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Review

Bibliometric Analysis of Soil Nutrient Research between 1992 and 2020

Xiaoyan Pan [1], Jialong Lv [1,2], Miles Dyck [3] and Hailong He [1,*]

1 College of Natural Resources and Environment, Northwest A&F University, Yangling 712100, China; pxy520@nwafu.edu.cn (X.P.); ljlll@nwsuaf.edu.cn (J.L.)
2 Key Laboratory of Plant Nutrition and the Agric-Environment in Northwest China (Ministry of Agriculture), Northwest A&F University, Yangling 712100, China
3 Department of Renewable Resources, University of Alberta, Edmonton, AB T6G 2E3, Canada; miles.dyck@ualberta.ca
* Correspondence: hailong.he@hotmail.com

Abstract: Soil nutrient balance is related to the interaction mechanism between soil fertilizer, soil water, climate change, and plant capability. This paper provides a perspective from bibliometric analysis based on data from the Web of Science core collection with software tools, including Vosviewer, HistCite Pro, and Citespace, in order to reveal the evolution of research trends in soil nutrients. The results show that publication outputs have increased exponentially from 1992 to 2020. The synthetic parameter of the sum of normalized data (SND), calculated from the default indicators of the bibliometric software tools, was used to rank the overall contribution of journal/authors/institutions/countries. The results demonstrate that *Agriculture Ecosystems & Environment*, *Soil Biology & Biochemistry* and *Science of the Total Environment* are the leading journals in the soil nutrient field. The Chinese Academy of Sciences had the highest total citations and collaborated most closely with other organizations, followed by United States Department of Agriculture (USDA) Agricultural Research Service (ARS) and Agr& Agri Food Canada. In addition, USA, China, and UK are the top three research centers for this topic. Moreover, Ken E Giller, Qirong Shen, and Rattan Lal were the top three authors, while Andrew Sharpley ranked the first depending on citations per publication. In terms of co-occurrence of keyword analysis, the results indicate that nitrogen fertilizer, green manure, and soil population have gained close attention from scholars, while soil amendment of biochar have evolved as a hot topic in recent years. Perspectives on future studies are also given.

Keywords: soil nutrient; bibliometric; visualization; citations; publication outputs

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1. Introduction

Soil nutrients are a critical factor determining crops growth [1,2], soil microbial activity [3,4], and potential environmental pollution [5–7]. The availability of soil nutrients is not only related to the absorption capacity of crops [8], but it is also related to the transformation, migration, and microbial decomposition of fertilizer in soil [9–11]. Soil nutrient balance is closely related to the concentration or proportion of soil fertilizers (e.g., nitrogen-N, phosphate-P, potassium-K, or carbon/organic-C). Studies have shown that the concentration or ratio of main N-, P-, and K-fertilizer in topsoil can be used as a good indicator illustrating soil nutrient status and can serve as the basis for calculating soil nitrogen content [12]. In addition, soil nutrients are closely linked to microbial community composition, which could impact on soil environment. Studies have shown that nitrogen status should be an important factor for sustainable agricultural management [13], while organic manure, applied alone or in combination with chemical fertilizers, would increase the soil fertility and functional diversity of soil microbial communities [14]. Generally, nitrogen deposition could change microbial community composition [15,16], and nitrogen addition significantly reduced microbial community diversity and changed bacteria and fungi communities [17]. Furthermore, the most commonly accumulated nitrogen or sulfur fertilizer exists in the form of nitrates or sulfate (S) in soil [18–20], which likely leads to aggravated secondary salinization insoil layer [8,21,22]. The aggravated secondary salinization may result in decreased availability of soil fertilizers, inhibiting the productivity of crops such as cotton [23,24], sunflower [25,26], and maize [22,27]. To some extent, soil; N-, P-, K-, and C-fertilizer; and the microbial community significantly affect plant growth and soil environment. Nonetheless, soil nutrient balance is difficult to achieve as soil fertilizer aims to maximize economic benefit. An overdose of N-, P-, K, -or S-fertilizer leads to soil pollution and plant poisoning, while insufficient fertilizer applications cannot meet the needs of plant growth, which leads to declined yield and quality due to plant malnutrition [28–30]. Therefore, the appropriate use of soil nutrient plays a vital role in sustainable soil ecological environment and the growth of plants.

Numerous studies have been conducted on soil nutrients field. However, no attempt has been made to provide a whole picture of the research status on soil nutrients from a bibliometric perspective. Bibliometrics or scientometrics is a quantitative analysis method based on mathematical statistics [31]. It has been widely applied to analyze research hotpots and development trends of a specific field. For instance, researchers have analyzed global research based on bibliometric reviews on soil moisture [32], soil environment [33–35], soil microplastics [36], soil hydrothermal properties [37], soil micro-morphological [38], soil pollution [39], soil health [40], and soil remediation [41–43]. In order to better understand the current research status of soil nutrient research, the scientometric review is adopted, which is conducive to show hot research topics in this field and their evolution. Perspectives are also given to promote further studies to fill knowledge gaps.

2. Material and Methods

The datasets on soil nutrient were searched from the database of the Web of Science Core Collection (WoSCC), including the Science Citation Index Expanded (SCI-EXPANDED, since 1992) and Social Sciences Citation Index (SSCI, since 2004). The data from January 1992 to December 2020 were downloaded from the WoSCC for analysis. The query sets used in the advanced search mode of WoSCC collection were: TS = ("soil fertility" OR "soil nutrient" OR "soil nutrition" OR "soil fertilizer" OR "soil fertilization" OR "plant nutrient" OR "plant nutrition" OR "chemical fertilizer" OR "organic fertilizer" OR "green manure" OR "inorganic fertilizer" OR "mineral fertilizer" OR "nitrogen fertilizer" OR "phosphorus fertilizer" OR "potassium fertilizer" OR "calcium fertilizer" OR "magnesium fertilizer" OR "sulphur fertilizer" OR "micronutrient fertilizer" OR "fertilizer with inhibitor" OR "Controlled-Release Fertilizer" OR "Slow-release fertilizer" OR "dry fertilizer" OR "Water-soluble Fertilizer") OR TS = ((compost OR manure OR "sewage sludge") AND (agricultur* OR farmland OR grassland OR forest OR ecosystem)), where TS indicates "topics" in Web of Science. Document types of publications containing "Article" OR "Book" OR "Book Chapter" OR "Data Paper" OR "Database Review" OR "Letter" OR "Note" OR "Review" written in English were retained. The resulted documents were exported as a text file with the "full record and citation data" for bibliometric analysis. This returned a total number of 51,640 publications.

Data visualization was analyzed using software tools containing the VOSviewer 1.6.15, HistCite Pro, and CiteSpace 5.6.R3. VOSviewer, as a freely available computer program, is developed for constructing and viewing bibliometric maps, and is especially useful for displaying large bibliometric maps in an easy-to-interpret way [44]. The co-authorship of authors/organizations/countries was performed using the VOSviewer. The full counting method was used in this paper, and publications with maximum 25 authors per document were kept for analysis by default. The default settings excluded 1232 publications for analysis that exceeded 25 authors per article. HistCite Pro, a modified version based on the original HistCite, was sorted the leading status of authors/institutions/countries depending on total global citation (TGCS) and total local citations (TLCS) [45]. CiteSpace can be applied to track the development of a field closely and extensively and provide a network analysis, which is used for the treatment and presentation of results [46]. Keywords with the strongest burst citations were found using CiteSpace, which vividly showed the research topics in this field. Figures in this study were produced using VOSviewer 1.6.15, Origin 2021, and Arc GIS 10.8.

In order to rank the overall contributions of journals/authors/institutions/countries and to eliminate the dimensional influence among indicators provided by the bibliometric software tools, the sum of normalized data (SND) method was adopted [47]:

$$SD = \frac{(X - X_{\min})}{(X_{\max} - X_{\min})} \tag{1}$$

$$SND = SD_1 + SD_2 + \cdots SD_n \tag{2}$$

where $X_{\max}$ and $X_{\min}$ are the maximum and minimum value of sample data, respectively, and n represents different indicators.

3. Results and Discussion

3.1. Publication Outputs Analysis over the Years

The annual number of publications and citations per paper between 1992 and 2020 are shown in Figure 1. The number of publications increased significantly from 1992 to 2020, from 480 publications in 1992 to 4614 in 2020. This is similar to results from previous studies pertaining to soil fertilizer [48] and soil monitoring [33]. The increasing trend may be attributed to the "green revolution" that is associated with the greater input of chemical fertilizer for greater yield [49–51], which intrigues scholars in the soil nutrient research field. In addition, easier access to online literature compared to library subscriptions since 1990 could be another reasons [32]. The number of citations per publication showed a fluctuated increasing trend from 1992 to 1998, reaching a peak value of 55.4 in 1998. It showed a decreasing trend thereafter, with only 1.1 in 2020. This value showed a general decreasing trend since 1999, especially after 2009, which could be attributed to the rapidly evolved research topics, high volume of publications, and shorter time for accumulating citations [32]. The trend of citations per publication was basically similar with the study result for soil fertilizer (from 2007 to 2016, there was a decreasing trend) [48].

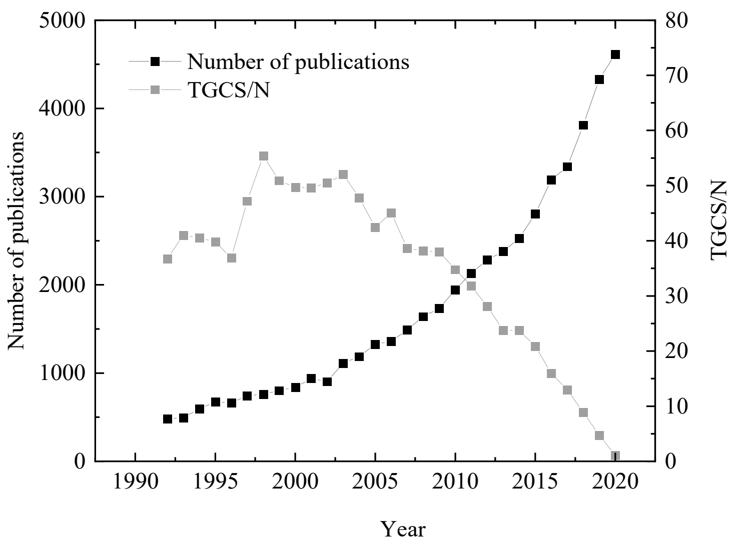

Figure 1. Annual number of publications and citations per article in soil nutrient field from 1992 to 2020.

3.2. Analysis of Primary Journals

A total of 2498 journals published research on soil nutrients. The top 10 productive journals are shown in Figure 2. *Communications in Soil Science and Plant Analysis* (1239 publications) made the highest contributions to the total number of publications, accounting for

14.4% of total publications, followed by *Science of the Total Environment* (1106 publications), *Agriculture Ecosystems & Environment* (1071 publications), and *Plant and Soil* (1061 publications), each accounting for 12~13%. There were no significant differences among the other five journals, including the *Journal of Environmental Quality* (760 publications), *Soil Biology & Biochemistry* (740 publications), *Journal of Plant Nutrition* (700 publications), *Nutrient Cycling in Agroecosystems* (678 publications), and the *Agronomy Journal* (667 publications) in terms of the total number of publications.

According to Table 1, *Agriculture Ecosystems & Environment* had the maximum TLCS (=12,048) and TGCS (=46,115). There was a large gap when *Agriculture Ecosystems & Environment* was compared to *Communications in Soil Science and Plant Analysis* (with TLCS = 2407 and TGCS = 9917). *Science of the Total Environment* has the greatest impact factor according to Journal Citation Report in 2019 (IF2019 = 6.6) and the greatest TGCS per year (TGCS/t = 4173). There was a significant difference when *Science of the Total Environment* was compared to *Communications in Soil Science and Plant Analysis* (IF2019 = 0.767 and TGCS/t = 741) and the *Journal of Plant Nutrition* (IF2019 = 1.132 and TGCS/t = 522). In addition, publications in *Soil Biology & Biochemistry* were highly cited with 58.9 citations per article, ranking first among journals (data not shown). According to synthetic parameter (sum of normalized data (SND)), *Agriculture Ecosystems & Environment* ranked the first with SND = 4.30, followed by *Soil Biology & Biochemistry* with SND = 3.72 and *Science of the Total Environment* with SND = 3.70. Therefore, they are the leading journals in this field.

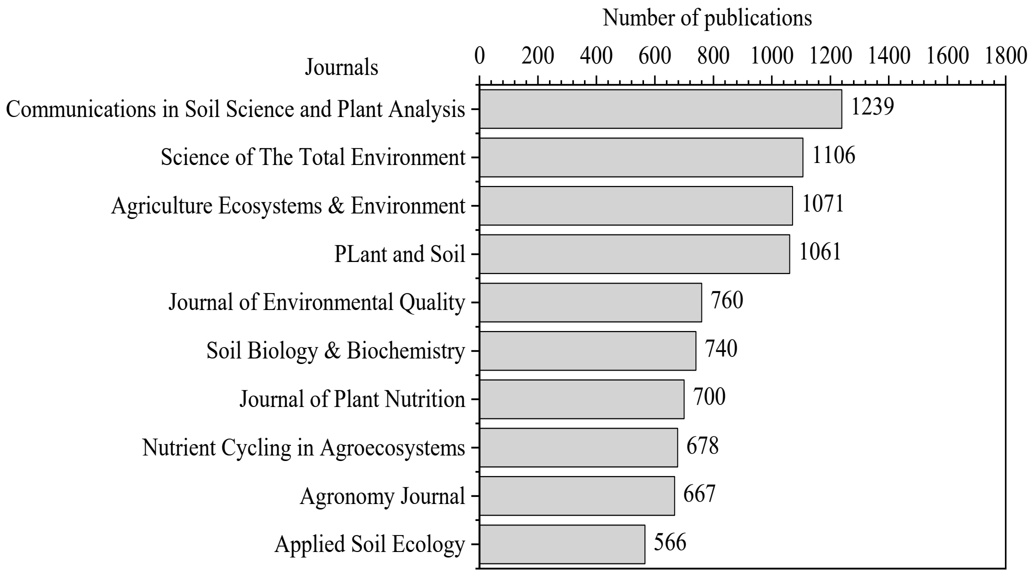

Figure 2. Top 10 productive journals in soil nutrition research between 1992 and 2020.

Table 1. Top 10 productive journals in soil nutrition research between 1992 and 2020.

Journals	N	TLCS	TGCS	IF	TGCS/t	SND
Communications in Soil Science and Plant Analysis	1239	2407	9917	0.767	741	1.25
Science of the Total Environment	1106	5219	27,645	6.551	4173	3.70
Agriculture Ecosystems & Environment	1071	12,048	46,115	4.241	3972	4.30
Plant and Soil	1061	9200	43,105	3.299	3164	3.56
Journal of Environmental Quality	760	8761	34,148	2.142	2140	2.36
Soil Biology & Biochemistry	740	9955	43,600	5.795	3612	3.72
Journal of Plant Nutrition	700	1308	6524	1.132	522	0.26
Nutrient Cycling in Agroecosystems	678	7162	20,013	2.45	1390	1.58
Agronomy Journal	667	4458	16,512	1.683	1192	1.04
Applied Soil Ecology	566	3857	14,952	3.187	1540	1.15

Note: TLCS, total global citation; TGCS, total local citations; IF, Journal impact factor trend 2019; TGCS/t, total global citation per year; SND, sum of normalized data (original data used for calculating SND include N (number of publications), TLCS, TGCS, IF, and TGCS/t).

3.3. Analysis of Authors, Institutions, and Countries

When 20 was set as the minimum number publications per author using the VOSviewer, the co-authorship network map of authors included 222 authors who had 2003 total link strength (TLS) and obtained 183 clusters closely linking with each other. However, some labels did not show due to overlap. For example, label of Christie Peter (China Agricultural University, China) in the dark blue network was overlapped by the label of Ken E Giller (Wageningen University, Netherlands) in the pink network (Figure 3). Among others, it was found Ken E Giller with 147 publications, Qirong Shen (Nanjing Agricultural University, China) with 133 publications, and Rattan Lal (Ohio State University, USA) with 131 publications were the top three productive researchers in soil nutrient field (Figure 3 and Table 2). In recent years, Ken E Giller is among the most active researcher in the topic of soil fertilizer [52–54]. Giller's publications were highly cited [55], accounting for 19% of 9647 total citations (Table 2). Rattan Lal (Ohio State University, USA) has focused on surface layer of carbon and nitrogen [56], the soil-plant system [57], and the variability of soil organic matter [58]. These papers had profound influence on the soil nutrient field because of their higher citations [59,60], accounting for 42% of 11,097 total citations (Table 2). It is noteworthy that papers written by Andrew Sharpley also obtained higher citations [61,62], accounting for 39% of 11,565 total citations (Table 2). The results indicate that these highly cited papers play a very important role in soil nutrition field, and the authors (Ken E Giller, Rattan Lal, and Andrew Sharpley) play a role in advancing this field. In addition, Andrwe Sharpley and Rattan Lal are the most influential figures in the soil nutrient field due to their high total citations and citations per publication (Table 2). For instance, each publications of Andrew Sharpley was cited 132.9 times on average, which was significantly higher than others. Recently, Andrew Sharpley has been the most active researcher on topic of soil phosphorus fertilizer loss [63–65] and agricultural soil pollution [66], while he has not been closely linked with others. Qirong Shen ranked the first in terms of collaborating with other authors, with the greatest TLS of 846, followed by Bernard Vanlauwe (International Institute of Tropical Agriculture, Nigeria) with TLS = 545, Ken E Giller with TLS = 543, and Minggang Xu (Chinese Academy of Agricultural Sciences, China) with TLS = 513 (Figure 3 and Table 2). According to synthetic parameter of SND, Ken E Giller ranked first with SND = 2.32, followed by Rattan Lal with SND = 2.16, Qirong, Shen with SND = 2.15, and Andrew Sharpley with SND = 1.37 (Table 2). These scholars are the top influential authors in this field.

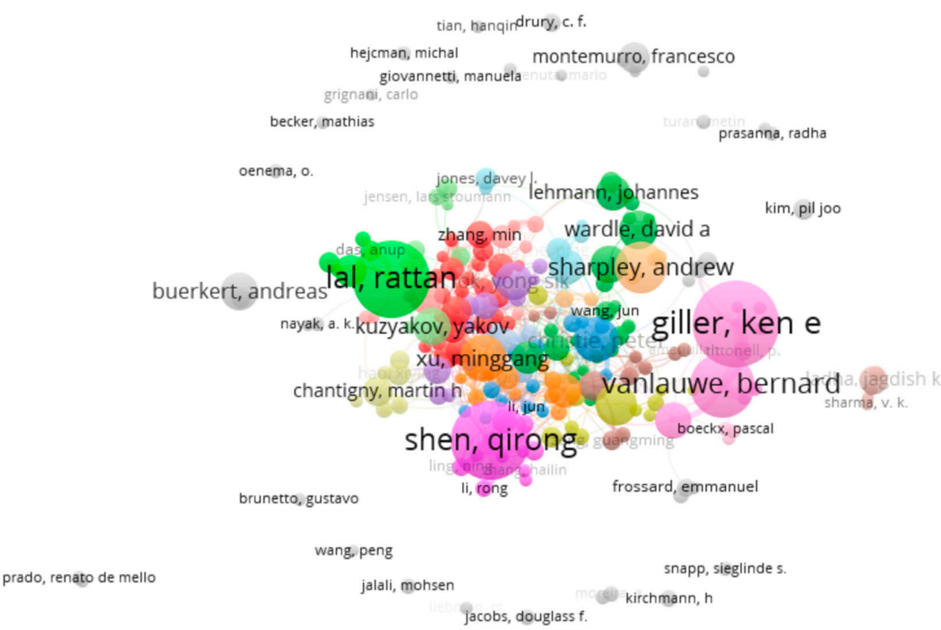

Figure 3. The network map of co-authorship analysis of authors between 1992 and 2020.

Table 2. Top 10 productive authors/institutions/countries in soil nutrition research from 1992 to 2020.

NO.	Items	N	TC	TLS	SND	TC/N
	Top 10 Authors					
1	Giller, Ken E. (Wageningen University, Netherlands)	147	9647	543	2.32	65.6
2	Shen, Qirong (Nanjing Agricultural University, China)	133	4326	846	2.15	32.5
3	Lal, Rattan (Ohio State University, USA)	131	11,097	478	2.16	84.7
4	Vanlauwe, Bernard (Int Inst Trop Agr, Nigeria)	108	4339	545	1.36	40.2
5	Sharpley, Andrew (University Arkansas, USA)	87	11,565	292	1.37	132.9
6	Xu, Minggang (CAAS, China)	77	2155	513	0.73	28.0
7	Christie, Peter (China Agricultural University, China)	76	2677	415	0.60	35.2
8	Olesen, Jorgen E. (Aarhus University, Denmark)	68	2306	279	0.25	33.9
9	Wardle, David A. (Nanyang Technol University, Singapore)	64	3909	262	0.32	61.1
10	Buerkert, Andreas (University Kassel, Germany)	63	978	241	0.00	15.5
11	Kuzyakov, Yakov (University Gottingen, Germany)	63	1559	369	0.27	24.7
12	Ok, Yong Sik (Korea University, Korea)	63	4178	390	0.55	66.3
	Top 10 organizations					
1	Chinese Academy of Sciences (China)	2579	61,078	2069	3.00	23.7
2	USDA ARS (USA)	1577	55,055	1214	1.92	34.9
3	Agr& Agri Food Canada (Canada)	880	25,193	473	0.61	28.6
4	University Chinese Academy Sciences (China)	735	8160	984	0.50	11.1
5	University Florida (USA)	693	20,361	377	0.37	29.4
6	Chinese Academy of Agricultural Sciences(China)	687	13,336	671	0.40	19.4
7	China Agricultural University (China)	665	13,839	608	0.37	20.8
8	Swedish University Agricultural Sciences (Sweden)	550	22,033	275	0.28	40.1
9	Wageningen University (Netherlands)	527	18,042	346	0.23	34.2
10	Nanjing Agricultural University (China)	514	14,712	354	0.17	28.6
	Top 10 countries					
1	USA	10,789	399,320	5876	3.00	37.0
2	China	8772	165,595	4472	1.83	18.9
3	India	3264	58,926	959	0.20	18.1
4	UK	3197	140,102	4384	1.12	43.8
5	Germany	3079	108,578	3457	0.83	35.3
6	Canada	2909	88,035	1858	0.43	30.3
7	Brazil	2698	42,463	1476	0.20	15.7
8	Australia	2516	94,612	2635	0.56	37.6
9	Spain	2362	69,576	1823	0.31	29.5
10	Italy	1852	45,912	1500	0.12	24.8

Note: N, total number of publications; TC, total citations; TLS, total link strength; TC/N (equal to TGCS/N), citations per publication. Int Inst Trop Agr, International Institute of Tropical Agriculture; CAAS, Chinese Academy of Agricultural Sciences. SND, sum of normalized data (original data include N, TC, and TLS).

When 100 was set as the threshold of the minimum number of publications per institution or per country, institutions were grouped into 144 clusters with TLS = 11,078, and countries were grouped into 73 clusters with TLS = 28,376. The top 10 most contributing institutions in this field are shown in Table 2. It was found that the ChineseAcademy of Sciences (China), with 2579 publications, made the most contributions, followed by the USDA ARS (USA), with 1577 publications. Agr& Agri Food Canada (Canada) had 880 publications, the University of Chinese Academy Sciences (China) had 735 publications, and the University of Florida (USA) had 693 publications. The top two institutions with the greatest total publication citations were the Chinese Academy of Sciences and the USDA ARS, with 61,078 and 55,055 citations, respectively. Their citations were considerably higher than other institutions, while per article citations of the Chinese Academy of Sciences were only 23.7, ranking sixth among the top 10 institutions. In addition, the Chinese Academy of Sciences was the most active organization that was in close connection with others, as indicated by the greatest total link strength of 2069. Although the number of publications for the Swedish University of Agricultural Sciences (Sweden) and Wageningen University (Netherlands) were only 550 and 527, respectively, roughly accounting for 1.0%, their respective per article citations were 40.1 and 34.2, ranking first and third. The Chinese Academy of Sciences obtained the greatest SND of 3.00, and the USDA ARS ranked second with SND = 1.92. Their SND were much greater than other organizations, which may indicate that the Chinese Academy of Sciences and the USDA ARS are the most impactful organizations in this field.

The top 10 most contributing countries in this field are shown in Table 2, and the distribution map of number of publications for the 180 contributing countries are shown in Figure 4. USA (with 10,789 publications) was the most productive country, accounting for 20.9% of the total publications, while the second most contributing country was China (with 8772 publications), accounting for 17.0%. The number of publications for the other top 10 countries was relatively small compared to USA and China, ranging from 3264 for India to 1852 publications for Italy. There were big differences in the total citations among countries as well. UK ranked the first in per publication citations with TC/N = 43.8. The most productive country, USA, ranked third with TC/N = 37, and China ranked eight with TC/N = 13.0. In addition, USA, China, and UK, with TLS = 5876, 4472, and 4384, respectively, were the most active countries in international collaboration. In addition, India showed a weaker international collaboration. USA, China, and UK were the top three countries leading soil nutrient studies according to SND.

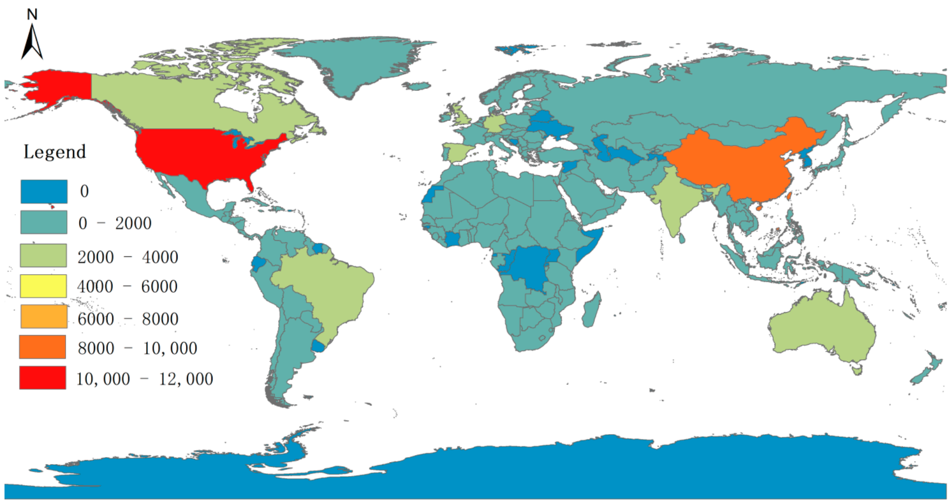

Figure 4. The distribution map of number of publications of countries between 1992 and 2020.

3.4. Analysis of Keywords

Keyword burst detection in the documents was analyzed by the CiteSpace to illustrate research hot spots in a specific period. The red dotted lines in Figure 5 are heat bars, representing the time period with the strongest citation bursts [67]. Hot topics of soil nutrient field could be divided into three stages: (1) The topic of soil nitrogen (with keywords of nitrate, N^{15}, denitrification, nitrogen fixation, ammonium, and aluminum) and crop (corn, tree and legume) became a research hot spot between 1992 and 2009. During this period, there were many theoretical studies on soil nutrition [68–71]. The relationships between soil fertilizers and plants were also gradually studied by scholars [72–74]. (2) The research directions were then gradually shifted to focus on soil pollution (with keywords of loss, litter, and population), forest (e.g., agroforestry, forest soil, and deforestation), and farmland manure (e.g., cattle slurry and broiler litter). The hot study region and climate was West Africa and Savanna, respectively. Scholars were interested in the research of maintaining soil fertility in West Africa [75,76], likely with the goal of improving the environment and the inherent poor soil fertility in West Africa [76], which could increase crop yield and reduce starvation and malnutrition [77,78]. (3) Between 2015 and 2020, soil health (including charcoal, biochar, and physicochemical property) and ecosystem service (e.g., biochar, physicochemical property, greenhouse gas emission, and pyrolysis temperature) became the hot research topics due to the increased concern on agricultural sustainability with the goal of food security. Our analysis indicated that soil nitrogen fertilizer, soil pollution, and soil health are of great importance in soil nutrient field. Scholars have tried to find the best solutions for soil pollution, using farmyard manure, bacteria, and biochar to remediate/reclaim soil properties [79–81]. These papers included topics of nitrogen fertilizer [61], nitrate [82], green manure [83], nitrogen loss [84], biochar [85], and microbial communities [86], which obtained higher citations. Biochar can impact soil biota [85], and microorganisms play a regulating role in soil nutrition [87–89], as they have reinforced soil nutrition health [90,91]. Therefore, these themes of nitrogen fertilizer, green manure, biochar, and microbial communities have been favored by authors. The soil remediation of biochar may become a breakthrough in the management of soil nutrients, as it had highest strength burst (Figure 5).

Keywords	Year	Strength	Begin	End	1992 - 2020
Nitrogen	1992	90.11	1992	2002	
Soil	1992	80.01	1992	2002	
Nitrate	1992	65.28	1992	2005	
Green manure	1992	60.06	1992	2001	
Growth	1992	51.16	1992	1997	
Corn	1992	46.87	1992	2006	
Fixation	1992	46.18	1992	2005	
Infection	1992	43.74	1992	2009	
N 15	1992	41.03	1992	2006	
Field	1992	39.95	1992	2001	
Denitrification	1992	37.70	1992	2005	
Legume	1992	35.03	1992	2001	
Plant	1992	34.15	1992	1997	
Nitrogen fixation	1992	34.07	1992	2003	
Ammonium	1992	31.23	1992	2007	
Tree	1992	25.66	1992	2005	
Seedling	1992	24.47	1992	2000	
Enrichment	1992	24.20	1992	2001	
Soil fertility	1992	24.19	1992	2001	
Aluminum	1992	21.07	1992	2009	
Root	1992	20.76	1992	2004	
Losse	1992	55.31	1993	2008	
Ecosystem	1992	39.01	1993	2003	
Agroforestry	1992	28.07	1993	2007	
Cattle slurry	1992	27.92	1993	2007	
Litter	1992	24.25	1993	2006	
Herbivory	1992	23.60	1993	2008	
Movement	1992	22.24	1993	2012	
Population	1992	57.45	1994	2008	
Pasture	1992	44.17	1994	2008	
Forest soil	1992	32.26	1994	2006	
Cultivation	1992	32.18	1994	2004	
Alfalfa	1992	22.61	1994	2010	
Leave	1992	21.50	1994	2005	
Model	1992	61.59	1996	2007	
West africa	1992	28.71	1997	2008	
Savanna	1992	28.55	1997	2009	
Runoff	1992	38.79	1998	2008	
Fallow	1992	37.56	1998	2009	
Drainage	1992	29.71	1999	2008	
Agricultural phosphorus	1992	21.04	2001	2010	
Deforestation	1992	21.08	2003	2008	
Broiler litter	1992	22.90	2008	2014	
Charcoal	1992	24.76	2012	2015	
Conservation agriculture	1992	21.05	2015	2020	
China	1992	55.34	2016	2018	
Ecosystem service	1992	28.29	2016	2020	
Co digestion	1992	22.26	2016	2020	
Biochar	1992	107.71	2017	2020	
Greenhouse gas emission	1992	31.89	2017	2020	
Pyrolysis temperature	1992	28.39	2017	2020	
Stoichiometry	1992	25.82	2017	2020	
Soil health	1992	25.40	2017	2020	
Physicochemical property	1992	23.31	2017	2020	

Figure 5. Top 54 keywords with the strongest citation bursts in soil nutrition research from 1992 to 2020.

4. Conclusions

The scientific literature data on soil nutrient were analyzed from scientometric perspectives. The results showed that the number of publications has increased remarkably from 1992 to 2020, while per article citations peaked in 1998 and then dropped during 1992–2020. *Agriculture Ecosystems & Environment*, *Soil Biology & Biochemistry* and *Science of the Total Environment* were the leading journals in this field. The Chinese Academy of Sciences (China) and USDA ARS (USA) made the most contributions to number of publications and total link strength, having strong collaborations with other institutions. USA and China were the top two contributing countries and had close cooperative relationships with others. USA was the most influential country according to its greatest total citations. The authors Ken E Giller from Netherlands, Qirong Shen from China, and Rattan Lal from USA were the leading authors in terms of the number of publications. Andrew Sharpley from USA was as the leading author in terms of the total citations and per article citations. For keyword analysis, soil nitrogen fertilizer, green manure, and soil population are ongoing hot topics because of their strongest burst strength in recent years. Recently, soil health, as indicated by keywords of microbial communities and amendment soil of biochar, has been paid close attention by researchers. For the sake of resilience to climate change and to increase the sustainability of soil productivity, the regenerative agriculture that aims to regenerate topsoil, increase biodiversity, improve the water cycle, enhance the ecosystem service, support biosequestration, and strengthen the health and vitality of farm soils could be among the future hot topics [92].

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