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THE SOIL ORGANIC MATTER DECOMPOSERS: A BIBLIOMETRIC ANALYSIS

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ABSTRACT

The growing global concern about sustainable food systems has driven the search to know the impact of Soil Organic Matter (SOM) decomposers on SOM formation, stabilization and loss. Soil organic matter is the major inorganic nutrient pool for agricultural productivity and long-term soil sustainability. Globally, scientists use bibliometric analysis to map the body of knowledge and identify the trends in research topics by understanding the development and scientific contribution of a particular field of knowledge. This article provides a bibliometric examination of the effectiveness and development of soil organic matter during the period 2012 to 2022 based on documents published in journals indexed in SCI-Expanded in the Web of Science. According to the survey, the 1723 documents under examination were written by 5886 authors. The annual growth rate of research on soil organic matter is declining (-12.82%). From 1723 documents examined, Kuzyakov Y (n = 35) was the most prolific author, the University of Chinese Academy of Sciences (n = 98) was the most active institution, and Soil Biology & Biochemistry (n = 126) was the most popular journal. The USA and the Peoples' Republic of China are the most prominent nations with the strongest collaboration in soil organic matter-related research. The results of this study can guide future research and provide crucial details for sustainable soil management.

Keywords: Bibliometric, Bibliographic coupling, Co-citation, Collaboration index, VOSviewer, Soil organic matter, Decomposers, Diversity.

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1. INTRODUCTION

Soil may appear as an inert material; however, it is the stomach of the earth, consuming, digesting, and cycling nutrients and organisms. The living organisms in the soil could be either macro and/or micro-organisms. These organisms are involved in various activities that invariably affect the physical, chemical, and biological component/fertility of the soil among which include the soil organic matter decomposition.

Soil organic matter is a basic component of healthy soil ecosystems and it plays important roles related to diverse soil functions, sustainability, fertility and productivity (Lal, 2020). All living organisms compose majorly of carbon and after their deaths, they decompose back to form soil, therefore, the fundamental component of soil organic matter are plant and animal remains at different stages of decomposition. Soil organic matter comprises plant and animal components which degrade speedily and produce more labile compounds such as sugar that persist longer in the soil (Grandy and Neff, 2008). The largest portion of organic carbon in soil is from the plant tissue whose composition varies greatly among species, physiological age, and ecological conditions (Paul and Clark, 1996).

The community of soil organic matter decomposers include a wide array of organisms such as bacteria (actinobacteria and proteobacteria), fungi (ascomycetes and basidiomycetes) and invertebrates such as nematodes, microarthropods, and earthworms (Schimel and Schaeffer, 2012; Johns, 2017). Although bacteria are said to be the most active decomposer, fungi on the other hand are involved in many transformation processes including organic matter decomposition in soil (Berg and McClaugherty, 2014). The quantity and quality of the organic litter or faeces, edaphic factors, micro, and macroclimate influence the biomass and activities of decomposers as well as their numbers (Eisenhauer *et al.,* 2018). This invariably affects the decomposition process such as nutrient cycling and transformation of nutrient elements within the soil. It has been estimated that a gram of soil contains over a billion organisms (Johns, 2017), these decomposers play a critical role in the flow of energy and are fundamental to the abundance of soil organic matter throughout the ecosystem.

Fundamentally, the formation of soil organic matter is not a straightforward process, it involves different stages – formation, stabilization and degradation (Schmidt *et al*., 2011). The process is very fast at the onset however gradually slows down towards the end. It is a complex and biologically mediated process which involves diverse organisms (decomposers) leading to the production of organic biopolymers that interacts with soil minerals and aggregates for stability (Frey, 2019). The process involves the physical breakdown and biochemical transformation of complex organic molecules of dead material into simpler organic and inorganic molecules.

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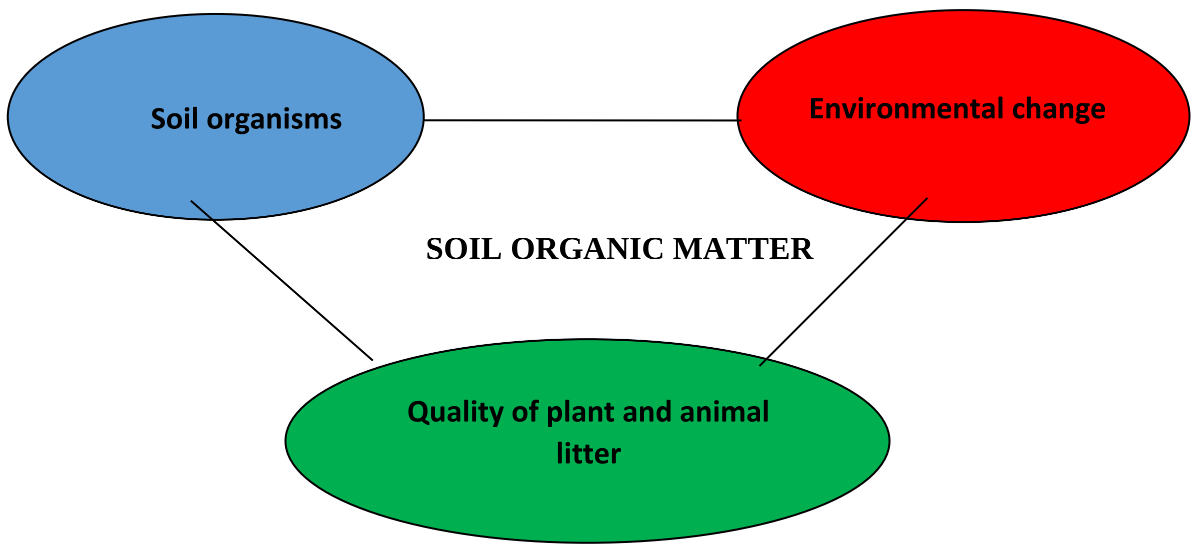

Figure 2: Factors of soil organic matter formation

This in turn releases essential nutrient and carbon compounds that are available for plant uptake and microbial growth respectively (Frey, 2019). Soil organisms are the most important and diverse group creating a unique linkage between aboveground and belowground ecosystem functions and processes while ensuring the decomposition of soil organic matter and plant litter (Zeng *et al.*, 2017). Frey, 2019 reported that some classes of fungi such as arbuscular mycorrhiza fungi do participate actively in the formation, distribution, and stabilization of organic matter. Fungi also produce metabolites (Wang *et al.*, 2017), which enhance mineral retention and stabilization.

Frey (2019) stated that arbuscular mycorrhiza fungi (AMF) are directly or indirectly involved in SOM decay through hydrolytic and oxidative activities. AMF are not saprotrophs, however, through facilitated decomposition of SOM by stimulating the activities of the free-living saprotrophic organisms through rhizosphere priming. The distribution and activities of soil fauna such as molluscs and earthworms are determined by the abundance of soil organic matter (Mansingh *et al.*, 2021). Angst *et al*. 2019 reported that earthworm converts labile plant compounds into microbial necromass thereby increasing soil resilience and sustainability.

Accumulation of soil organic matter is affected by many factors such as environmental changes (Hu *et al.*, 2018), macro and microorganisms (Morrissey *et al.*, 2017), and the quality of plant and animal litter (Cordova *et al.*, 2018). Figure 2 shows the major factors that contribute to soil organic matter formation. Environmental factors such as temperature, soil moisture content, and soil physical and chemical properties have been identified as factors that control soil organic

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matter decomposition. Wang *et al.,* 2016 reported a significant interaction between soil moisture and temperature in an incubation study.

The process involves the breakdown of plant and animal materials into simpler organic and inorganic substances. Plant and animal materials pass through the process of decomposition which is majorly biological with activities of different macro and microorganisms at each stage (Table 1).

Table 1: Stages of organic matter residue decomposition and the organisms involved (Patil *et al*., 2019)

Stages of decomposition	Organisms
Consumption of plant and animal litter	Macro and Meso Fauna - Earthworms, termites, molluscs
Cellulose	Fungi: Penicillium, Aspergillus, Trichoderma
	Bacteria: Streptomyces, Pseudomonas, Cellulomonas, Clostridium thermocellum
Hemicellulose	fungi, bacteria, actinomycetes
Chitin	actinomycetes, Streptomyces, Nocardia
	Fungi, Trichoderma, verticillium
Lignin	Fungi- Basidiomycetetous, Phanerochaete, Chrysosporium

The decomposition of some plant materials such as wheat straw depends on soil moisture than soil physicochemical properties (Tulina *et al*., 2009). Other physicochemical properties such as pH serve as predictors for soil organic carbon stabilization as well as a determinant of microorganism's richness and abundance (Rasmussen, *et al.* 2018). Soil fauna consumes substantial amounts of litter and during passage through the guts of litter-feeding fauna, litter modifications include fragmentation, consumption of associated microorganisms, pH and redox changes, removal of easily decomposed polysaccharides, increase in the proportion of lignin, and decrease in soluble polyphenols and carbon: nitrogen (C: N) ratios.

Furthermore, soil organic matter decomposers play significant role in nutrient cycling, carbon sequestration, and soil fertility. The breakdown of complex organic molecules by soil organic matter decomposers results in the release of vital nutrients including nitrogen, phosphorous, and sulfur in plant-available forms (Camenzind *et al*., 2018). Through enzymatic activity,

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microorganisms like bacteria and fungus break down organic matter, allowing the release of nutrients into the soil solution. This procedure improves the availability of nutrients to plants, which has an impact on their growth, development, and ecosystem productivity (Zifcakova, 2020, Camenzind *et al.*, 2018). SOM decomposers impact carbon sequestration by dissolving organic materials and turning it into carbon dioxide (CO2), decomposers actively take part in the carbon cycle and are essential for carbon sequestration as well (Sun *et al.*, 2020). Decomposers aid in stabilizing the carbon in the soil, efficiently absorbing atmospheric CO2, and reducing climate change by assimilating organic carbon into their biomass or generating resistant organic molecules (Six *et al.*, 2006, Panettieri *et al.*, 2022).The quantity and activity of soil organic matter decomposers are directly related to soil fertility. Decomposers help create solid soil aggregates, which strengthen the soil's structure and water-holding ability (Mayel *et al.*, 2021). Additionally, they exude enzymes and metabolites that increase nutrient availability, resulting in improved plant growth and nutrient uptake. Decomposers also aid in the creation of humus, a stable type of organic matter that boosts soil fertility by retaining more nutrients and promoting soil microbial activity (Cui & Holden2015, Mayel *et al.*, 2021).

Soil organic matter accumulation, decomposition, mineralization, and stabilization depend on the quality of animal and plant litter. Cordova *et al*. 2018 reported that plant litters with a high rate of mineralization enhance the accumulation of soil organic matter than those characterized with a lower rate. From the above, it could be seen that study and/or research activities on soil organic matter cannot be said to be the responsibility of a particular discipline. A multidisciplinary approach will be required to tackle matters related to soil organic matter across the globe. Therefore, it is vital to assess the extent of existing works that contribute to the soil organic matter and their impacts.

For assessing the developments and trends in research in a particular area of interest, the bibliometric technique is helpful (Ma *et al*., 2018, Lu *et al*., 2018). The scientific influence of articles that have been published over the years is quantified using a variety of methodologies to offer ideas, concepts, and directions for future research. In the scientific community, bibliometric analysis is popular since it can be applied to mapping foci and trends associated with authors, institutions, and nations, including the identification of research gaps in a certain niche (Roldan-Valadez *et al*., 2019, Wang *et al*., 2019). Typically, sources for the mining of bibliometric data include Scopus and the Web of Science (WoS). Bibliometric reports on soil organic matter are scarce, hence, we assessed published articles on soil organic matter and scientific plots were developed to identify a collaborative index among authors, institutions, and countries, as well as top authors and journals. This paper is a condensed knowledge database that provides important information on trends and current gaps for prospective research that could impact positively soil organic matter.

2. METHODOLOGY

2.1 Extraction of data

Bibliometric analysis has been used over the years to assess the current trend and relevant research outputs in a field of interest for published articles (Kamdem *et al*., 2017, Okaiyeto *et al*., 2021). Padilla et al 2018 describe bibliometric as a retrieval tool for assessing an existing state of the art and its theoretical base. The Web of Science (WoS) was adopted to retrieve bibliometric data on research related to soil organic matter globally from 2016 to 2021. Castor *et al*. (2020) reported WoS as the most effective and widely used database for bibliometric analysis. It is the oldest citation index for science databases and was launched by the ISI in 1964 as a data recovery tool called the Science Citation Index (SCI) (Garfield, 1964). Over the years, a range of products spanning social sciences, arts, humanities and others were collated and launched on the world wide web (www) as WoS in 1997. The keywords used as a search strategy were TITLE ("Soil organic matter" OR "Decomposer"). The period of search ranged between 2012 – 2022. A collection of papers (n = 1952) were retrieved but the search was limited to documents written in English Language (n = 1884). We excluded documents written in Chinese (n = 37), Portuguese (n = 20), Spanish (n = 5), French (n = 3), Polish (n = 2) and Croatian (n = 1) due to global recognition of English language. In the WoS Citations Indexes, Science Citation Index Expanded (SCI-Expanded) is the most suitable for obtaining scientific information (Akinpelu and Nchu 2022). Hence, we refined our search to those indexed in SCI-Expanded (n = 1829). Our main goal in terms of the document type was to look for research publications and their contributions to the subject. Therefore, the search was refined to research articles only (n = 1723). These documents were exported from WoS and saved as a Bibtex file for further processing.

2.2 Data Analysis

Rstudio (v.4.1.1) was used for data analysis. The extracted data were uploaded into biblioshiny in Rstudio and analysed accordingly (Akinpelu and Nchu 2022). Subsequently, VOSviewer software version 1.6.17 was used to analyse the bibliographic coupling among authors, institutions and journals, including references and co-citation networks in soil organic matter-related research within the time limit stipulated (Van Eck and Waltman, 2010).

3. RESULTS AND DISCUSSION

3.1 Main information

In this study, current research articles on soil organic matter from 2012 to 2022 were considered. Data generated on our literature search from WoS revealed 1723 research articles (Table 2). It was observed that the articles were published in 350 sources by 5886 authors. The document's average age was 5.9 while the average number of citations per document is 28.95. The authors of

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single-authored documents were 30. The total keyword plus and the author's keywords identified from these articles were 3794 and 4636, respectively. From the table, it could be seen that there is a decline in the annual growth rate (-12.82%) of soil organic matter-related research.

Table 2: Main information on soil organic matter-related research from 2012 to 2022.

Description	Results
Timespan	2012:2022
Sources (Journals, Books, etc)	350
Documents	1723
Annual Growth Rate %	-12.82
Document Average Age	5.9
Average citations per document	28.95
References	55205
DOCUMENT TYPES	
Article	1693
article; data paper	1
article; proceedings paper	29
DOCUMENT CONTENTS	
Keywords Plus (ID)	3794
Author's Keywords (DE)	4636
AUTHORS	
Authors	5886
Authors of single-authored documents	30
AUTHORS COLLABORATION	
Single-authored documents	31
Co-Authors per Documents	5.1
International co-authorship %	40.86

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3.2 Annual Scientific Production

Figure 2a shows the annual scientific production and average total citations per year. Variations in the volume of research papers produced on a particular topic provide a critical indicator of the direction of growth (Mao et al., 2020). Understanding the state of the research as well as potential trends might benefit from a plot of publications over time with statistical analysis. There was no consistent increase in the number of publications during the time under review. The highest research output was observed in the year 2021 with 238 documents representing 13.8% of the total documents. The annual growth rate of -12.82% is a sign that the soil organic matter field is experiencing a downward research trend globally. The advancement in soilless plant cultivation research, as well as the impact of rapid development in genetically modified research on food and crop production, may have impaired the soil organic matter-related research (Barrett *et al.*, 2016, Fussy and Papenbrock 2022). Sustainable agricultural land use and management practices with reduced impact on climate change could result in new prospects for soil organic matter research.

The mean total citations per year analysed showed varying citation patterns over the period. Citations are thought to represent the quality of the research; however, occasionally this is not the case. Many factors can influence how a research document is cited. These consist of the journal's open or paid access policy and year of publication. It is normal for older papers to receive more citations than more recent ones (Aksnes *et al.*, 2019). However, as open-access journals make their content widely accessible to other academics, they receive more citations than premium-access journals. The highest citation was observed in 2015, followed by 2019.

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a)

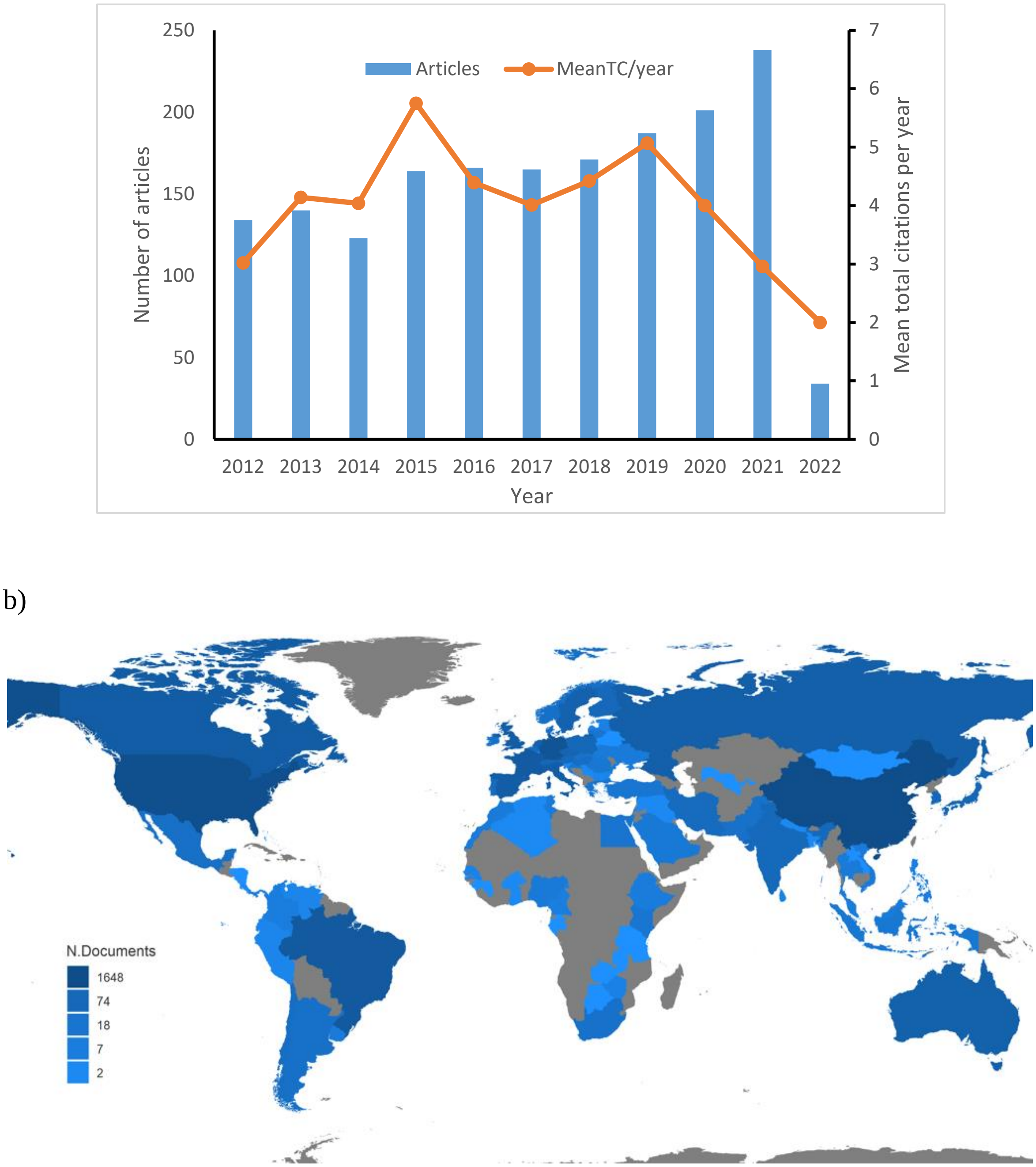

Figure 2: (a) Annual scientific production and average total citations per year on soil organic matter-related research from 2012 to 2022. (b) Country Scientific production on soil organic matter-related research between 2012 and 2022

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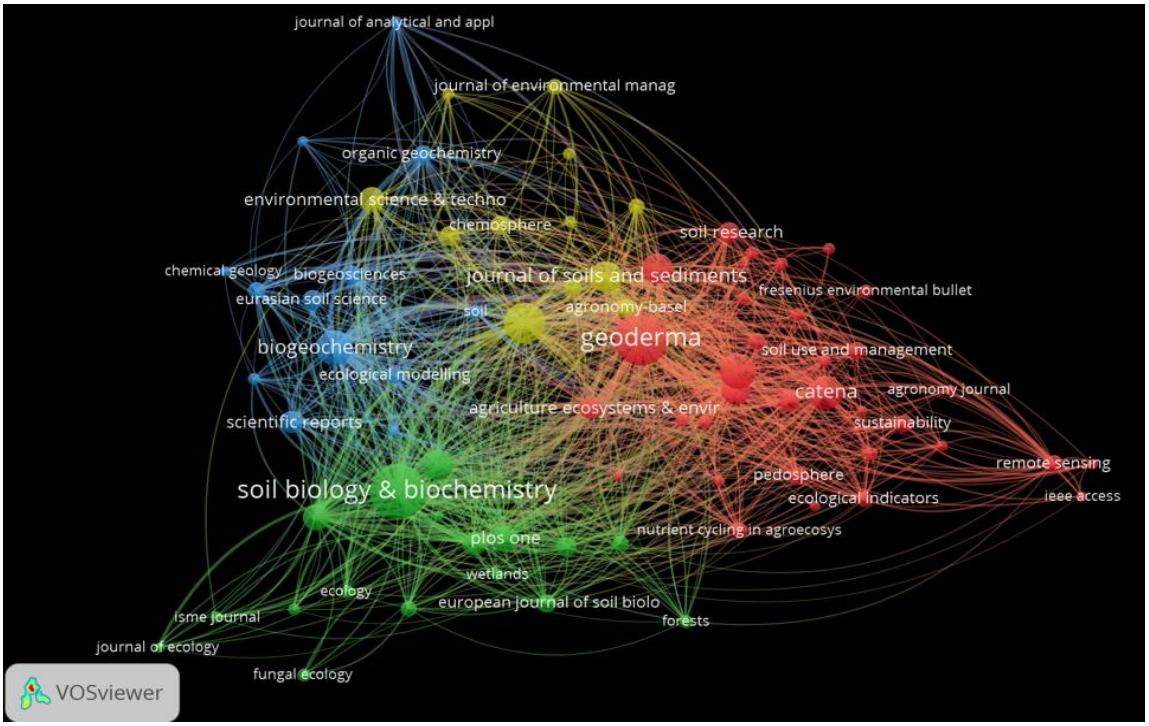
The top five nations in soil organic matter research globally are China (n = 1648), USA (n = 1324), Germany (n = 714), Brazil (n = 401) and France (n = 310). The top contributors in Africa are South Africa (n = 25), Egypt (n = 18), Kenya (n = 16), Nigeria (n = 11) and Morocco (n = 10). Figure 2b displays the countries that contributed the most, with the darker the blue, the more documents that were published. The majority of the top contributors are from economically developed or developing nations that place a high value on scientific research and publish in journals that are indexed by WoS. The data from WoS might not accurately reflect all scientific articles that have been published in a given subject because some researchers don't care about the quality of the journals or are just interested in those that publish quickly without taking visibility into account.

3.3 Bibliographic coupling analysis of authors, countries, organisations and sources

A comparison metric known as "bibliographic coupling analysis" establishes the relationship between documents based on the number of common references (Kessler 1963). To demonstrate the collaborative network in research on soil organic matter, bibliographic coupling analysis creates an information map of the study authors, institutions, and journals and confirms the likelihood that the documents treat similar issues. In this study, bibliographic coupling of authors, countries, organizations and sources was done using the fractional counting method in VOSviewer software. For sources, a minimum of five documents of a source was chosen and only 75 out of 350 sources meet the threshold. For each 75 sources, the total strength of bibliographic coupling links with other sources was calculated. The sources with the greatest total link strength are shown with four clusters in Figure 3a. Soil Biology and Biochemistry journal has the highest total link strength. For authors, a maximum of twenty-five authors per document and a minimum of five documents an author were chosen. 116 of the 6793 authors meet the threshold. For each 116 authors, the total strength of bibliographic coupling links with other authors was calculated. The authors with the greatest total link strength are shown with 12 clusters in Figure 3b. Kuzyakov, yakov has the highest total link strength. For organisations, a maximum of twenty-five organisations per document and a minimum of five documents of an organisation were chosen. Of the 1844 organisations, 230 meet the threshold. For each 203 organisations, the total strength of bibliographic coupling links with other organisations was calculated. The organisations with the highest total link strength are shown with 10 clusters in Figure 3c. Chinese Academy of Sciences has the highest total link strength. For countries, a maximum of twenty-five countries per document and a minimum of five documents per country were chosen. 56 of the 99 countries meet the threshold. For each 56 countries, the total strength of bibliographic coupling links with other countries was calculated. The countries with the greatest total link strength are shown with 9 clusters in Figure 3d. The USA has the highest total link strength, closely followed by the Peoples's Republic of China.

a)


journal of analytical and appl
journal of environmental manag
organic geochemistry
environmental science & techno
chemosphere
soil research
chemical geology
biogeosciences
journal of soils and sediments
fresenius environmental bullet
eurasian soil science
soil
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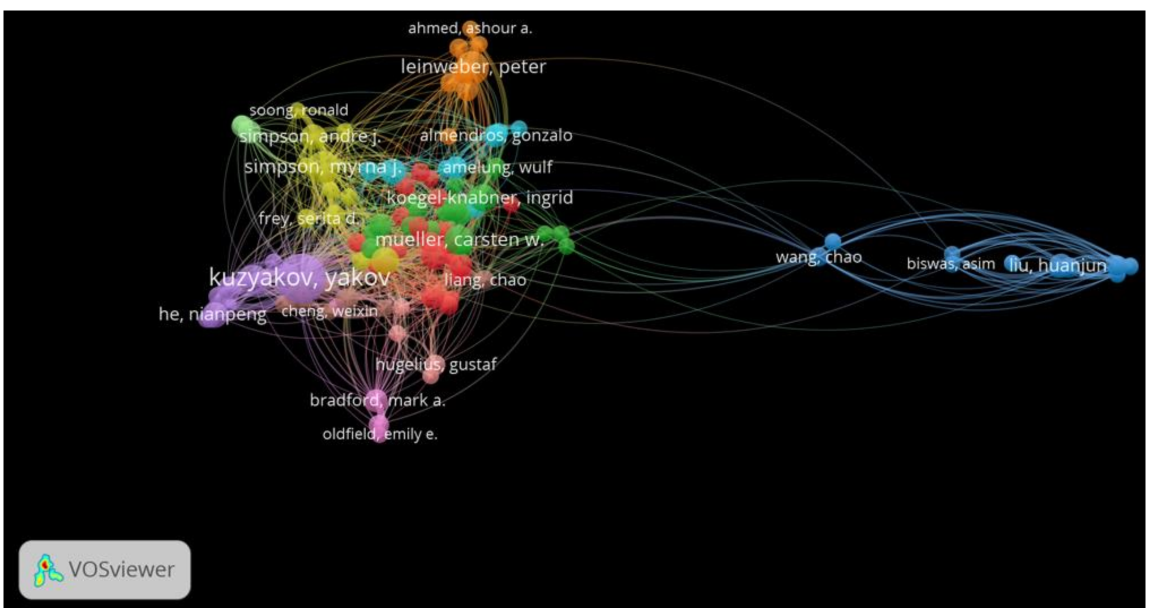
b)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koegel-knabner, ingrid
frey, serita d.
mueller, carsten w.
wang, chao
biswas, asim
liu, huanjun
kuzyakov, yakov
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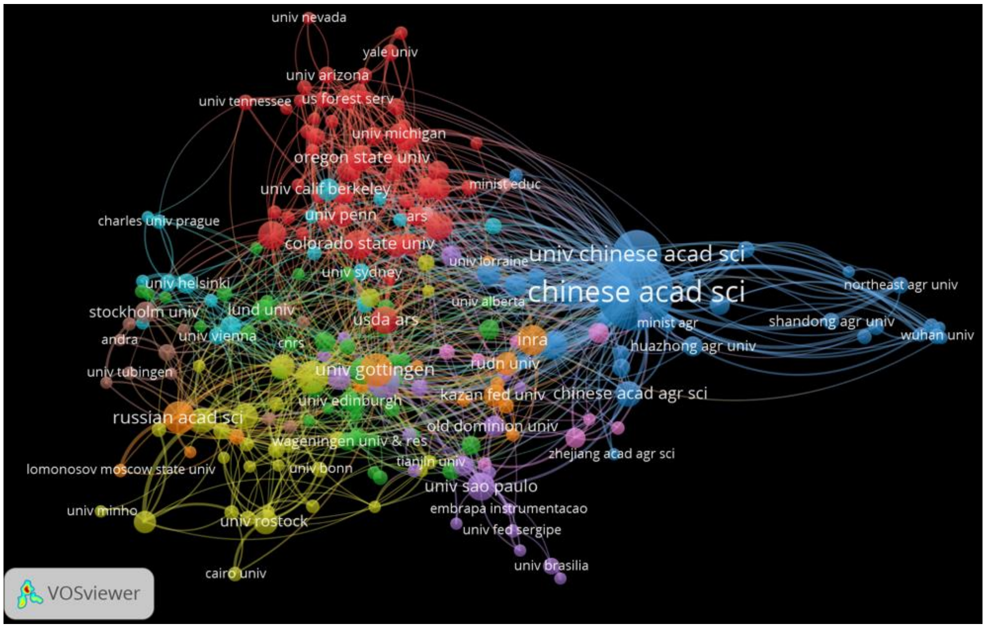
bradford, mark a.
oldfield, emily e.
VOSviewer

c)



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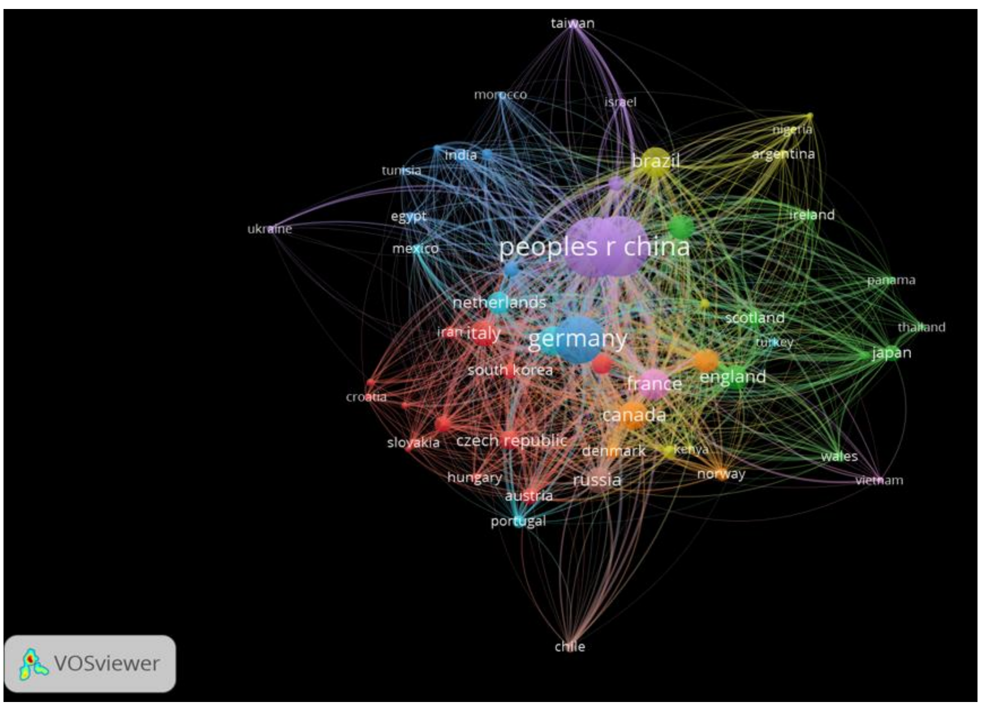
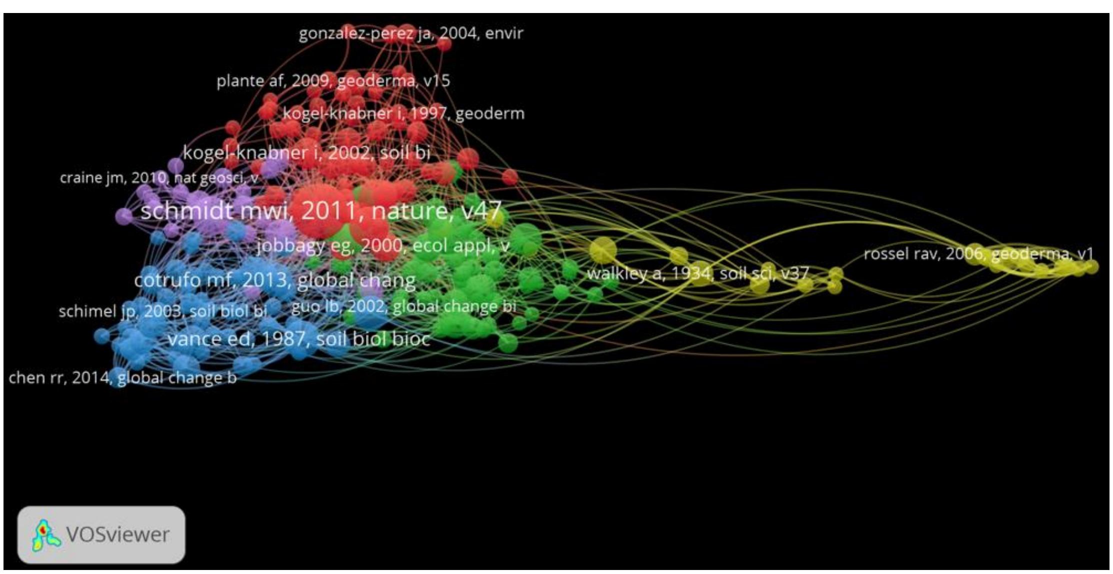


Figure 3: Bibliographic coupling analysis of sources (a), authors (b), organisations (c) and countries (d)

3.4 Co-citation network analyses

This was done to evaluate the connections or relatedness of objects, which are determined by how frequently they were referenced together in a published publication. The significant understanding of a subject or topic in a certain field may be easily determined from the majority of cited authors, sources, and references thanks to co-citation analysis, which aids in the assessment of the most pertinent papers on a particular subject (Mao *et al.*, 2020). In this study, co-citations of cited references, cited sources, and cited authors were analysed using the fractional counting method in VOSviewer Software—Figure 4. The minimum number of citations for cited references, cited sources and cited authors was set as 20 each. Of the 55064 cited references, 242 meet the threshold. For each 242 cited references, the total strength of co-citation links with other cited references was calculated. The cited references with the highest total link strength are shown in 5 clusters – Figure 4a. The most cited reference was published in Nature by Schmidt, MWI et al 2011 with 286 citations and total link strength of 284 (Schmidt *et al.*, 2011). For cited sources, 425 out of the 10742 sources meet the threshold. For each 425 sources, the total strength of co-citation links with other sources was calculated. The sources with the highest total link strength are shown in 7 clusters – Figure 4b. Soil Biology and Biochemistry journal is the most cited source with 7665 citations and total link strength of 6300.50. For cited authors, 615 of the 31922 authors meet the threshold. For each 615 authors, the total strength of co-citation links with other authors was calculated. The authors with the highest total link strength are shown in 5 clusters – Figure 4c. The most cited author is Six, J with 560 citations and total link strength of 531.27.

a)



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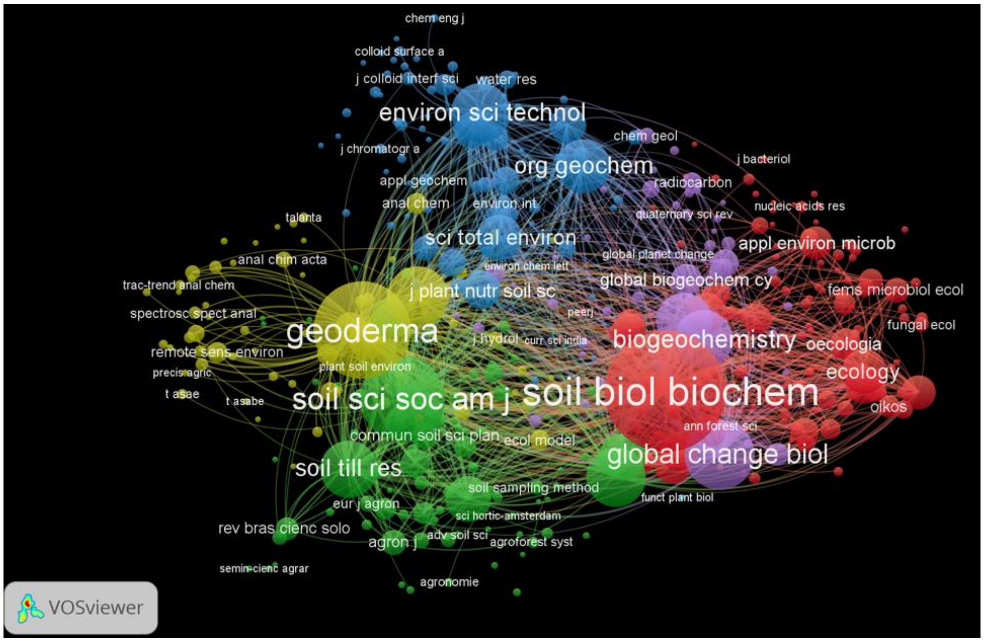

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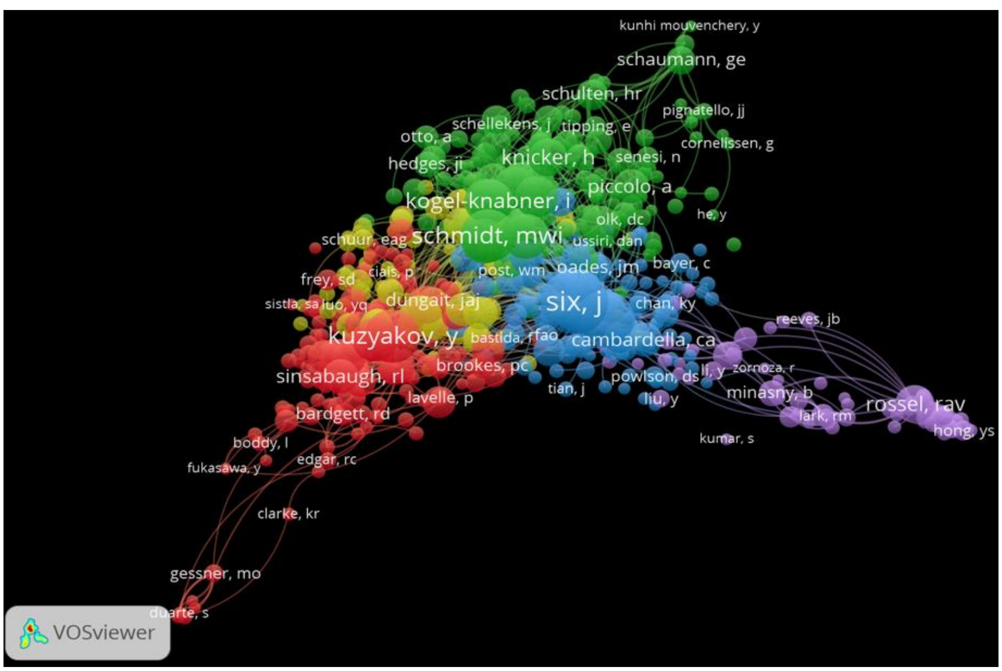

Figure 4: Co-citation analyses of cited references (a), cited sources (b), and cited authors (c) in soil organic matter related research from 2012 to 2022

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3.5 Co-occurrence of keywords

In this part, we analyzed to visualise the network of co-occurrence of keywords frequently used in the 1723 documents on soil organic matter-related research that was extracted from SCI-Expanded between 2012 and 2022. The findings are shown in Fig. 5. The magnitude of a keyword in the visualization of the keywords co-occurrence network indicates how many publications contain the term, and the distance between two keywords gives an approximation of how closely connected the terms are (Palmblad and van Eck, 2018). In this analysis, the fractional counting method and a minimum number of occurrences of a keyword were 5. Out of the 7358 keywords, 712 meet the threshold. For each 712 keywords, the total strength of co-occurrence links with other keywords was calculated. The keywords with the highest total link strength are grouped into 7 clusters – Figure 5a. The following were the top5 keywords: carbon (571 occurrences, 570 link strength), soil organic matter (445 occurrences, 439 link strength), nitrogen (343 occurrences, 343 link strength), decomposition (264 occurrences, 264 link strength), and dynamics (251 occurrences, 251 link strength). These keywords were to be a research hotspot over the last ten years among researchers, and several scholars have employed keywords to find research trends in specific fields (Liu *et al*., 2020, Guo *et al*., 2023). The number of co-occurrences of terms was used to estimate their closeness or relatedness. It is worth noting that the greater the number of articles in which two keywords appear simultaneously, the stronger the relationship between the keywords and, on average, the smaller the space between the keywords in the visualization. Figure 5b shows the word cloud of frequently used words in soil organic matter-related research.

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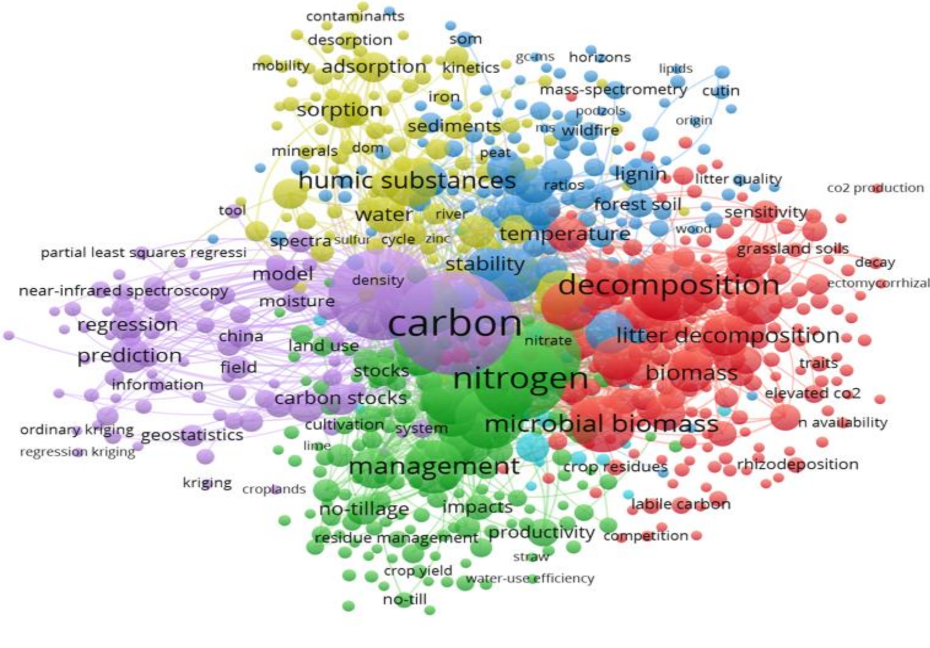
a)



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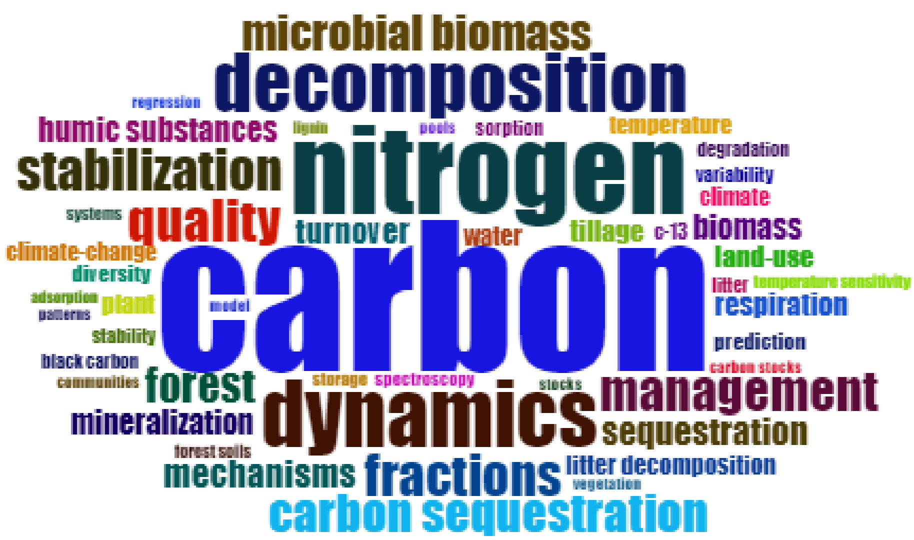

Figure 5: Co-occurrence of keywords (a) and word cloud (b) in soil organic matter-related research from 2012 to 2022

3.6 Relevant authors, journals and organisations

The relevant authors, journals and organisations were analysed in RStudio using biblioshiny. According to WoS data, 5886 authors wrote the 1723 documents considered in the analysis, with an average of 3.4 authors per document – Table 2.Analysis of authors' output and impact on citations was done with h_index. Some of the top authors are Kuzyakov, Y (n = 35, h_index = 21, total citation = 1866), Wang, X (n = 30, h_index = 14, total citation = 713), Liu, Y (n = 28, h_index = 19, total citation = 1178), Wang, J (n = 27, h_index = 17, total citation = 962), and Zhang, X (n = 26, h_index = 15, total citation = 644). The top 20 authors are shown in Table 3. Although Kuzyakov has the highest number of publications and h_index, Cotrufo MF has the highest total citation. H_index is a reliable measure of researchers' accomplishments, however, it is insufficient to appraise diverse fields (Guilak and Jacobs 2011). Similarly, citations are an inadequate means of quantifying an author's effect on a subject because various factors influence the citation of a research work. (Stern and Arndt 1999).

Table 3: Top relevant authors in soil organic matter-related research from 2012 to 2022

Author	AF	h_index	g_index	m_index	TC	NP	PY_start
KUZYAKOV Y	6.06	21	35	1.909	1866	35	2013
LIU Y	3.90	19	28	1.727	1178	28	2013
WANG J	4.88	17	27	1.417	962	27	2012
ZHANG X	4.36	15	25	1.25	644	26	2012
WANG X	5.74	14	26	1.273	713	30	2013
SIMPSON MJ	3.40	13	16	1.182	530	16	2013
CHEN Y	2.95	12	18	1	444	18	2012
ZHANG Z	3.10	12	15	1	437	15	2012
COTRUFO MF	2.86	11	12	1	3011	12	2013
PLANTE AF	3.46	11	13	0.917	704	13	2012
RUMPEL C	2.44	11	12	0.917	314	12	2012
ZHANG Y	2.74	11	18	1.222	442	18	2015
BLAGODATSKAYA E	1.68	10	10	0.833	738	10	2012

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LEINWEBER P	3.68	10	15	0.833	226	16	2012
LI Y	3.94	10	22	0.833	495	22	2012
MUELLER CW	1.85	10	11	0.833	481	11	2012
SHI Z	1.98	10	10	0.833	440	10	2012
TIAN J	1.52	10	10	0.909	538	10	2013
ZHANG J	2.49	10	15	1.111	269	15	2015
ZHOU J	2.28	10	13	1	431	13	2014

TC: total citation, NP: Number of publications, PY: Publication Year, AF: Article Fractionalised

In bibliometric analysis, the distributions of research scope in a certain field are best explained in journals and subject categories (Leydesdorff and Rafols 2009). The 1723 documents examined were published in a total of 350 periodicals. 48% of all documents are made up of the top 20 productive journals. The most significant journals on the topic are Soil Biology and Biochemistry (n = 126, IF = 8.546), Geoderma (n = 116, IF = 7.422), Science of the Total Environment (n= 67, IF = 10.754), Biogeochemistry (n = 52, IF = 4.812), and Global Change Biology (n = 30, IF = 13.211). The Soil Biology and Biochemistry journal is the most prominent with the highest h_index and total citation in soil organic matter-related research from 2012 to 2022. Table 4 shows the top 20 relevant journals.

Table 4: Top relevant journals in soil organic matter-related research from 2012 to 2022

Journal	h_index	g_index	m_index	TC	NP	PY_start
SOIL BIOLOGY & BIOCHEMISTRY	48	72	4	6043	126	2012
GEODERMA	37	55	3.083	3879	116	2012
SCIENCE OF THE TOTAL ENVIRONMENT	27	38	2.25	1780	67	2012
BIOGEOCHEMISTRY	26	46	2.167	2208	52	2012
GLOBAL CHANGE BIOLOGY	25	30	2.083	4654	30	2012

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SOIL & TILLAGE RESEARCH	23	39	1.917	1639	53	2012
CATENA	21	35	1.75	1368	50	2012
PLANT AND SOIL	19	28	1.583	877	37	2012
ENVIRONMENTAL SCIENCE \& TECHNOLOGY	18	25	1.5	983	25	2012
JOURNAL OF SOILS AND SEDIMENTS	18	27	1.5	847	42	2012
SOIL SCIENCE SOCIETY OF AMERICA JOURNAL	17	29	1.417	909	36	2012
EUROPEAN JOURNAL OF SOIL SCIENCE	16	26	1.333	778	38	2012
APPLIED SOIL ECOLOGY	14	24	1.167	667	24	2012
AGRICULTURE ECOSYSTEMS \& ENVIRONMENT	13	22	1.083	766	22	2012
BIOGEOSCIENCES	13	17	1.182	373	17	2013
BIOLOGY AND FERTILITY OF SOILS	13	16	1.182	597	16	2013
PLOS ONE	13	24	1.083	597	26	2012
CHEMOSPHERE	12	16	1.091	423	16	2013
ORGANIC GEOCHEMISTRY	11	15	0.917	327	15	2012
ENVIRONMENTAL POLLUTION	10	16	0.833	275	16	2012

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The results of the investigation into the publications linked to the leading organisations on the topic are shown in Table 5. The most prominent organisation in soil organic matter-related research is the University of Chinese Academy of Sciences with 98 publications, followed by the Institute of Soil Science with 86 publications. The table below provides information about the top pertinent organisations.

Table 5: Top relevant organisations in soil organic matter-related research from 2012 to 2022

Organisations	Number of Articles
UNIV CHINESE ACAD SCI	98
INST SOIL SCI	86
TECH UNIV MUNICH	69
UNIV GOTTINGEN	66
UNIV SAO PAULO	61
COLORADO STATE UNIV	58
INST GEOG SCI AND NAT RESOURCES RES	57
CHINA AGR UNIV	53
UNIV ROSTOCK	50
INST APPL ECOL	45
CHINESE ACAD SCI	43
UNIV TORONTO	42
UNIV HOHENHEIM	41
UNIV MINNESOTA	41
MAX PLANCK INST BIOGEOCHEM	40
NORTHEAST INST GEOG AND AGROECOL	40
IOWA STATE UNIV	37

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WAGENINGEN UNIV	36
UFZ HELMHOLTZ CTR ENVIRONM RES	35
UNIV KOBLENZ LANDAU	35

4. LIMITATIONS

The mapping of research on the soil organic matter between 2012 and 2022 is shown in this work. However, since we focused on papers indexed in the Web of Science and excluded publications indexed in PubMed and Scopus, among other scientific databases, the analysis might not be comprehensive of research publications on the issue. A bias in our analysis may have resulted from the fact that we probably did not exhaust all of the keywords related to the soil organic matter within the allotted period. Additionally, because English is the most widely spoken language in the world, we did not include any papers written in other languages, like French, in the data we pulled from SCI-Expanded, which would have left out some relevant published research articles. Also, certain scholars may have worked closely with a variety of researchers from several organisations, which has an impact on the number of publications linked to each affiliation in the study. Finally, while this study visualized research patterns on the topic, it did not examine the content of each publication to establish the scientific merit or otherwise of the work.

5. CONCLUSION

This study provided a thorough scientific global mapping of research on soil organic matter between 2012 and 2022. 5886 authors contributed to about 1723 papers that were recovered from the Web of Science. The most well-known nations with the most publications and citations were the USA and the People's Republic of China. The most relevant journals on the topic are Soil Biology & Biochemistry and Geoderma. We observed a downward trend in the annual growth rate of soil organic matter-related research which is a call for urgent action on sustainable soil management. No African country or organisation is among the top relevant nations and institutions. This study suggests government and private organisations need to show more interest in soil organic matter-related research due to its impact on climate change and human health. This study, we feel, would help researchers interested in this sector find possible collaborators and provide useful data for the efficient planning and management of soil organic matter, especially in Africa.

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DECLARATION OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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