RESEARCH ARTICLE

Mapping agroecosystems in BRICS nations: A comprehensive bibliometric and visualization analysis

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Received: March 15, 2024; **accepted:** May 1, 2024.

Healthy agricultural ecosystems underpin both environmental and societal sustainability. In January 2024, Argentina, Egypt, Ethiopia, Iran, Saudi Arabia, and the United Arab Emirates officially joined BRICS, expanding their crucial role in shaping global economies and sustainable development. To fully assess the current state of agroecosystem research in BRICS+ nations and gain an in-depth understanding of their contributions to the environmental domain, this study systematically examined the contributions of BRICS+ nations to agroecosystems using bibliometric methods. A total of 392 papers from the 2023 Web of Science database were comprehensively analyzed using tools of VOSviewer and Scimago Graphica. The criteria for data collection were the selection of English-language articles on agroecosystems from BRICS+ nations published in 2023. The key findings included enriching research by Chinese scholars, the highly cited article by Liu *et al*., the notable role of the China Agricultural University, College of Resources and Environmental Sciences, and the impact of Science of the Total Environment and Elsevier. The main research topics covered economic growth, agroecosystem management, healthy soil element cycling, and plant studies. Hot keywords included soil, rhizosphere, rice, fertilization, and use efficiency. This study provided a comprehensive and detailed framework for future research and contributed to the global sustainable development agenda.

Keywords: agroecosystems; BRICS+; bibliometric analysis; visualization analysis; Scimago Graphica; VOSviewer.

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Introduction

Global climate change poses a substantial threat to biodiversity and the sustainable progress of agriculture, ultimately threatening the balanced and prosperous development of human civilization [1–3]. Ecosystems enhance human well-being by providing a diverse range of ecological services [4]. Agroecosystems play a crucial role in meeting the increasing demands of a growing population for food, fuel, fiber, and other natural materials. Moreover, as a crucial part of land-based systems, agroecosystems significantly contribute to the release of trace gases and affect the quality and consumption of vital natural resources, including water, soil, and biodiversity [4, 5]. Hence, it is crucial to efficiently manage agroecosystems to promote the sustainable exploitation of climate, land, and water resources. Furthermore, such management has a beneficial effect on the attainment of sustainable food, the alleviation of poverty, and the eradication of hunger [3, 6, 7]. Ultimately, the efficient administration of

agroecosystems will actively assist in maintaining the ecological balance of agricultural systems, establishing a strong basis for the well-being and sustainable progress of future societies [5, 8–10].

BRICS is an intergovernmental organization that represents five prominent developing market nations including Brazil, Russia, India, China, and South Africa [11]. BRICS consists of rising economies that possess investment prospects and potential competitive power, making them significant global actors [12–14]. BRICS expanded its membership in January 2024 to include Argentina, Egypt, Ethiopia, Iran, Saudi Arabia, and the United Arab Emirates [15]. The term BRICS+ is used in this study to denote the nations that are BRICS members after the 2024 membership expansion [16, 17]. BRICS currently plays a significant role in global affairs due to the organization's exceptional capabilities, and it makes substantial contributions to world economic development, environmental governance, and sustainable progress [18–20]. Hence, BRICS+ members not only infuse fresh energy into the global landscape but also assume a pivotal role in the overall attainment of sustainable development objectives.

Bibliometric analysis plays a crucial role in scholarly research by providing a quantitative evaluation of literature patterns and trends [21]. Tools such as VOSviewer are instrumental in this domain, offering the ability to create visual maps that detail the relationships between co-authorship, co-occurrence, citation, bibliographic coupling, and co-citation within a body of research. These maps produced by VOSviewer allow for a more accessible analysis of clustering within complex datasets, simplifying the identification of core research themes and influential papers [22, 23]. Similarly, Scimago Graphica is a specialized tool designed for both the professional visualization of data and the exploratory analysis that precedes it. This tool is adept at transforming intricate data into clear, communicative visual formats [24]. The utility of these tools extends beyond mere data presentation, which provides researchers with the means to delve deeper into the structural fabric of academic networks, enhancing the comprehension and dissemination of bibliometric data.

The objective of this research was to examine the contribution of BRICS+ nations to agroecosystem studies focusing on the topic of agroecosystems by using VOSviewer and Scimago Graphica to create knowledge maps and perform visualization analysis. The results of this study would offer significant insights into the role of BRICS+ nations in the environmental sphere and make meaningful contributions to the worldwide sustainable development agenda. In addition, this study would provide an overview of current studies and cooperation networks in the domain of agroecosystems across BRICS+ nations.

Materials and methods

VOSviewer 1.6.18 (https://www.vosviewer.com) and Scimago Graphica (https://graphica.app) were employed for conducting bibliometric analysis and constructing literature knowledge maps in this study. The research data were collected from the Web of Science database (https://www.webofscience.com/wos/woscc/basic-search). The data selecting criteria included the topic (agroecosystems), publication year (2023), document type (article), country (China, South Africa, India, Russia, Brazil, Argentina, Egypt, Ethiopia, Iran, Saudi Arab, United Arab Emirates), and language (English). A total of 392 articles of high quality and significance were selected for comprehensive visualization and analysis. Seven critical elements were addressed in this study to understanding agroecosystem research within BRICS+ countries, which were integral the key contributing nations, the most productive researchers, the most cited works, the foremost institutions, the leading journals, the publishers with the greatest impact, and the patterns of keyword cooccurrence. The results of these elements were used to construct a

framework that provided a holistic view of the research landscape, advancing the comprehension of the current trends and progress in agroecosystem studies in these nations.

Results and discussion

Analysis of the top contributing countries

The top ten countries in terms of research output on agroecosystems were ranked based on the number of articles published (Figure 1). The dots in the graph were scaled proportionately to accurately depict the magnitude of the contribution to the literature. A greater dot size corresponded to a greater number of publications, signifying a more substantial contribution. China was ranked first with 230 publications followed by Brazil with 53 publications and United States of America (USA) with 43 publications. Furthermore, the literature from various countries was not independent but rather known for its strong level of collaboration.

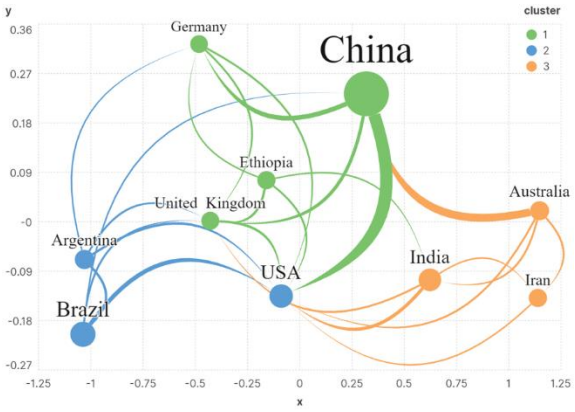

Figure 1. Publication of agroecosystems articles by country.

The results illustrated the worldwide scope of agroecosystem research, offering compelling insights. China played a prominent role in promoting advancement and innovation in this field, surpassing Brazil and USA. Chinese scholars have made notable progress in enhancing the understanding of agroecosystems. This research improved the understanding of pertinent areas and offered vital perspectives for worldwide efforts aimed at agricultural sustainability and ecological equilibrium. The significance of teamwork and knowledge exchange in tackling intricated issues such as sustainable agriculture and environmental preservation. Scholars are committed to improving collaboration in future research to make significant contributions to tackling important global agricultural concerns.

Analysis of most cited articles

The articles with citation counts exceeding 7 in the Web of Science were listed in Table 1. The article written by Liu *et al*. in 2023 received 18 citations and 281 references, while the article written by Peerzada *et al*. in 2023 received 15 citations and 55 references. Further, the articles of Li *et al*., Wu *et al*., Hou *et al*., Chen *et al*., Dai *et al*., and Xiao *et al*. in 2023 each reached 7 citations. The articles from Liu *et al*. and Peerzada *et al*. in 2023 captured a notable level of scholarly attention. Liu *et al*. examined the impact of incorporating crop straw back into the soil on reducing carbon limitations caused by inorganic fertilizer usage, preserving soil ecological balance, improving soil organic matter stability, and increasing grain yields. The results of their global data study showed that incorporating straw into soil increases carbon, nitrogen, and phosphorus levels, promotes grain yield, and maintains ecological balance. The article focused on Chinese research related to composting, fertilizer application, crop residue, and straw management and their effects on soil fertility, microbial populations, and crop yields, emphasizing sustainable soil health and productivity methods. The article of Peerzada *et al*. focused on Johnsongrass (*Sorghum halepense*), an invasive weed that poses a substantial danger to agriculture worldwide. Johnsongrass thrives in warm climates and has expanded to more than 53 nations, showing resilience to herbicides. Comprehensive management strategies are required to control the spread of this species due to its reproductive strategy and ecological impact. Sustainable management solutions include chemical,

Table 1. Highly cited articles in Web of Science (2023).

Author	Title	Citations	References
Liu *et al*. [25]	Crop residue return sustains global soil ecological stoichiometry balance	18	281
Peerzada *et al*. [26]	Eco-biology, impact, and management of *Sorghum halepense* (L.) Pers.	15	155
Dai *et al*. [27]	Phylogenetic diversity of stochasticity-dominated predatory myxobacterial community drives multi-nutrient cycling in typical farmland soils	7	84
Xiao *et al*. [28]	Silicon nanodots increase plant resistance against herbivores by simultaneously activating physical and chemical defenses	7	73
Chen *et al*. [29]	Interactive effects of polystyrene microplastics and Pb on growth and phytochemicals in mung bean (*Vigna radiata* L.)	7	66
Hou *et al*. [30]	Effects of substituting chemical fertilizers with manure on rice yield and soil labile nitrogen in paddy fields of China: A meta-analysis	7	61
Li *et al*. [31]	The effect of soil microplastics on *Oryza sativa* L. root growth traits under alien plant invasion	7	57
Wu *et al*. [32]	Correlation of climate change and human activities with agricultural drought and its impact on the net primary production of winter wheat	7	54

cultural, mechanical, and biological means. This study explored the allelopathic effects on plants, herbicide resistance, and the implications for agriculture. Numerous unresolved concerns persist regarding the subject of agroecology. Researchers should expand on the studies done by those who came before them and explore new methods to address complex issues in the global agricultural system.

Affiliation contribution analysis

Based on the detailed data records in the Web of Science, the top three institutions by departments were determined (Table 2). The most prominent affiliation was the College of Resources and Environmental Sciences, China Agricultural University (Beijing, China) with 13 articles, accounting for approximately 3% of the total number of documents. Additionally, College of Pastoral Agriculture Science and Technology, Lanzhou University (Lanzhou, Gansu, China), and College of Agronomy, Northwest A&F University (Yanling, Shaanxi, China) each had 8 articles published. The Department of Agroecology, Faculty of Technical Sciences, and National Centre for Food and Agriculture in Aarhus University (Aarhus, Denmark) each contributed 7 articles. The results indicated that the College of Resources and Environmental Sciences in China Agricultural University made the most significant contributions to the study of agroecosystems, which highlighted the leadership role of the institution in shaping discourse and driving progress in agricultural ecosystem research. Their active involvement highlighted the significance of institutional backing and expertise in furthering research goals focused on enhancing agricultural sustainability and environmental management. Ongoing cooperation among leading institutions and other entities in the industry is essential for tackling the complex issues that agricultural ecosystems are currently experiencing. By combining resources and knowledge, these institutions may work together to find creative solutions, advocate for sustainable farming practices worldwide, and improve ecosystem resilience.

Analysis of top journals with the most publications in Web of Science

The top 3 journals ranked according to the number of their contributions were listed in

Table 2. Top 3 recorded institutions with the department in Web of Science.

Affiliation with Department	Record Count	Percentage
College of Resources and Environmental Sciences, China Agricultural University	13	3.316
College of Pastoral Agriculture Science and Technology, Lanzhou University	8	2.041
College of Agronomy, Northwest A&F University	8	2.041
College of Natural Resources and Environment, Northwest A&F University	8	2.041
Department of Agroecology, Aarhus University	7	1.786
Faculty of Technical Sciences, Aarhus University	7	1.786
National Centre for Food and Agriculture, Aarhus University	7	1.786

Table 3. The top 3 journals with the most publications in Web of Science.

Publication Titles	Record Count	Percentage
Science of the Total Environment	26	6.633
Agriculture Ecosystems Environment	13	3.316
Agronomy Basel	13	3.316
Journal of Environmental Management	10	2.551
Plants Basel	10	2.551
Sustainability	10	2.551

Table 4. The top 6 publishers with the most publications in Web of Science.

Rank	Publishers	Record Count	Percentage
1	Elsevier	155	39.541
2	MDPI	64	16.327
3	Springer Nature	54	13.776
4	Wiley	31	7.908
5	Frontiers Media Sa	24	6.122
6	Taylor & Francis	9	2.296

Table 3. The Science of the Total Environment journal showed the most publications compared with all other journals and represented approximately 7% of all publications. Among all journals, Agriculture Ecosystems Environment and Agronomy Basel demonstrated the second and third highest number of publications with 13 articles in each journal, accounting for 3% of the total publications. These three prestigious journals played a crucial role in disseminating research findings, facilitating information exchange, and fostering collaboration among individuals with diverse geographic and disciplinary backgrounds, including academics, practitioners, and policymakers. The outstanding contributions featured in these publications underscored the robust academic climate that supported the study of agroecosystems. These journals will continue to be important platforms for advancing scientific knowledge and promoting innovation in addressing urgent issues such as food security, environmental protection, and sustainable agriculture.

Analysis of high-contributing publisher

The leading publishers in agroecosystem-related publications were shown in Table 4. Notably, Elsevier (Amsterdam, Netherlands) held a dominant position with 155 papers, contributing to approximately 40% of all publications and establishing itself as a market leader. Multidisciplinary Digital Publishing Institute (MDPI) (Basel, Switzerland) ranked the second

with 64 articles, representing approximately 16% of total publications. Springer Nature (London, UK) ranked third with 54 articles, comprising approximately 14% of total publications. Elsevier, MDPI, and Springer Nature are essential for influencing the academic discussion on agroecosystem research. The variety of publishers showcased the ever-changing publishing environment in the subject, indicating its engaged character. In the future, those periodicals will remain crucial for sharing knowledge and cooperating.

Analysis of keyword cooccurrence

This study conducted a comprehensive analysis of keyword cooccurrence, encompassing a range of keywords, such as "authors' keywords" and "keywords plus", as recommended by VOSviewer. The cooccurrence network of keywords in agroecosystem studies were shown in Figure 2. Researchers set the minimum cooccurrence of keywords to 14, which yielded a total of 32 eligible keywords. Four distinct clusters were identified with different colors (Figure 3). Cluster 1, marked in red, consisted of 12 items, focusing primarily on economic growth. The most crucial keywords were growth (total line strength = 77, occurrences = 38), yield (total line strength = 63, occurrences = 31), and soil (total line strength = 54, occurrences = 30). Cluster 2, marked in green, comprised 7 items that focused on the significance of effective agroecosystem management with the keyword of management (total line strength = 93, occurrences = 49) as the most significant one followed by agroecosystems (total line strength = 79, occurrences = 46), and biodiversity (total line strength = 80, occurrences = 39). Cluster 3, marked in blue, comprised 7 items that primarily studied issues such as nitrogen cycling and carbon dynamics of soils in agroecosystems. The keywords included nitrogen (total line strength = 86, occurrences = 39), carbon (total line strength = 95, occurrences = 38), and organic matter (total line strength = 58, occurrences = 24). Cluster 4, marked in yellow, consisted of 6 items that focused on research on plants or food provision. The most important keywords were maize (total line strength = 41, occurrences = 18), rice (total line strength = 39, occurrences = 17), and response (total line strength = 38, occurrences = 17). The results illustrated the co-occurrence overlay network of agroecosystem studies. Utilizing the overlay network, researchers identified five recent popular terms including soil (occurrences = 30, Avg. pub. year: 2023.10), rhizosphere (occurrences = 21, Avg. pub. year: 2023.10), rice (occurrences = 17, Avg. pub. year: 2023.12), fertilization (occurrences = 16, Avg. pub. year: 2023.12), and use efficiency (occurrences = 15, Avg. pub. year: 2023.13).

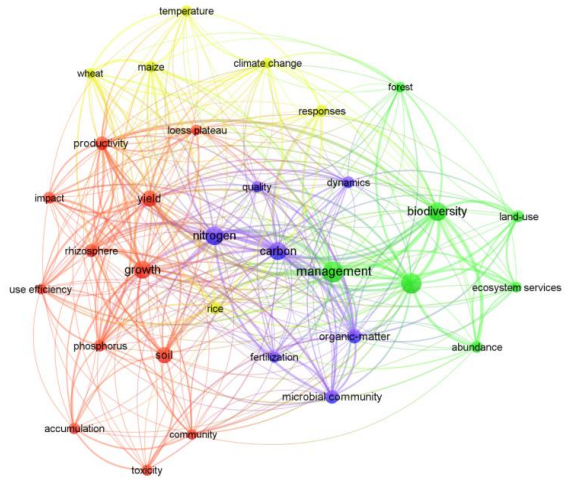

Figure 2. Keyword co-occurrence in the network of agroecosystems studies.

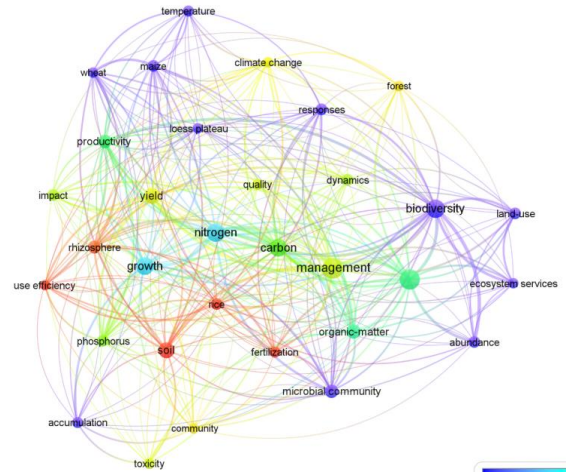

Figure 3. Keyword co-occurrence in the overlay network of agroecosystems studies.

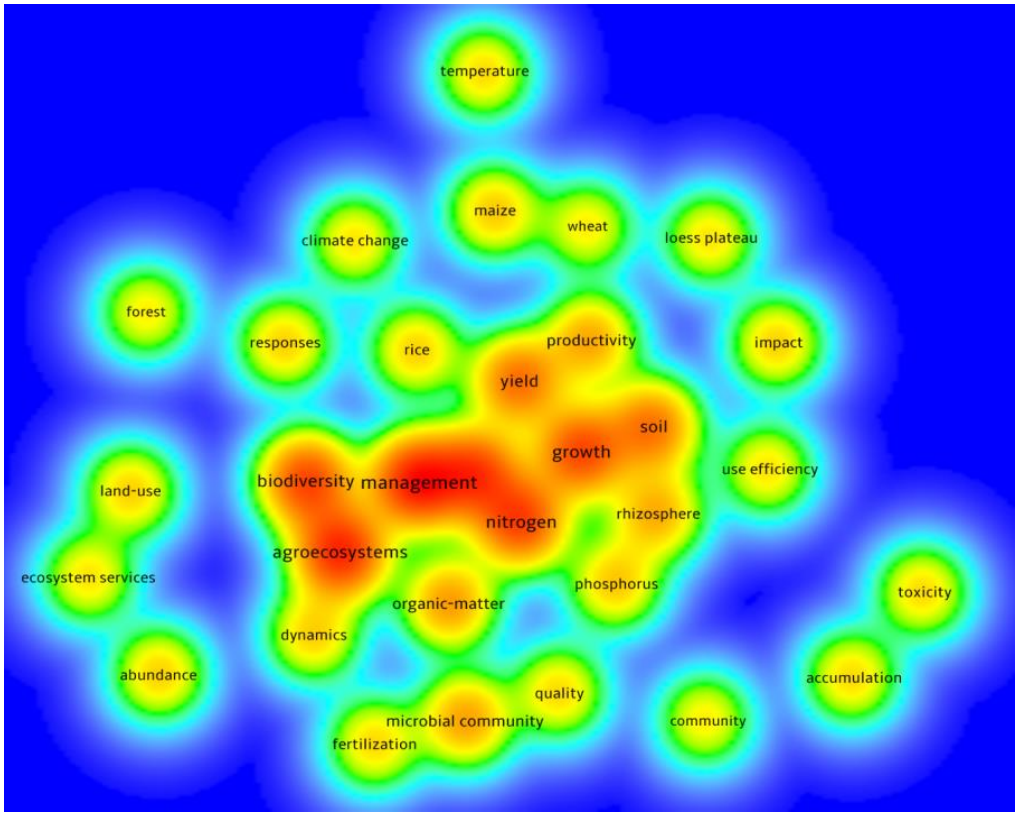

Figure 4. Keyword co-occurrence in the clusters of agroecosystems studies.

The keyword cooccurrence in the clusters of agroecosystem studies was shown in Figure 4. Management, agroecosystems, biodiversity, nitrogen, and growth were the most prevalent terms. The results indicated the academic preference for specific topics in the study of agroecosystems. The results displayed in Figures 2 and 3 presented a detailed study of the cooccurrence network, highlighting major issues and research focal points in agroecosystem studies. Researchers can acquire useful insights into current trends, difficulties, and opportunities in this subject by finding different clusters and core keywords. These insights can provide data for future research priorities, guide policy actions, and promote innovation in sustainable agriculture and environmental preservation. The results shown in Figures 3 and 4 emphasized the multidisciplinary aspect of agricultural ecosystem research and the importance of academic investigations in tackling the complex challenges of global agricultural and environmental sustainability. As researchers delve into new areas and expand the limits of knowledge, these findings will help shape the future direction of agroecosystem science. Healthy agroecosystems play a pivotal role in promoting sustainable development across ecological, economic, and social dimensions [3, 9, 33]. BRICS+, as a significant participant in worldwide sustainable development efforts [18, 20], plays a vital role in analyzing visual changes in agricultural ecosystems. This study improved the understanding of academic contacts and information dissemination within BRICS+ nations, offering scientific support for researchers investigating agroecosystems in these nations. Furthermore, it can advance the overall progress of agroecosystem studies, ultimately making a valuable contribution to the sustainable development of global agricultural ecosystems.

Conclusion

This study highlighted the critical contributions of Chinese scholars to the field of agricultural sustainability with a focus on a select group of high-impact researchers and institutions. The key areas of interest that were identified included soil management, agroecosystem management, and efficient fertilizer use. The visualization of collaboration networks offered a strategic view of international research partnerships. Future directions of study should prioritize ecological economics and the advancement of sustainable agricultural practices with the aim of emphasizing innovative soil and plant studies to harmonize economic and environmental objectives.

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