in terms of having the most published research with a total of 1562 articles, which accounted for 36.62% of the total literature, and which was significantly higher than the output of India (which accounted for 10.38%) (Table 2) (Figure 3). The data reflect that China has relatively in-depth knowledge and high status in the field of phytoremediation of soil polluted with potentially toxic elements, but it also indicates that China might need more practical attention as compared to other countries.

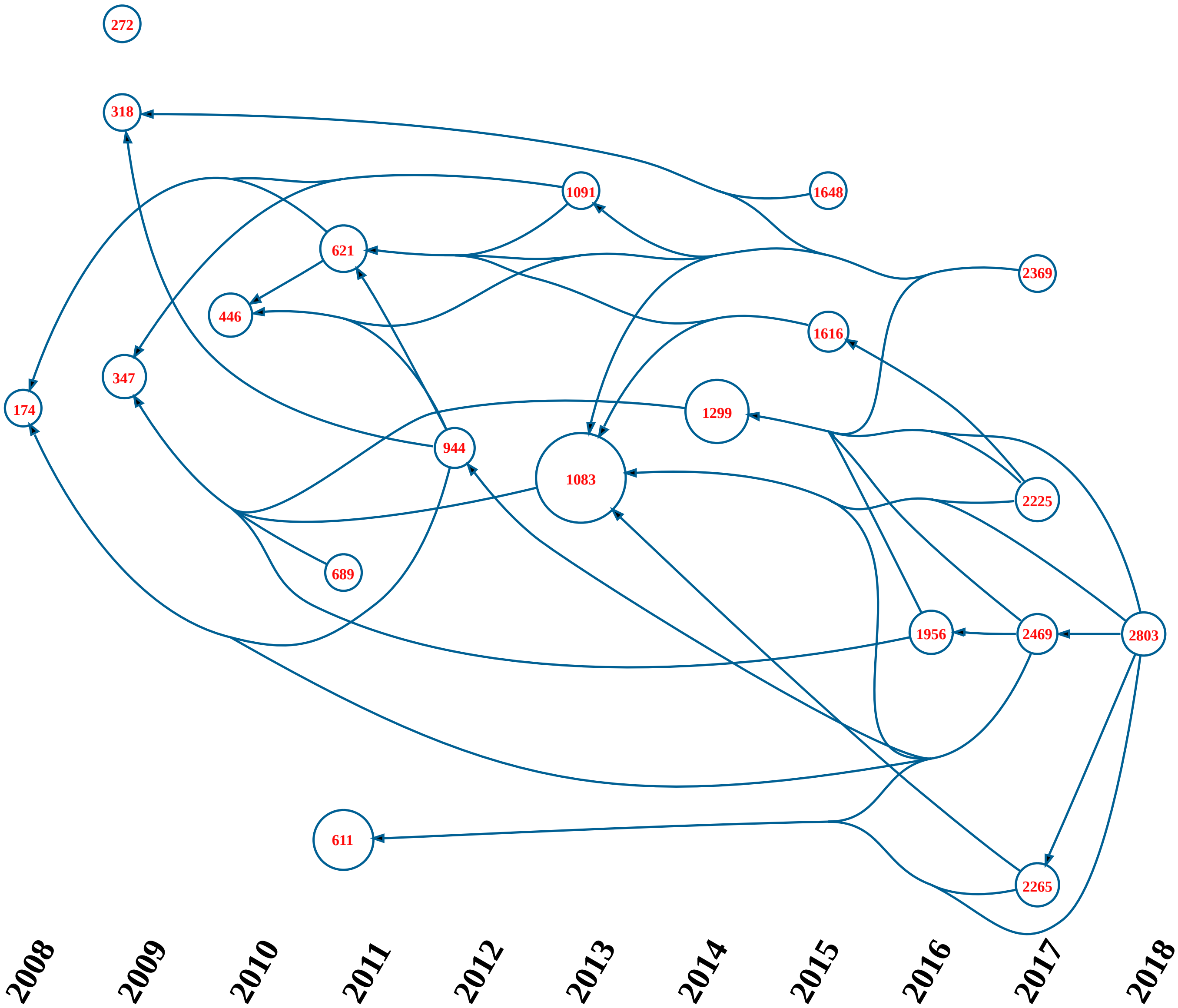

Figure 2. Citation analysis chart of journals from 2008 to 2021 regarding phytoremediation of soil containing potentially toxic elements.

Table 2. Top 10 countries with the highest published articles on phytoremediation of potentially toxic elements.

Countries	Published Articles	Proportion	TLCS	TGCS
China	1562	32.62	8231	36,602
India	497	10.38	3764	17,266
United States	343	7.16	2317	11,394
Pakistan	339	7.08	3441	12,773
Spain	308	6.43	1580	9205
Italy	284	5.93	2350	9765
Poland	234	4.89	931	4377
France	189	3.95	1602	6637
Iran	188	3.93	699	2531
Brazil	179	3.74	575	2995

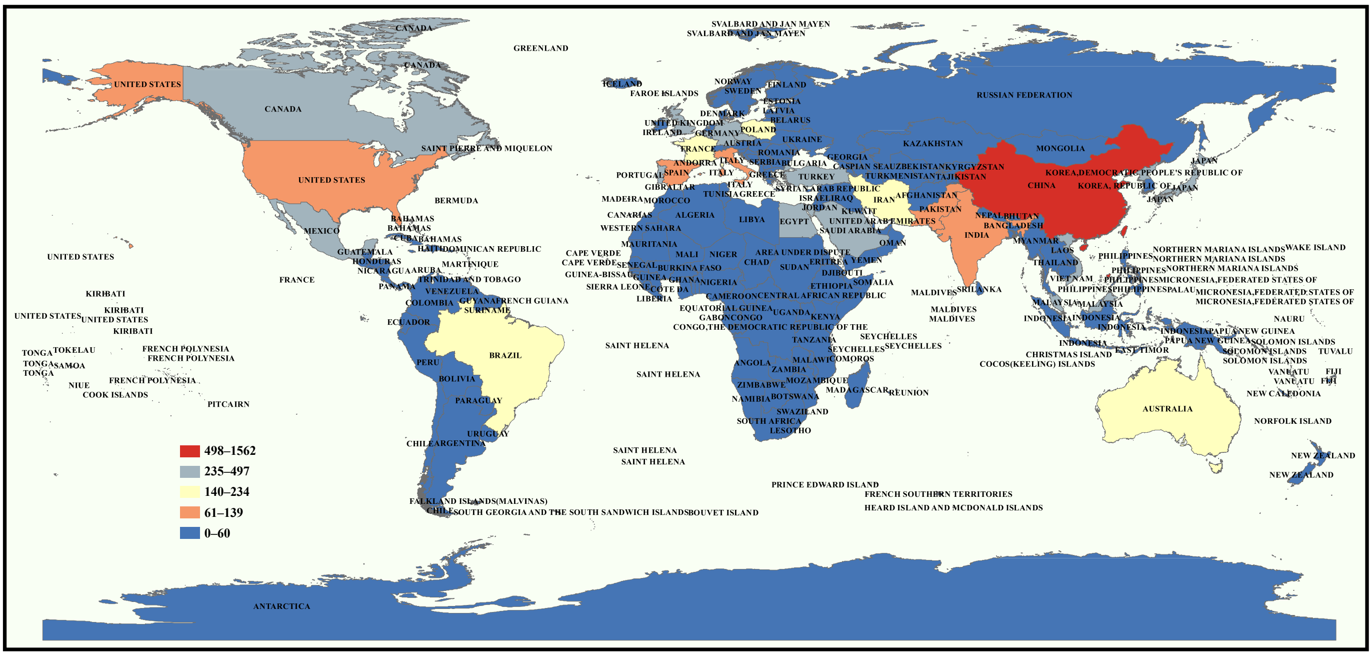

Figure 3. Publications on phytoremediation of soil's potentially toxic elements in different countries from 2008 to 2021.

The summarized citation frequency of the literature (Table 2) shows a positive correlation with the number of publications. In terms of total citation frequency, China has the highest citation frequency; however, the average citation frequency is low, indicating that Chinese researchers in this field need to improve the quality of their articles. The country with the highest citation frequency per article was Pakistan, with 339 articles published, and the total citation frequency was higher than that of the United States (343 published articles) indicating that Pakistan has a deeper understanding of this field and a higher influence per article.

When the time trends of the top five countries with the highest number of published articles were compared (Figure 4), China and Pakistan showed an obvious growth trend in recent years. With respect to the proportion of total articles published, China has published far more than other countries, and this proportion has increased significantly in the past three years, indicating that China has paid increasing attention to this research field.

Figure 5 depicts the proportion of publications and the cooperation relationships between countries in the field of phytoremediation of soil's potentially toxic elements from 2008 to 2021. Different circles represent different countries, and the circle size represents the number of articles published. The more connections there are between countries, the more frequent the cooperation between those countries. The shorter the connecting line, the closer the cooperation between the connected countries. A total of 77 countries conducted research in this field and a total of 11 clusters and 675 cooperative relationships between these countries were observed. As indicated by the clusters, there are many cooperative relationships among countries, but they are scattered. Although China has a large number of publications, it has few cooperative relations with other countries (though countries it has collaborated with include Spain, Poland, and Germany). India, Poland, and Italy have the most collaborative studies. France and Pakistan have close cooperation relationships with many countries, but less cooperation with each other.

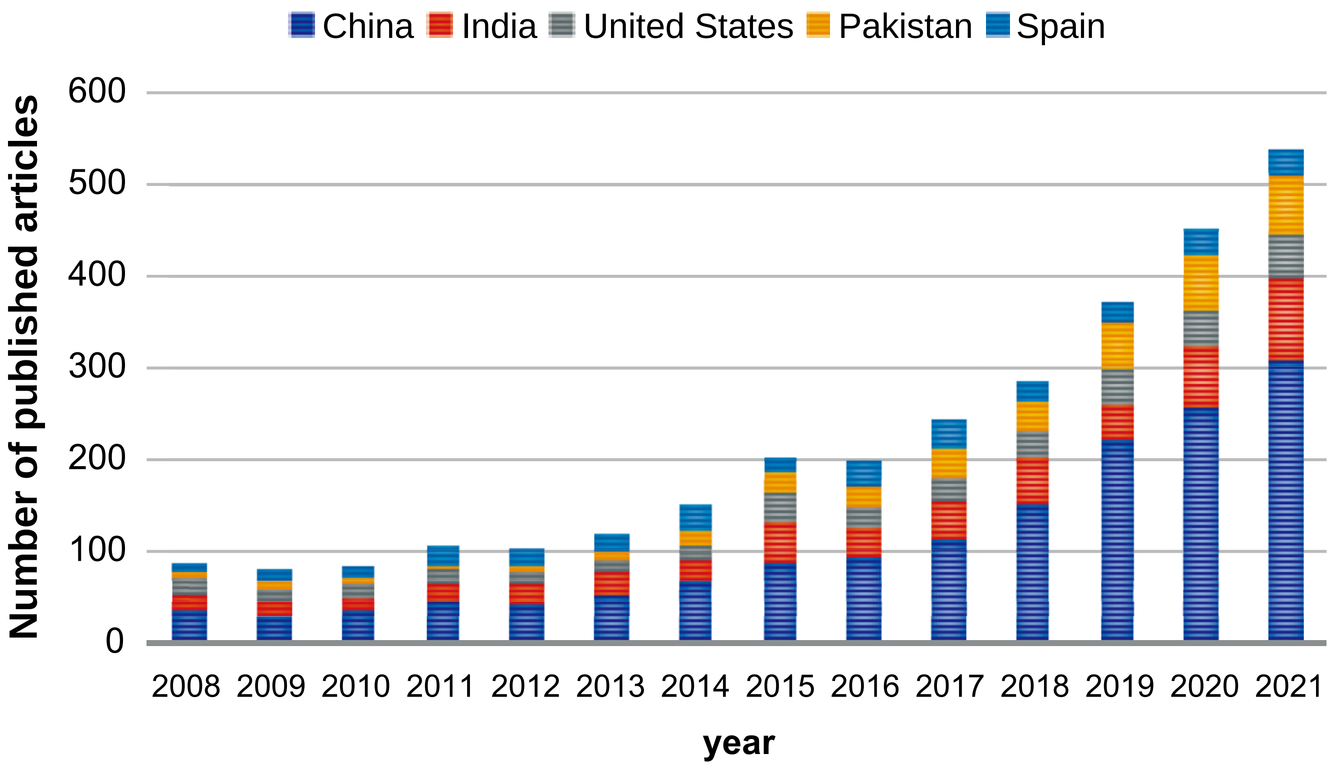

Figure 4. Trends in the publication of papers on the phytoremediation of soils' potentially toxic elements by different countries from 2008 to 2021.

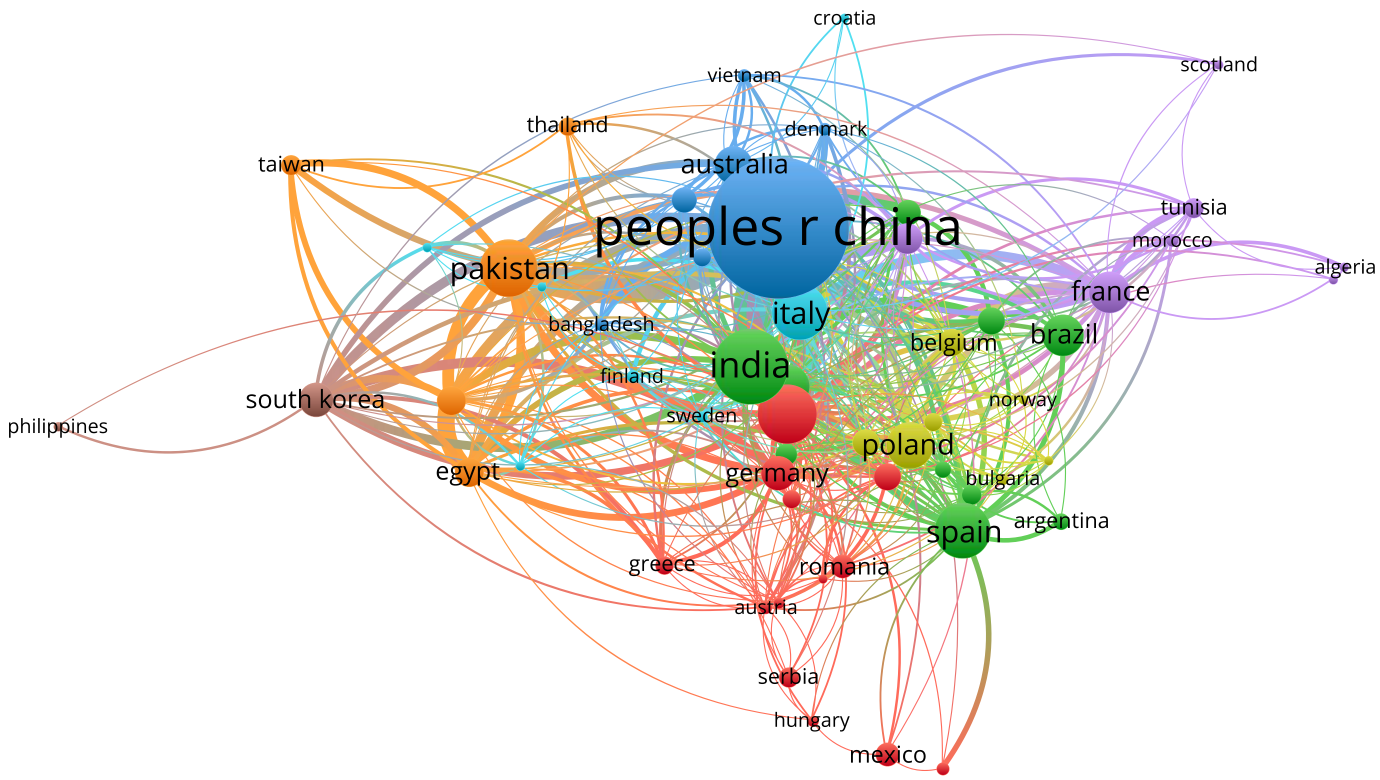

Figure 5. Atlas of cooperation between major countries in the field of phytoremediation of soil's potentially toxic elements from 2008 to 2021. Note: connection = partnership; the size of a circle indicates the number of articles issued by the associated country; different colors represent different categories. There are 11 clusters in the figure, 77 countries, and 675 connections.

3.3.2. Analysis of Major Research Institutions

A total of 3342 articles were published on this topic from 2008 to 2021, and these were mainly published by universities and scientific research institutions. The top 10 scientific research institutions in terms of the number of published papers are shown in Table 3. The top three globally ranked institutions are from China, with a total of 547 publications, which shows how involved Chinese scholars are in this field. From 2008 to 2021, the Chinese Academy of Sciences published 322 papers in the field of phytoremediation of soil's potentially toxic elements, accounting for a total of 6.72% of all papers, much higher than the University of Chinese Academy of Sciences (114 papers) and Zhejiang University (111 papers). These statistics indicate that China has done extensive research in this field, and that it also has a serious pollution problem.

Figure 6 shows the number of publications and cooperative relationships of institutions in the field of phytoremediation of soil's potentially toxic elements. The circle size represents the number of publications, the distance represents the distance of the relationship, and the number of lines represents the amount of cooperation. As a leading research institution in this field, the Chinese Academy of Sciences has close cooperation with many institutions, but the cooperative relationship is relatively concentrated.

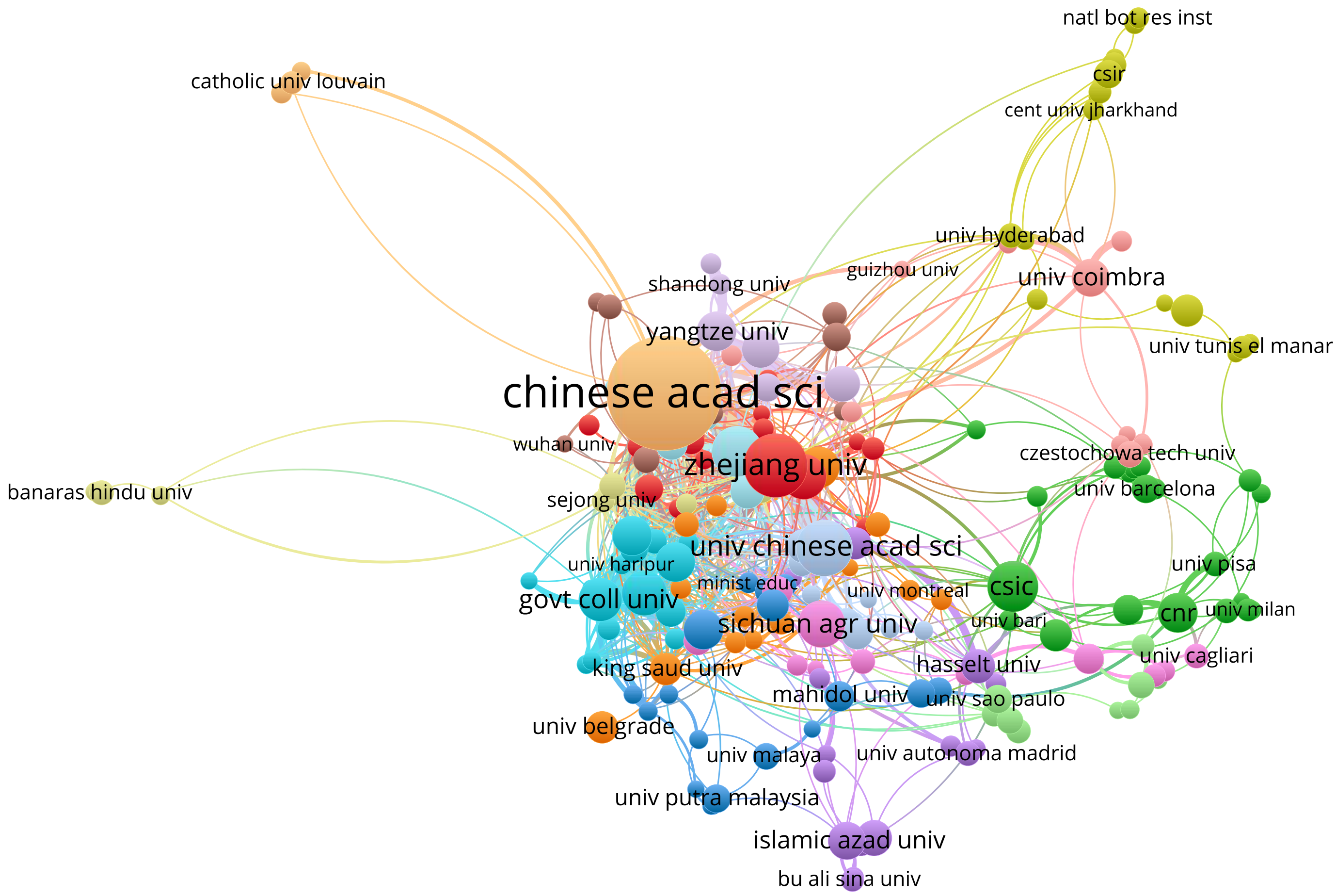

Figure 6. Map of important research institutions and their cooperative relationships for studying the phytoremediation of soil's trace toxic elements. Note: connection stands for partnership; circle size represents the number of agency publications; and different colors indicate different categories. There are a total of 10 clusters; 483 institutions; 2184 cables.

Table 3. Top 10 research institutions in the field of phytoremediation of soil's potentially toxic elements.

Institution	Records	Proportion
CHINESE ACADEMY OF SCIENCES	322	6.72
UNIVERSITY OF CHINESE ACADEMY OF SCIENCES (CAS)	114	2.38
ZHEJIANG UNIVERSITY	111	2.32
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (CSIC)	98	2.05
COUNCIL OF SCIENTIFIC INDUSTRIAL RESEARCH (CSIR) INDIA	95	1.98
EGYPTIAN KNOWLEDGE BANK (EKB)	93	1.94
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS)	90	1.88
LEAGUE OF EUROPEAN RESEARCH UNIVERSITIES (LERU)	87	1.82
UNIVERSITY OF AGRICULTURE FAISALABAD	80	1.67
INRAE	77	1.61

3.4. Keywords Collinear Network

When analyzing the research trends in a field, the keywords of the articles can reflect the focus of scholars in that field, and also reflect the main research direction of an article. In this paper, CiteSpace was used to analyze the common keywords in the published literature from 2008 to 2021. The most used keywords included the outbreak frequency of "sky blue restraining blue cabbage", which was mainly concentrated in the literature from 2008 to 2013 [34]. The heat duration of "population", "colonization", and "chelating auxiliary plants" was longer. In 2019, scholars pay more attention to "hexavalent chromium", "biochar", and "chemical form", which is predicted to be the research hotspot and trend in the coming years (Figure 7).

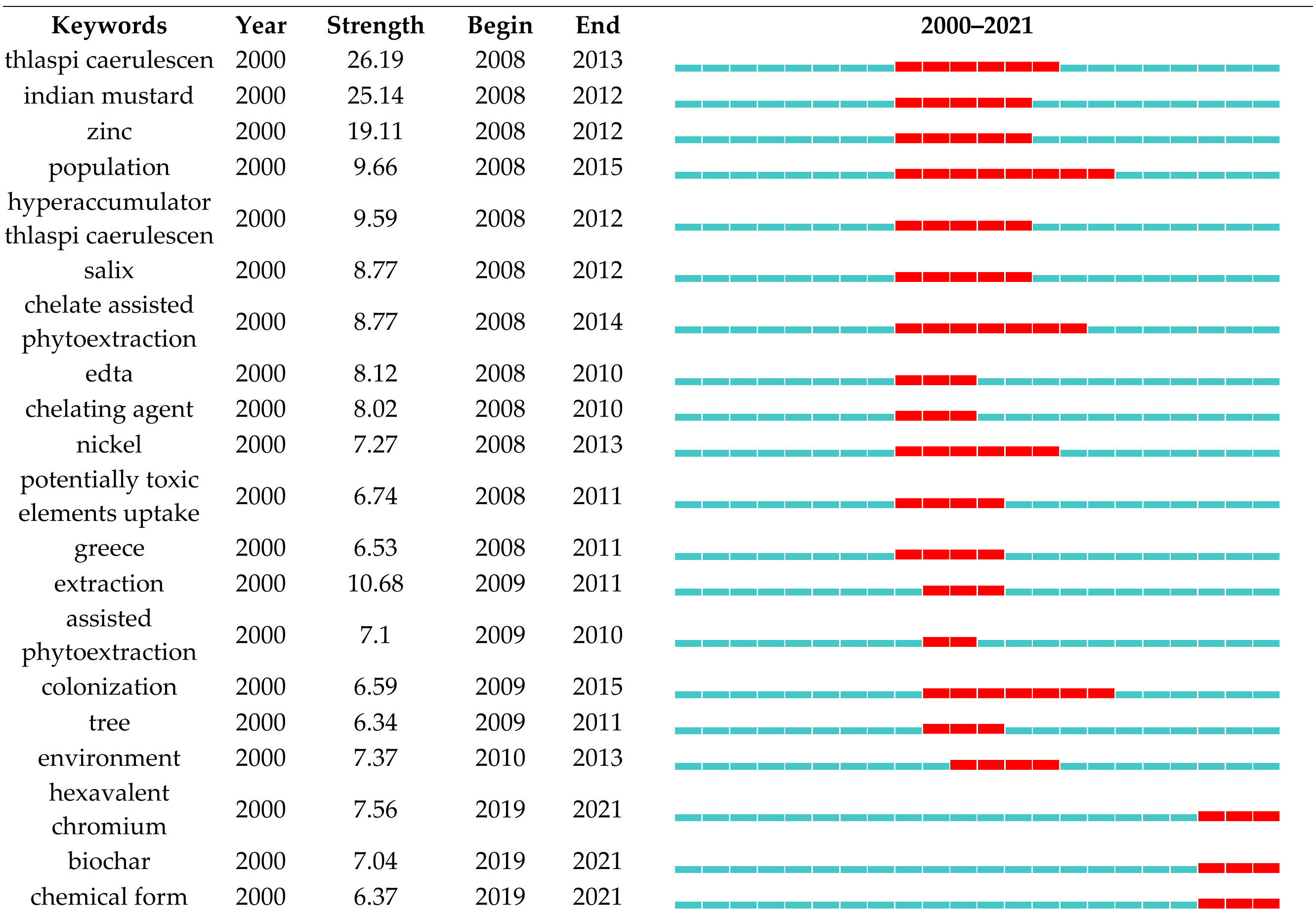

Figure 7. CiteSpace-based burst word mapping from 2008 to 2021.

With the help of a coordinate map drawn by Biblioshiny (https://www.bibliometrix.org/home/ accessed on 5 June 2022) (5 keywords/cluster), a total of nine clusters were generated (Figure 8). A, B, and C represent the "slow and steady stage", "gradually ascending stage", and "rapid development phase", respectively, which shows the overall change in this field. In the slow and steady phase, the research content was more focused, but the depth was weak, and the correlation between "soil, effects, Cd, Pb, and Zn" was higher. In the gradual improvement stage, the research was mainly centered on "phytoremediation, accumulation, plants, growth, and soil". The research was in-depth and had high connections. During the rapid development stage, some scholars began to perform more in-depth research on "plant growth, contaminated soil, bacteria, arbuscular mycorrhizal fungi, and bio-rerepair", which is the main research direction and focus of this field in the coming years.

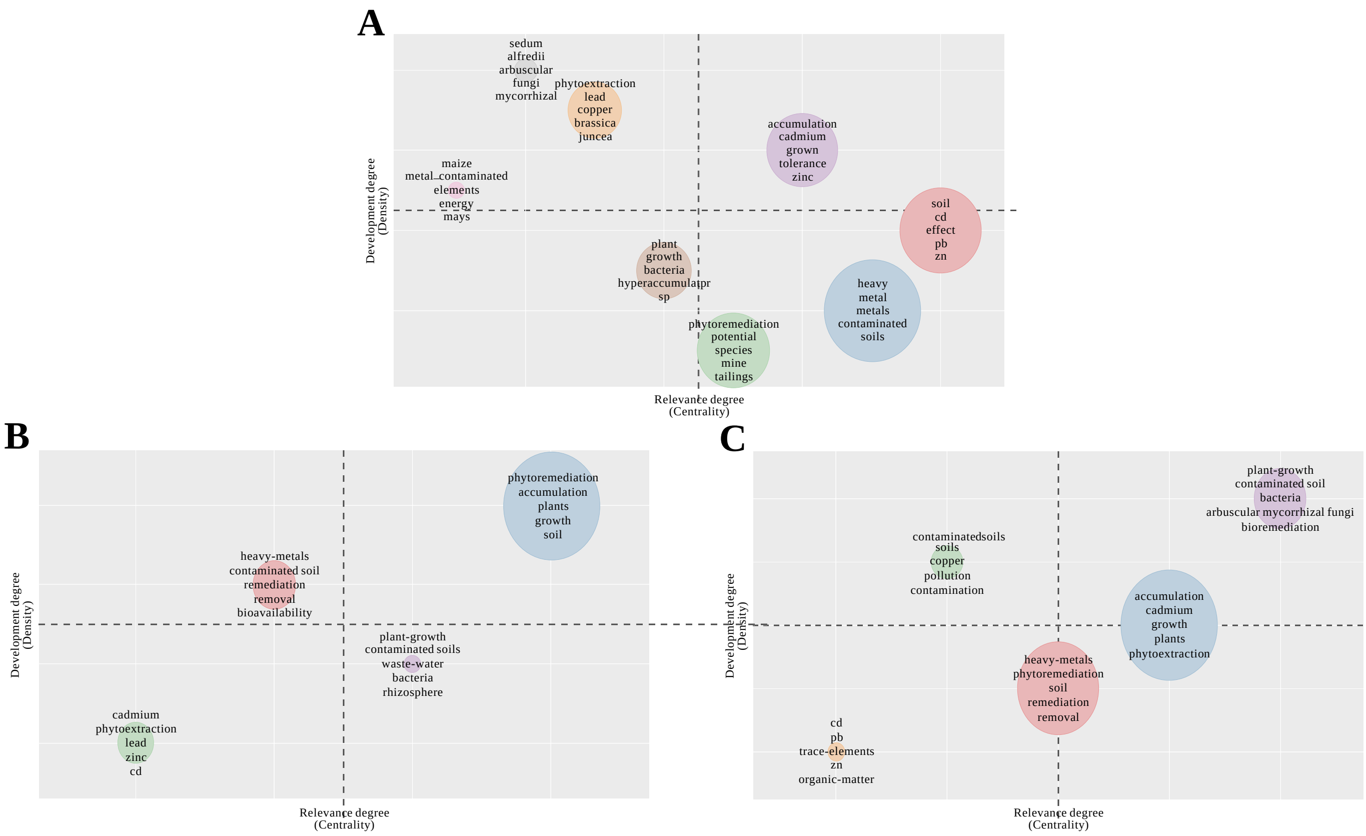

Figure 8. Keyword clustering in phytoremediation of soil's potentially toxic elements at different stages. (**A**–**C**) represent the "slow and steady stage", "gradually ascending stage", and "rapid development phase", Note: Ordinate density indicates the internal connection of the research topic, while high density indicates the close internal connection of the research topic. The research is seen to gradually mature. The horizontal coordinate Centrality represents the mutual influence of topic classes, which is the research center of this field. The size of the circle indicates the number of articles issued by a country and different colors represents different categories.

VOSviewer was used to conduct statistical analysis on different keywords used for the topic of concern (>12) (Figure 9), and these can be divided into five clusters. The word "phytoremediation" was the most frequently used keyword in articles, and the top five most used keywords after "phytoremediation" were "accumulation", "plants", "tolerance", "Cd", and "Pb". Keywords can reflect researchers' focus and research depth in this field to a certain extent. As time has passed, the focus of researchers has shifted from the enrichment of toxic elements in super-enriched plants ("Indian mustard", "extraction", "zinc", "Pb", "Cu", etc.) to the diversified restoration mode ("biochar", "salicylic acid", etc.). However, only a few studies have been carried out on diversified restoration mode and it is in a stage of rapid development.

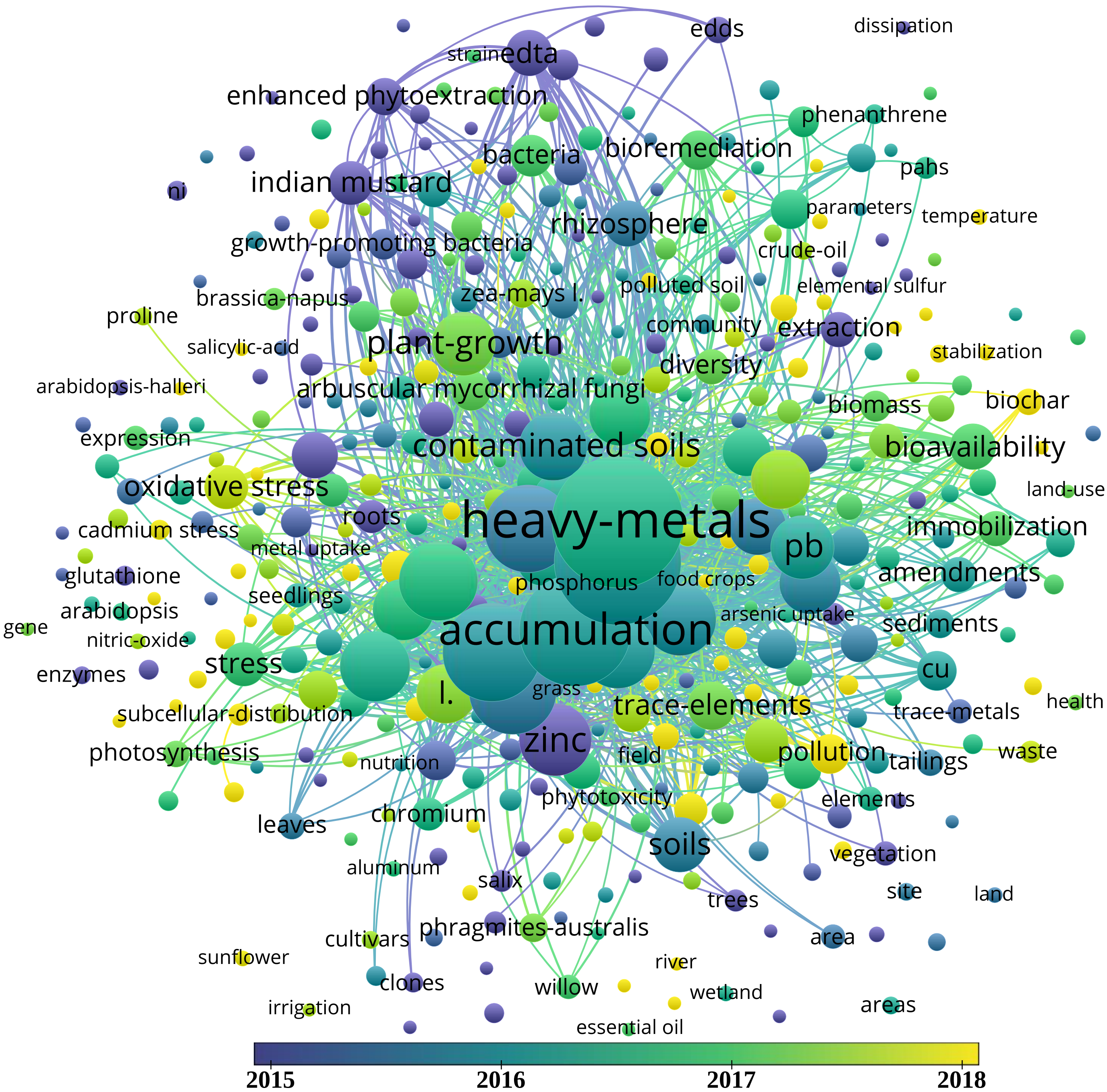

Figure 9. Keyword collinearity network in phytoremediation of soil's potentially toxic elements from 2008 to 2021. Note: the size of the circle represents the number of times the keyword was used, different colors represent different years, and lines represent relationships.

4. Conclusions and Discussion

Conclusions

With the development of industry, a variety of toxic elements have entered and polluted the soil. This has led to the attention of more scholars toward the remediation of soil pollution. However, there is currently very little understanding of the research trends and status quo in this field and it is difficult to make targeted references. This study conducted a comprehensive bibliometric analysis of the literature in the field of phytoremediation of soil containing heavy metals, using the WoS database. Based on the number of publications, journals, countries, and keywords, this paper identifies the basic trends and framework of this research field.

The publication trend map analysis revealed that scholars around the world are gradually paying more and more attention to phytoremediation of soil containing heavy metals, and the trend of multi-disciplinary and multi-technology integration of phytoremediation of soil is also increasing gradually. China, India, and the United States have done extensive research in this field and during recent years, China and Pakistan have significantly increased their research in this field. China has gradually become the country with the most in-depth scientific research in this field and its top research institutions include the Chinese Academy of Sciences, the University of Chinese Academy of Sciences, Zhejiang University, the Supreme Scientific Research Council, etc. There is less collaboration among different research institutions and papers are mainly concentrated in journals such as *Environmental Science and Pollution Research*, *The International Journal of Phytoremediation*, and *Chemosphere*. Keyword analysis found that in worldwide soil research on heavy metals, "Zn/Cd hyperaccumulation plants", and "shamrock fixing blue food" were the most frequently used keywords. Before 2010, people paid close attention to metal enrichment pioneer plants, Cd, Pd, Zn, and other metals' migration and accumulation in the soil, while after 2010 knowledge of the effects and hazards of these toxic elements on plant growth increased, and in recent years attention has mainly been focused on bioremediation of contaminated soils.

Plant enrichment of trace toxic elements can occur in two possible ways: natural enrichment and induction. Induction means adding chelating agents to the soil to increase metal activity in the soil, which is conducive to plant absorption. In the future, collaborative research across disciplines can be conducted to discover new ideas. We need to find new, efficient, super-enriched plants, for example, transgenic plants that can be used to repair heavy metals in the soil [32]. Brachypodium is an ideal heavy metal repair plant, which can reduce the bioavailability of Cr, Zn, As, and Cd [35]. Portulaca oleracea is another plant that grows widely, has a short cycle, is likely to survive, has a good repair ability against most potentially toxic elements, can exudate organic acid through its roots to absorb nutrient ions, and thus has a high tolerance; all of these qualities make this plant valuable for research in this field [36]. The use of ornamental plants for phytoremediation not only provides ornamental value but also avoids the impact of potentially toxic elements on human health, as they are inedible. Additionally, ornamental plants also have a high tolerance, rapid growth, and high biological yield [37,38].

Through the analysis of the dynamic change in keywords, it was found that the current repair mechanisms for potentially toxic elements include:

1. Returning farmland to forest, using perennial non-edible plants to repair soil potentially polluted by toxic elements (for example, the use of trees as vegetation cover). The roots and stems of trees are more developed and resistant, and they can survive in harsh environmental conditions [39].
2. Plant–bacteria interaction for remediation of contaminated soil. Plant nodules can be used to remove potentially toxic elements from the soil, and aquatic plant roots can also remove potentially toxic elements from polluted waters [40].
3. Cultivate plants that can absorb toxic elements, have strong stress resistance, and can adapt to local conditions. Because of global warming, it is necessary to cultivate transgenic plants that can maintain good phytoremediation ability under high temperatures, to cope with the pollution of toxic elements in high-emitting industrial areas [41].

Research on the phytoremediation of heavy metals in soil has become more extensive in recent years. China, India, the United States, Pakistan, Italy, Spain, and other countries have significantly increased their attention to it. However, the publication trends of different countries expose some problems:

1. Soil pollution in China is mainly caused by toxic elements and metalloids, of which farmland soil pollution accounts for 19%. The phenomenon of potentially toxic element pollution in southern China is rapidly increasing; therefore, it is necessary to increase the remediation of soil pollution, or change the use of soil to stop planting food crops [42].
2. India pays more attention to the pollution by chromium and Pb, and a breakthrough is urgently required for the application of phytoremediation to soil polluted with these metals [43,44].
3. Italian scholars focus more on reducing the accumulation of potentially toxic elements in edible parts of agricultural plants and the absorption of pollutants by crops [45,46].
4. Most studies in Pakistan are conducted on the remediation of single potentially toxic elements such as Cd and arsenic. Currently, the focus is on using microorganisms and chelates combined with plants for the remediation of soil's potentially toxic elements, in the hopes of finding a comprehensive removal method for various potentially toxic elements [47].
5. Countries such as France, Brazil, Poland, and Belgium need to strengthen their cooperation with other countries.

It is hoped that this study can provide a reference for scholars concerned with the phytoremediation of trace toxic elements in the soil.

5. Outlook

In recent years, the field of phytoremediation of soil's potentially toxic elements has matured and shows a trend of rapid growth. Different countries have different targeted research and pollution status. The development of cooperation between institutions is more or less concentrated. The future of research in this field is mainly concerned with the following aspects: (1) breeding new varieties, the use of genetically modified plants, and grafting methods to cultivate more adaptive, short-growth-cycle plants with the ability to accumulate a wider range of potentially toxic elements; (2) cultivation of super-enriched plants suitable for different soil conditions; (3) plant absorption of potentially toxic elements by chelating and bacterial agents; and (4) selection of non-edible ornamental plants for restoration. In this paper, the overall trend, the distribution of research strength, and the main journals in the field of phytoremediation of soil containing potentially toxic elements were comprehensively analyzed in hopes of providing direction and new ideas to scholars of this field. This paper does not summarize the research trends of specific background areas (mining area pollution, cadmium pollution, lead pollution, etc.), but summarizes the situation of local areas polluted by trace toxic elements for long periods of time, and puts forward suggestions so as to have an obvious guiding effect on local plant production.

Author Contributions: The conceptualization, writing, editing, and finalization of the manuscript were performed by Y.-L.Z., G.-D.H. and Y.-Q.H.; Supervision, T.-B.H. All authors have read and agreed to the published version of the manuscript.

Funding: The Science and Technology Project of Guizhou Province (Guizhou Science Foundation-Zhongke (2022) No. 054), the Youth Science and Technology Talents Development Project of General Colleges and Universities in Guizhou (Guizhou Provincial Department of Education, Qianjiaohe Qizi (2022) No. 154), and the Talent Introduction Scientific Research Project of Guizhou University (Gui Da Renji He Zi (2021) No. 52).

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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