E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(1): 173-179
Received: 13-10-2023
Accepted: 22-11-2023

J Moshahary
Assistant Professor, Department of Agricultural Statistics, SCS College of Agriculture, AAU, Dhubri, Assam, India

M Choudhury
Assistant Professor, Department of Soil Science, SCS College of Agriculture, AAU, Dhubri, Assam, India

P Ahmed
Associate Professor, Department of Agronomy, SCS College of Agriculture, AAU, Dhubri, Assam, India

B Sarma
Associate Professor, Department of Horticulture, SCS College of Agriculture, AAU, Dhubri, Assam, India

RK Nath
Associate Professor, Department of Entomology, SCS College of Agriculture, AAU, Dhubri, Assam, India

S Saha
Assistant Professor, Department of Horticulture, SCS College of Agriculture, AAU, Dhubri, Assam, India

Corresponding Author:
J Moshahary
Assistant Professor, Department of Agricultural Statistics, SCS College of Agriculture, AAU, Dhubri, Assam, India

A bibliometric analysis of biochar in sustainable agriculture

J Moshahary, M Choudhury, P Ahmed, B Sarma, RK Nath and S Saha

DOI: https://doi.org/10.33545/2618060X.2024.v7.i1Sc.255

Abstract
This study explores the intricate interaction between biochar and sustainable agriculture and uses a rigorous quantitative approach to disentangle the different aspects. The temporal dimension shows an increase in scientific productivity since 2019, fostering elaborate author collaboration networks. The dominant publication comes from countries such as the Netherlands, Switzerland, Great Britain, Germany, and the United States. Careful analysis of citation dynamics and co-occurring keywords picks up nuanced thematic foundations. The dominant influence of highly cited articles, linked by common scientific references, is significantly reflected in academic discourse. The projections provide insight into continued expansion, highlighting a promising trend in the development of biochar and sustainable agricultural research.

Keywords: Bibliometric, biochar, sustainable agriculture, forecasting, hotspots

Introduction
The concept of agricultural sustainability began a long time ago and gained momentum in the last three decades (Bongiovanni and Lowenberg-Deboer, 2004; Çakmakçı *et al*., 2023; Hansen, 1996; Lampridi *et al*., 2019; Muhie, 2022; Ruttan, 1999, Thompson, 2007; Tilman *et al*., 2002; Zeweld *et al*., 2020) [4, 5, 12, 15, 18, 26, 28, 29, 33]. Traditional agriculture underwent drastic changes when the concept of sustainable agriculture emerged to maintain yield levels and minimize environmental pollution (Abukari *et al*., 2021; Ayaz *et al*., 2021; Çakmakçı *et al*., 2023; Oni *et al*., 2019; Zeweld *et al*., 2020) [1, 3, 5, 20, 33]. Biochar is considered a valuable ingredient in sustainable agriculture, as its strategic use in soil offers many agronomic, economic, and environmental benefits (Gałwa-Widera, 2021; Osman *et al*., 2022; Yeboah *et al*., 2018; Zhou *et al*., 2022) [10, 21, 32, 34]. Improved soil nutrition, crop growth and productivity, enhanced crop physiological parameters and quality, reduced bioavailability of pollutants, and overall reduction of greenhouse gases emission from soil are some of the important benefits of biochar amendments (Kalu *et al*., 2022; Martin *et al*., 2015; Yeboah *et al*., 2018) [13, 16, 32]. Additionally, the benefits of carbon sequestration due to its highly persistent nature can help mitigate climate change (Murtaza *et al*., 2023) [19]. The economic benefits of improved yields and frequent reductions in fertilizer use and irrigation can help achieve economic stability and profitability for farmers without jeopardizing the conservation of surrounding ecosystems (Kumari *et al*., 2023) [14]. Interest in biochar has grown tremendously worldwide due to its multidimensional benefits (Gabhane *et al*., 2020; Purakayastha *et al*., 2015) [9, 23].
Bibliometrics is a science that helps to understand the scientific achievements in certain fields and helps researchers to grasp the current research goals and limits as quickly as possible and guides them in choosing future research directions (Rousseau & Rousseau, 2017; Zuccala, 2016; Zupic & Čater, 2015) [25, 35, 36]. Detailed information about the literature, such as authors, keywords, countries, publishers, and references can be obtained through bibliometric analysis. Softwares commonly used in bibliometrics include CiteSpace (Chen, 2004, 2006) [6, 7], VOSviewer (van Eck and Waltman, 2010) [30], and the R package "bibliometric" (Aria and Cuccurullo, 2017) [2]. The task of the software is to visualize the results as evidenced from their application in diversified research fields by many workers (Fan *et al*., 2020; Glynatsi and Knight, 2021; Iftikhar *et al*., 2019; Moustakas, 2022; Rojas-Sánchez *et al*., 2023; Wu *et al*.,

2023) [8, 11, 17, 24, 31]. However, to our knowledge, there are few bibliographic analyses in biochar-sustainable agriculture though biochar has great potential as part of sustainable agriculture. To fill this gap, we performed a bibliometric analysis of articles on biochar in sustainable agriculture.

Material and methods

A comprehensive review of global scholarly articles concerning biochar and its role in sustainable agriculture was meticulously conducted using the lens.org research database. The targeted keywords for retrieving relevant publications included "biochar," and "sustainable agriculture". Publications related to biochar and sustainable agriculture from lens.org database on 11.08.2023 was retrieved.

Query: (Title: (biochar) OR (Abstract: (biochar) OR (Keyword: (biochar) OR Field of Study: (biochar)))) AND (Title: (sustainable AND agriculture) OR (Abstract: (sustainable AND agriculture) OR (Keyword: (sustainable AND agriculture) OR Field of Study: (sustainable AND agriculture))))

Filters: Published Year. from = 2009, PublishedYear.to = 2022, Publication Type = Journal Article

Data Analysis

The bibliometric analysis of these curated articles was executed using the powerful analytical tool, VOSviewer (Version 1.6.19), revealing intricate insights into the network of research in the context of biochar and sustainable agriculture. Microsoft Office Excel 2019 was used to conduct the analyses.

Results and Discussion

Quantitative analysis of publication

After refining our search strategy and eliminating duplicate entries, we identified a total of 870 unique articles by August 11, 2023. This dataset was then used for our analysis. As illustrated in Figure 1, the count of articles relating to the intersection of biochar and sustainable agriculture has exhibited a steady rise over time. Notably, there has been a remarkable surge in the number of articles from the year 2019 onwards, indicating a period of rapid expansion.

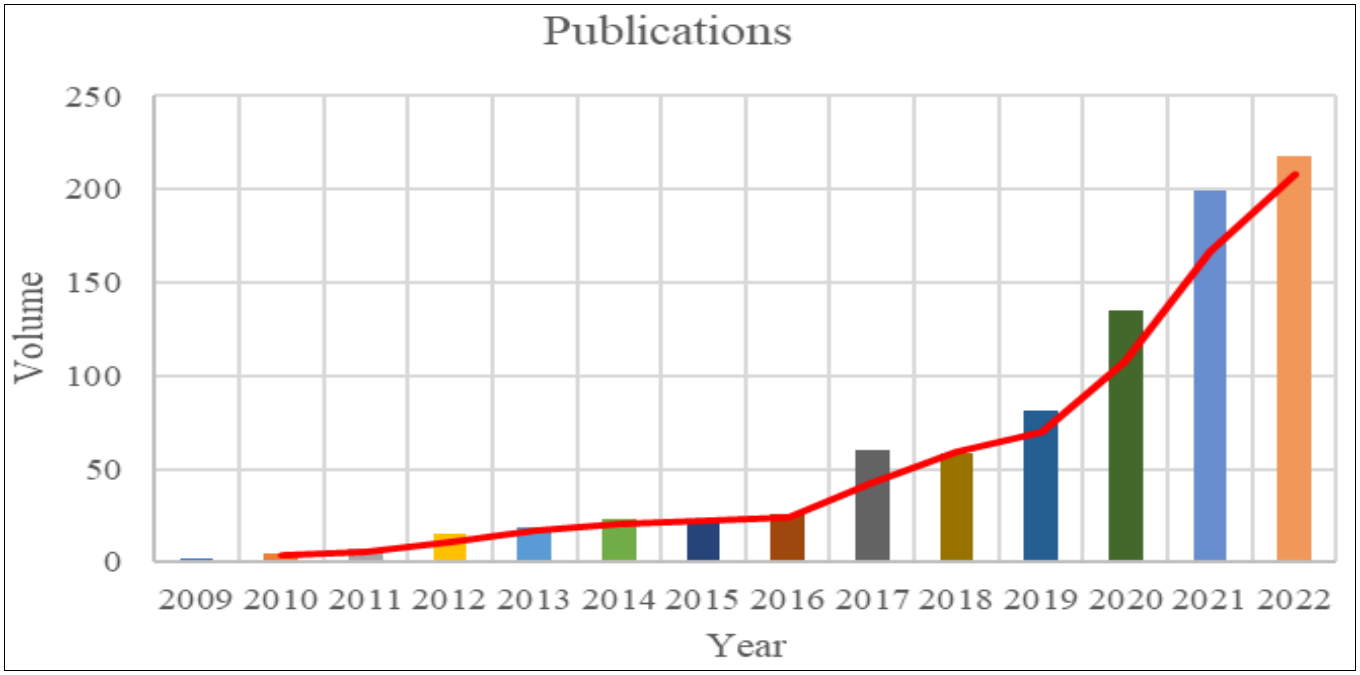

Fig 1: Year wise publication on biochar and sustainable agriculture from 2009-2022

Co-authorship analysis

We have focused on authors who have contributed at least one publication. Mining the database, it was observed that a total of 4023 authors published research articles on biochar and sustainable agriculture during the period under study. In this context, Yong Sik Ok (16), Genxing Pan (11), Lianing Li (12), Xiaoyu Liu (10), and Jufeng Zheng (9) are authors contributing the most. Our attention has been directed towards examining co-authorship patterns within this subset of articles. The findings and insights into these collaborative networks are visually presented in Figure 2. This visual representation sheds light on the connections and interactions among authors who have collaborated on articles related to biochar and sustainable agriculture, the bigger size of the nodes the greater is the collaboration and interaction among the co-authors.

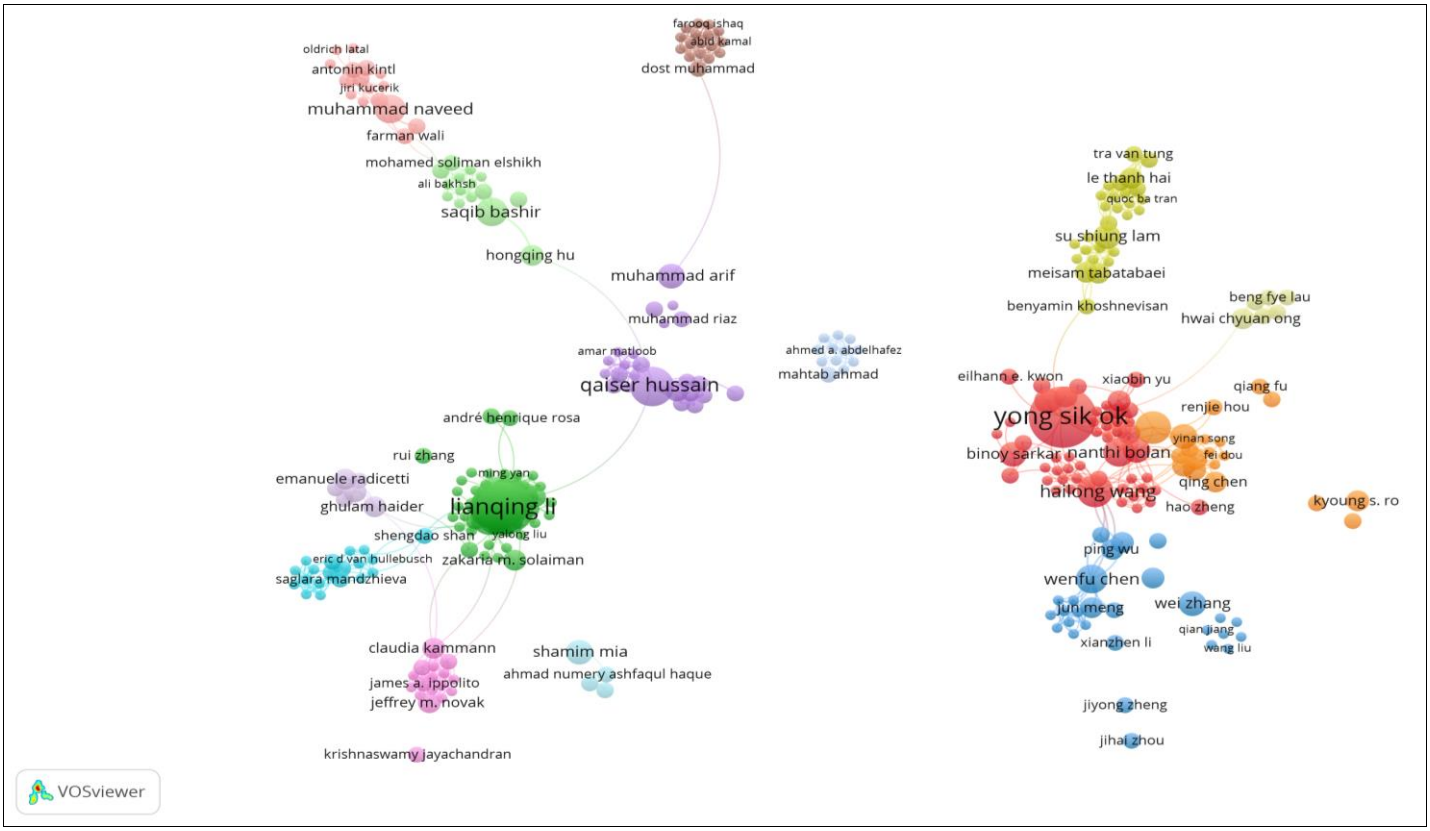

Fig 2: Co-authorship Analysis of biochar and sustainable agriculture

Source of publications analysis

The analysis revealed that the articles have been published in different journals by 28 countries out of which the top 5 contributing countries in the context are the Netherlands (187), Switzerland (128), the United Kingdom (109), Germany (89), and the USA (73). The dark blue colour represents the countries with highest publication and light blue colour represents the countries the least publication as shown in the Figure 3.

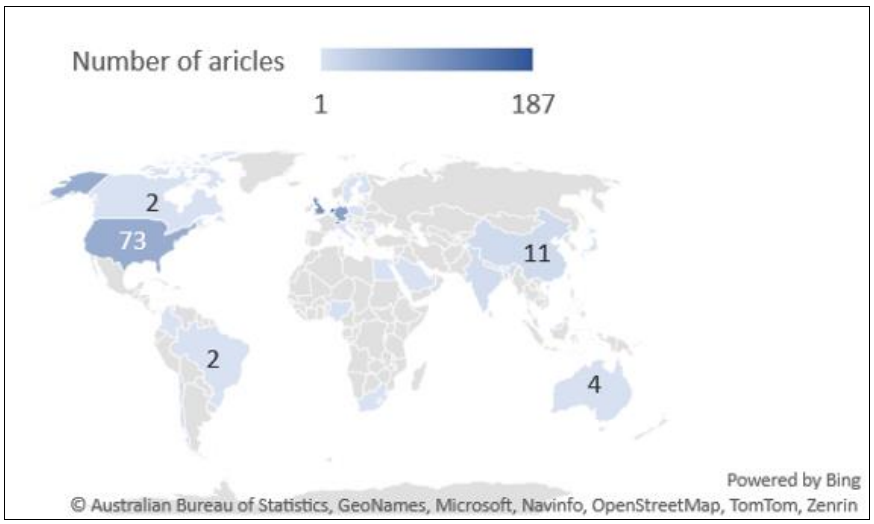

Fig 3: Country source published in biochar and sustainable agriculture

Citation Analysis

Authors established a criterion for citation analysis, requiring a minimum of one published article per author and a minimum of 100 citations received by each of the authors. Top (5) authors citation received and their number of documents, citations along with total link strength is shown in the Table 1.

Table 1: Citation analysis by authors for biochar and sustainable agriculture

Author	Documents	Citations	Total Link Strength
David A. Laird	3	1668	80
Yong Sik Ok	16	1070	222
Baiqun Wang	1	1047	40
Dedrick D. Davis	1	1047	40
Douglas L. Karlen	1	1047	40

In this context, the varying sizes of nodes in our network graph symbolize the differing degrees of citation frequency garnered by authors is shown in the Figure 4. The larger node size thus serves as an empirical marker of the broader impact and influence these findings have wielded, substantiated by the substantial citation counts of the authors.

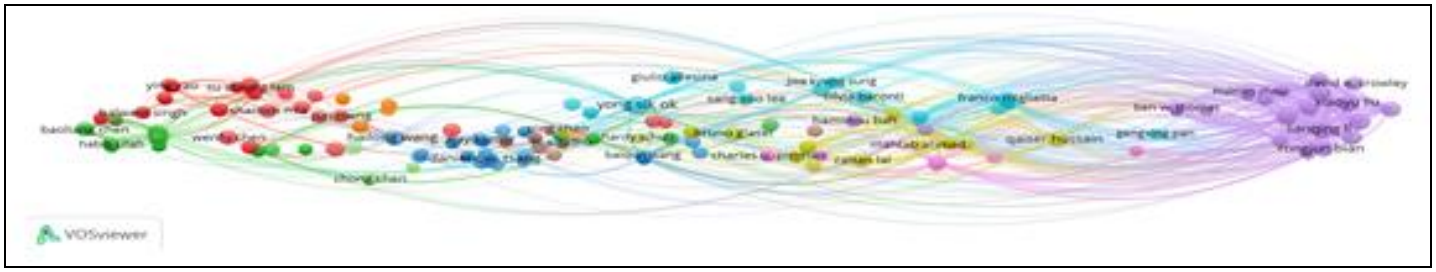

Fig 4: Citation Analysis by authors in biochar and sustainable agriculture

Co-occurrence of keyword

In the realm of keyword co-occurrence analysis, our focus has been on identifying instances where keywords appear together in documents. This criterion helps us pinpoint research hotspots in this context. Currently top keywords that frequently appear alongside each other are biochar, heavy metals, pyrolysis, soil amendment and soil remediation.

To visually represent these keyword associations, we have employed network visualization techniques. In the graphical representation as shown in Figure 5, each keyword is represented as a node, and connections or links between nodes indicate instances where the keywords co-occur within the same documents. This network visualization offers a concise yet insightful overview of the interconnectedness and patterns among keywords, allowing us to grasp the relationships that contribute to biochar and sustainable agriculture.

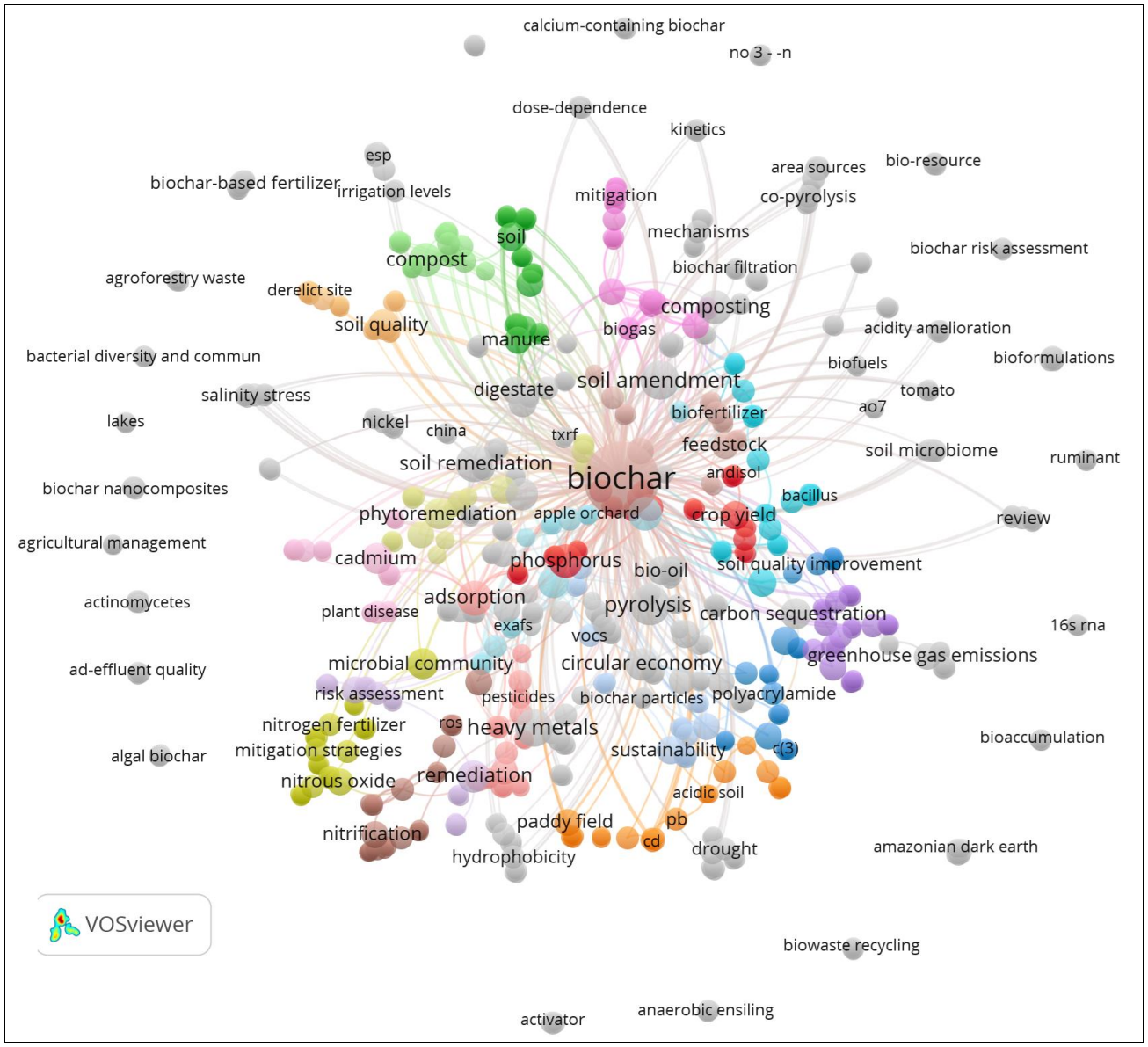

Fig 5: Keyword analysis for biochar and sustainable agriculture

Bibliography coupling by authors

In this context, we examined the bibliography coupling among authors. Specifically, we have focused on analysing instances where authors' bibliographies share common references. In the present study the criterion was set in such a way where authors of at least five articles in common were considered. Table 2 shows the list of top 5 authors along with their number of documents, citations, and total link strength (Table 2)

Table 2: Bibliography coupling by authors for biochar and sustainable agriculture

Author	Documents	Citations	Total link strength
Lianqing Li	12	771	10927
Genxing Pan	11	670	10118
Xiaoyu Liu	10	639	9470
Jufeng Zheng	9	609	9265
Xuhui Zhang	8	592	8518

Figure 6 is the visual representation of bibliography coupling by authors' contribution in the field of biochar and sustainable agriculture. The size of the nodes corresponds to the number of articles penned by the individual author. The network diagram illustrates the connections or links between authors who have shared references in their works, creating a visual depiction of the interconnected relationships among authors and their shared scholarly contributions.

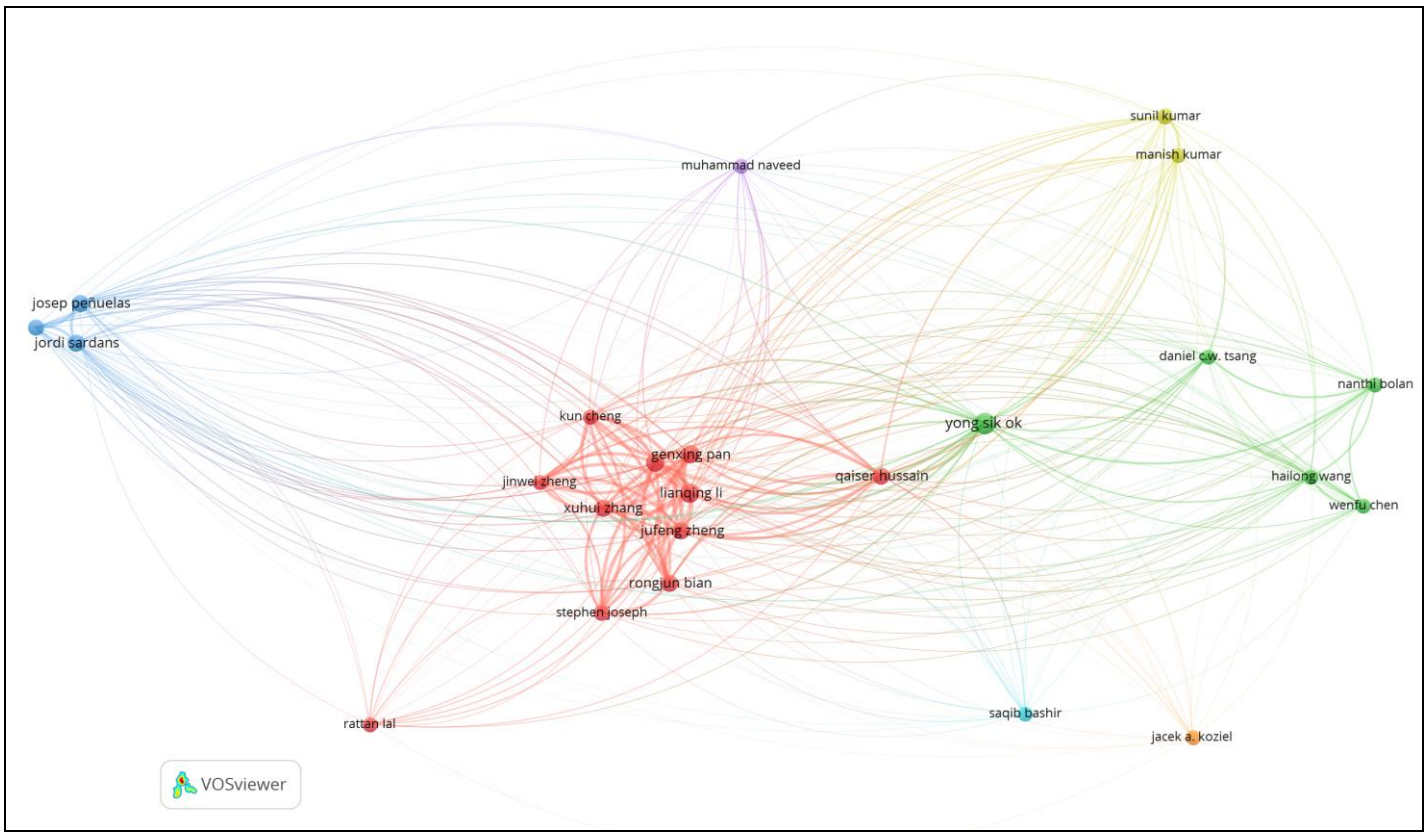

Fig 6: Bibliography coupling by authors contribution biochar and sustainable agriculture

Forecasting

Based on the analysis of year wise publication for the period from 2009 to 2022 the forecasting trend over the next four years was attempted and depicted in Figure 7. This forecasting trend suggests a sustained and accelerated growth trajectory for the upcoming years. This visual representation underlines the potential for continued expansion in research output in the biochar and sustainable agriculture domain, painting a promising picture for the field's development in the near future.

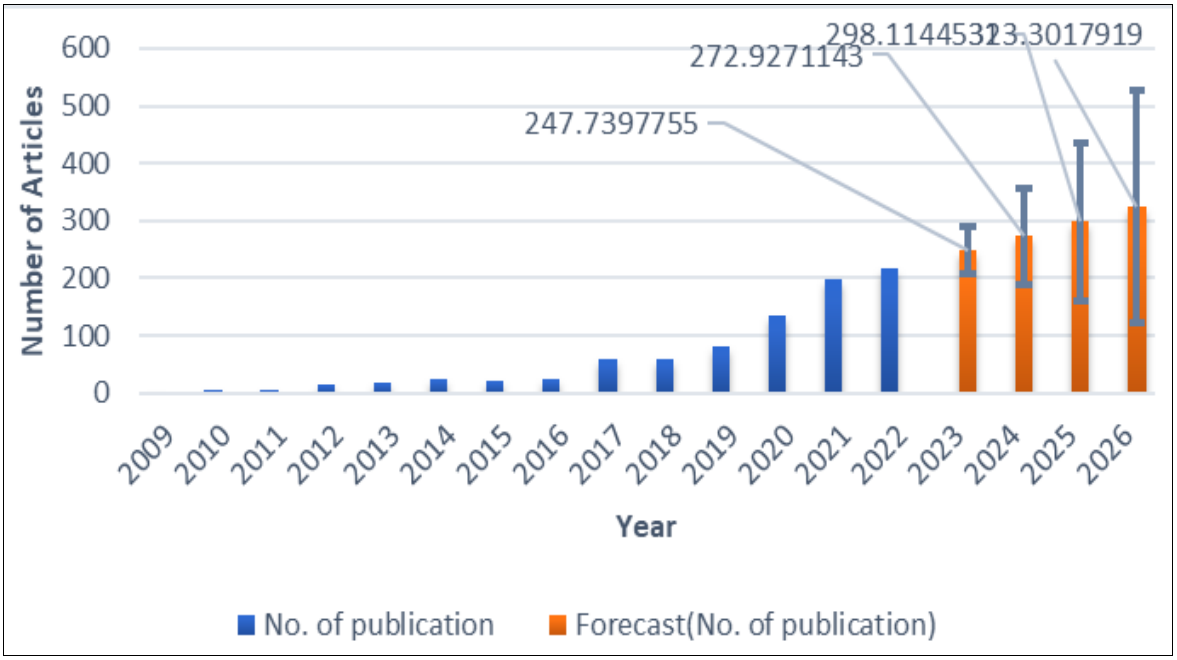

Fig 7: Forecasting of number of article publications in biochar and sustainable agriculture

Conclusion

This investigation provides a comprehensive quantitative analysis of the symbiotic relationship between biochar and sustainable agriculture. The temporal evolution underscores a notable surge in scholarly output since 2019, coinciding with escalating collaborative author networks. The research landscape is dominated by countries such as the Netherlands, Switzerland, the UK, Germany, and the USA. Citation dynamics and keyword co-occurrences unveil intricate research themes. Highly cited documents, interconnected through shared references among authors, wield significant influence within the scholarly discourse. Future projections augur a sustained growth trajectory, auguring a promising avenue for the advancement of research in the realm of biochar and sustainable agriculture.

Conflict of interest: The authors declare no conflict of interest.

References

1. Abukari A, Abukari IZ, Zarouk IA, Ballu DA. Sustainable Use of Biochar in Environmental Management. In Environmental Health (Intech Open); c2009. p. 1-21.
2. Aria MS, Cuccurullo C. Bibliometrix: An R-tool for comprehensive science mapping analysis. J Informetr. 2017;11(4):959-975.
3. Ayaz M, Feizienė D, Tilvikienė V, Akhtar K, Stulpinaitė U, Iqbal R. Biochar Role in the Sustainability of Agriculture and Environment. Sustainability. 2021;13(3):1330.
4. Bongiovanni R, Lowenberg DJ. Precision Agriculture and Sustainability. Precis Agric. 2004;5(4):359-387.
5. Çakmakçı R, Salık, MA, Çakmakçı S. Assessment and Principles of Environmentally Sustainable Food and Agriculture Systems. Agriculture. 2023;13(5):1073.
6. Chen C. Searching for intellectual turning points: Progressive knowledge domain visualization. Proceedings of the National Academy of Sciences. 2004;101(suppl_1):5303-5310.
7. Chen C. CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. J Am Soc Inf Sci Tec. 2006;57(3):359-377.
8. Fan J, Gao Y, Zhao N, Dai R, Zhang H, Feng X, *et al*. Bibliometric Analysis on COVID-19: A Comparison of Research Between English and Chinese Studies. Front Public Health. 2020;8:477.
9. Gabhane JW, Bhange VP, Patil PD, Bankar ST, Kumar S. Recent trends in biochar production methods and its application as a soil health conditioner: a review. SN Appl Sci. 2020;2(7):1307.
10. Gałwa WM. Biochar – Production, Properties, and Service to Environmental Protection against Toxic Metals. In Handbook of Assisted and Amendment: Enhanced Sustainable Remediation Technology (Wiley); c2021. p. 53-75.
11. Glynatsi NE, Knight VA. A bibliometric study of research topics, collaboration, and centrality in the iterated prisoner's dilemma. Humanit Soc Sci. 2021;8(1):45.
12. Hansen JW. Is agricultural sustainability a useful concept? Agric Sys. 1996;50(2):117-143.
13. Kalu S, Kulmala L, Zrim J, Peltokangas K, Tammeorg P, Rasa K, *et al*. Potential of Biochar to Reduce Greenhouse Gas Emissions and Increase Nitrogen Use Efficiency in Boreal Arable Soils in the Long-Term. Front Environ Sci. 2022;10:914766.
14. Kumari K, Kumar R, Bordoloi N, Minkina T, Keswani C, Bauddh K. Unravelling the Recent Developments in the Production Technology and Efficient Applications of Biochar for Agro-Ecosystems. Agriculture. 2023;13(3):512.
15. Lampridi M, Sørensen C, Bochtis D. Agricultural Sustainability: A Review of Concepts and Methods. Sustainability. 2009;11(18):5120.
16. Martin SL, Clarke ML, Othman M, Ramsden SJ, West HM. Biochar-mediated reductions in greenhouse gas emissions from soil amended with anaerobic digestates. Biomass Bioenergy. 2015;79:39-49.
17. Moustakas L. A Bibliometric Analysis of Research on Social Cohesion from 1994-2020. Publications. 2022;10(1):5.
18. Muhie SH. Novel approaches and practices to sustainable agriculture. J Agric Food Res. 2022;10:100446.
19. Murtaza G, Ahmed Z, Eldin SM, Ali B, Bawazeer S, Usman M, Iqbal R, Neupane D, Ullah A, Khan A, Hassan

MU, *et al*. Biochar-Soil-Plant interactions: A cross talk for sustainable agriculture under changing climate. Front Environ Sci. 2023;11:1059449.
20. Oni BA, Oziegbe O, Olawole OO. Significance of biochar application to the environment and economy. Ann Agric Sci. 2019;64(2):222-236.
21. Osman AI, Fawzy S, Farghali M, El-Azazy M, Elgarahy AM, Fahim RA, *et al*. Biochar for agronomy, animal farming, anaerobic digestion, composting, water treatment, soil remediation, construction, energy storage, and carbon sequestration: a review. Environ Chem Lett. 2022;20(4):2385-2485.
22. Pretty J. Agricultural sustainability: concepts, principles and evidence. Philosophical Transactions of the Royal Society B: Biol Sci. 2008;363(1491):447-465.
23. Purakayastha TJ, Kumari S, Pathak H. Characterisation, stability, and microbial effects of four biochars produced from crop residues. Geoderma. 2015, 239-240, 293-303.
24. Rojas SMA, Palos SPR, Folgado FJA. Systematic literature review and bibliometric analysis on virtual reality and education. Educ Inf Technol. 2023;28(1):155-192.
25. Rousseau S, Rousseau R. Being metric-wise: Heterogeneity in bibliometric knowledge. El Profesional de La Información. 2017;26(3):480.
26. Ruttan VW. The transition to agricultural sustainability. Proceedings of the National Academy of Sciences. 1999;96(11):5960-5967.
27. Schaller N. The concept of agricultural sustainability. Agric Ecosyst Environ. 1993;46(1-4):89-97.
28. Thompson PB. Agricultural sustainability: what it is and what it is not. Int J Agric Sustain. 2007;5(1):5-16.
29. Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S. Agricultural sustainability and intensive production practices. Nature. 2002;418:671-677.
30. Van ENJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics. 2010;84(2):523-538.
31. Wu Y, Meng S, Liu C, Gao W, Liang XZ. A bibliometric analysis of research for climate impact on agriculture. Front Sustain Food Syst. 2023;7:1191305.
32. Yeboah S, Lamptey S, Cai L, Song M. Short-Term Effects of Biochar Amendment on Greenhouse Gas Emissions from Rainfed Agricultural Soils of the Semi–Arid Loess Plateau Region. Agronomy. 2018;8(5):74.
33. Zeweld W, Van HG, Tesfay G, Azadi H, Speelman S. Sustainable agricultural practices, environmental risk mitigation and livelihood improvements: Empirical evidence from Northern Ethiopia. Land Use Policy. 2020;95:103799.
34. Zhou S, Kong F, Lu L, Wang P, Jiang Z. Biochar — An effective additive for improving quality and reducing ecological risk of compost: A global meta-analysis. Sci. Total Environ. 2022;806:151439.
35. Zuccala A. Inciting the metric-oriented humanist: Teaching bibliometrics in a faculty of humanities. Educ. Inf. 2016;32(2):149-164.
36. Zupic I, Čater T. Bibliometric Methods in Management and Organization. Organizational Research Methods. 2015;18(3):429-472.