Smallholders and Sustainable Agriculture: A Comprehensive Bibliometric Mapping

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ABSTRACT

Sustainable agriculture has emerged as a significant research focus, especially concerning smallholder farmers and the increasing influence of digital technologies on farming practices. This study synthesizes insights from 1,540 scholarly articles published up to 2025, employing bibliometric methods alongside quantitative analysis to examine the evolving landscape of research in this field. Although existing Systematic Literature Reviews (SLRs) on smallholders and sustainable agriculture have contributed valuable perspectives, many tend to adopt a narrow approach—either by concentrating on specific thematic issues or by limiting their scope to a single bibliographic database like Scopus or Web of Science. Addressing these limitations, the present study applies a comprehensive bibliometric approach that systematically maps prevailing research trends, highlights key thematic clusters, and offers critical insights into global research contributions. By doing so, it lays a robust groundwork for future scholarly inquiry and fosters a more integrated understanding of the role that small and medium farmers play in shaping the agricultural economy.

Keywords: Bibliometric Analysis, Agricultural Research Trends, Food Security and Rural Livelihood

1. INTRODUCTIONS

Agriculture is the cornerstone of economic activity across numerous least developed nations. It serves as a major source of employment, income production, and food security for substantial sectors of the population (Abaynew et al., 2025; Trentinaglia et al., 2023). Within these agricultural systems, smallholders play a pivotal role in sustaining rural livelihoods and ensuring food availability. Smallholders—comprising small-scale farmers, pastoralists, fishers, and forest stewards—typically manage land areas ranging from less than one hectare to about ten hectares. Their operations are often driven by family-centered goals, prioritizing household stability, utilizing primarily family labor, and reserving a portion of the harvest for personal consumption. These characteristics make smallholders vital not just for economic output, but also for the social fabric of rural communities. However, a major challenge in assessing the true impact of smallholders stems from the inconsistent use of terminology by global organizations, including the UN FAO (United Nations Food and Agriculture Organization). Terms like "small farms" and "family farms" are frequently used interchangeably, even though they represent distinct concepts. This lack of clarity affects how we interpret data on agricultural contributions. For instance, as Hannah Ritchie (2021) notes, conflating these terms leads to inflated estimates of food production by smallholders. Contrary to widely circulated claims, smallholders are responsible for producing roughly one-third of the world's food—substantially less than what is often reported.

The necessity of smallholder consolidation, in which farmers collectively obtain inputs for cultivation and sell their goods in formal trade centers, comes from the reality that the majority of the world's farms are small and marginal. Around 475 million, or eighty-four percent of the 570 million projected worldwide farmland, are lesser than 2 hectares (Graeub et al., 2016; FAO, 2014; Gomez y Paloma et al., 2020). Although estimates that small farms will combine as the farming sector's relevance in comparison to the service and industrial sector's drops in developing nations, they have remained and, in numerous instances, elevated in quantity. (Hazell et al., 2010). Whereas small farms represent only 12% of the worldwide land for farming, they house the majority of the world's impoverished and malnourished, feed more than two billion individuals, and contribute 80% of the world's food in both Africa and Asia (Galdeano-Gómez et al., 2017; FAO, 2015) Consequently, small-scale farmers agricultural growth and progression are crucial for lowering poverty, ensuring adequate nutrition, and the advancement of economic and social growth in developing and emerging countries (Pingali et al., 2019). considering the present situation of small-scale farmers in emerging economies, they typically find themselves with the following choices: "get up" or "keep up," in which small-scale farmers capitalize on and boost their market position as a way to establish

themselves as a beneficial business entity, or receive support to exit farming and seek other kinds of employment (Fan & Rue, 2020; Abraham et al., 2022).

Additionally, sustainable farming is a multidimensional way to farming that balances earnings with ecological, economic, and social integrity. As legally defined in the 1990 U.S. Farm Bill, sustainable agriculture refers to a site-specific integration of plant and animal production systems that, over the long term, aim to: (1) fulfill human needs for food and fiber, (2) maintain or improve the quality of the environment, (3) maximize the efficient use of both renewable and non-renewable resources through natural biological processes, (4) ensure the long-term economic viability of farming operations, and (5) elevate the quality of life for farmers and communities (Velten et al., 2015). On the other hand, the term "sustainable agriculture" gained prominence in the early 1980s in the United States, reflecting a growing recognition of the adverse effects of industrial farming on soil, water, biodiversity, and rural livelihoods. It emphasized agricultural practices that mimic the ecological balance found in natural systems. This approach aligns closely with agroecology, conservation farming, organic agriculture, integrated crop-livestock systems, and other low-input, high-efficiency practices that reduce dependence on synthetic chemicals and fossil fuels (Gomiero et al., 2011). Contemporary understanding of sustainability in agriculture revolves around three interconnected goals—often known as the **"three pillars of sustainability"**: environmental stewardship, economic profitability, and social responsibility (Wohlenberg et al., 2020). These pillars aim to foster a resilient food system that not only addresses ecological and economic challenges but also promotes social equity across the agricultural value chain.

U.S. legislation, particularly Title 7, Section 3103 of the U.S. Code, reiterates that sustainable agriculture should be location-specific and evolve over time to cater to local needs. It highlights goals like improving ecosystem services, conserving water and soil, reducing greenhouse gas emissions, and enhancing biodiversity—factors essential for long-term agricultural resilience (Jeranyama et al., 2020). The push for sustainable practices is partly a response to the realization that post-World War II farming methods— characterized by monocultures, heavy mechanization, and chemical dependence—are inadequate to meet the nutritional demands of a growing global population, projected to exceed 9.7 billion by 2050 ((J. S. Singh et al., 2011; FAO, 2023). These methods often degrade natural resources and increase vulnerability to climate change, pests, and market shocks. Moreover, global interest in sustainable agriculture has expanded in recent years. (Galdeano-Gómez et al., 2017) noted that the increasing volume of scholarly research in this domain reflects a deeper awareness of the need for systemic agricultural reforms. Researchers and policymakers are emphasizing the importance of developing comprehensive frameworks to evaluate agricultural sustainability, including tools for measuring social impact, environmental performance, and economic viability. The Sustainable Development Goals of the United Nations (SDGs), specifically SDG

2 (zero hunger) and SDG twelve (responsible consumption and production), underscore the urgent need to transition towards sustainable agriculture. This transition is crucial not just for food security, but also for environmental preservation, rural development, and climate adaptation.

Furthermore, while research on smallholder and sustainable agriculture in the agricultural sector endures to gain popularity, there is still a scarcity of studies that comprehensively assess both the benefits and hazards of smallholders in sustainable agriculture. While numerous studies have conducted Systematic Literature Reviews (SLRs) on smallholders and sustainable agriculture, they often remain narrowly focused—either by thematically analyzing specific topics or by relying on just one major bibliographic source (such as Scopus or Web of Science) (Sarkar et al., 2022; Bathaei & Štreimikienė, 2023) or occasionally both (Okolie et al., 2024; Der Tambile et al., 2024). However, there's no comprehensive bibliometric investigation that draws from a broader range of databases—including emerging ones like Dimensions or Google Scholar—to offer a holistic mapping of research trends and gaps in this field. Thus, there's a clear need for a wider, more inclusive database analysis to advance knowledge on smallholders and sustainable agriculture. However, these studies do not provide a thorough and quantitative picture of smallholders' dual impact on both opportunities and developing threats in the dynamic agricultural business context. This study tackles these gaps through bibliometric analysis, which maps research patterns, identifies subject areas, and provides insights into worldwide contributions. Such a study lays the groundwork for future research topics while also ensuring a fair understanding of small and medium-sized farmers' roles in the agricultural industry. This would provide a thorough quantitative assessment of current research trends, identify significant topic areas, evaluate the impact of foundational works, and analyze the geographic and institutional distribution of research contributions in this constantly evolving field of research and practice.

Bibliometric evaluation is a quantitative tool commonly employed in academics to methodically evaluate scholarly publications (R. Kumar, 2025; Udin & Dananjoyo, 2025). This technique evaluates academic outputs, including publication history, characteristics, and research trajectory, using quantitative measures (Akinlolu et al., 2022; Lu & Zhang, 2022; Wang et al., 2022; Shu et al., 2024). It evaluates the performance and trends in scholarly contributions by people, journals, and institutions, exposing collaborative patterns that highlight the matrix within the academic community (Seyman Guray & Kismet, 2023). This sort of study reveals important influences, pivotal studies, and significant publication sites, highlighting the main personalities and institutions pushing a topic (Mohamed et al., 2025). Furthermore, bibliometric analysis investigates the breadth of research themes and stimulates interdisciplinary ideas by evaluating contributions across numerous publications and subject areas (Aliu et al., 2023). It also detects emergent changes and shifts in concentration within a discipline, frequently revealing new research avenues and topical trends (Cobo et al., 2011). Furthermore, bibliometric evaluation reveals research gaps, identifying

topics that need adequate investigation or geographic coverage, thereby directing future research agendas (Passas, 2024). This sort of analysis is critical for academic decision-making and research governance, including the evaluation of journal and institutional performance. Furthermore, it acts as a useful tool for politicians and funding agencies, assisting in the strategic allocation of research funding and resources based on empirical evidence (Lunny et al., 2022).

1.1. Research Questions

To guide this study, the following research questions have been formulated:

RQ1: What have been the key themes and emerging areas of focus in research on smallholder farming and sustainable agriculture between 2014 and 2024?

RQ2: Which countries, institutions, and individual researchers have played the most prominent roles in advancing knowledge in this field?

RQ3: In what ways have patterns of keyword usage and the evolution of research topics shaped the development of ideas and priorities over the past decade?

RQ4: What do the patterns of regional and international collaboration reveal about the distribution and influence of research across the globe?
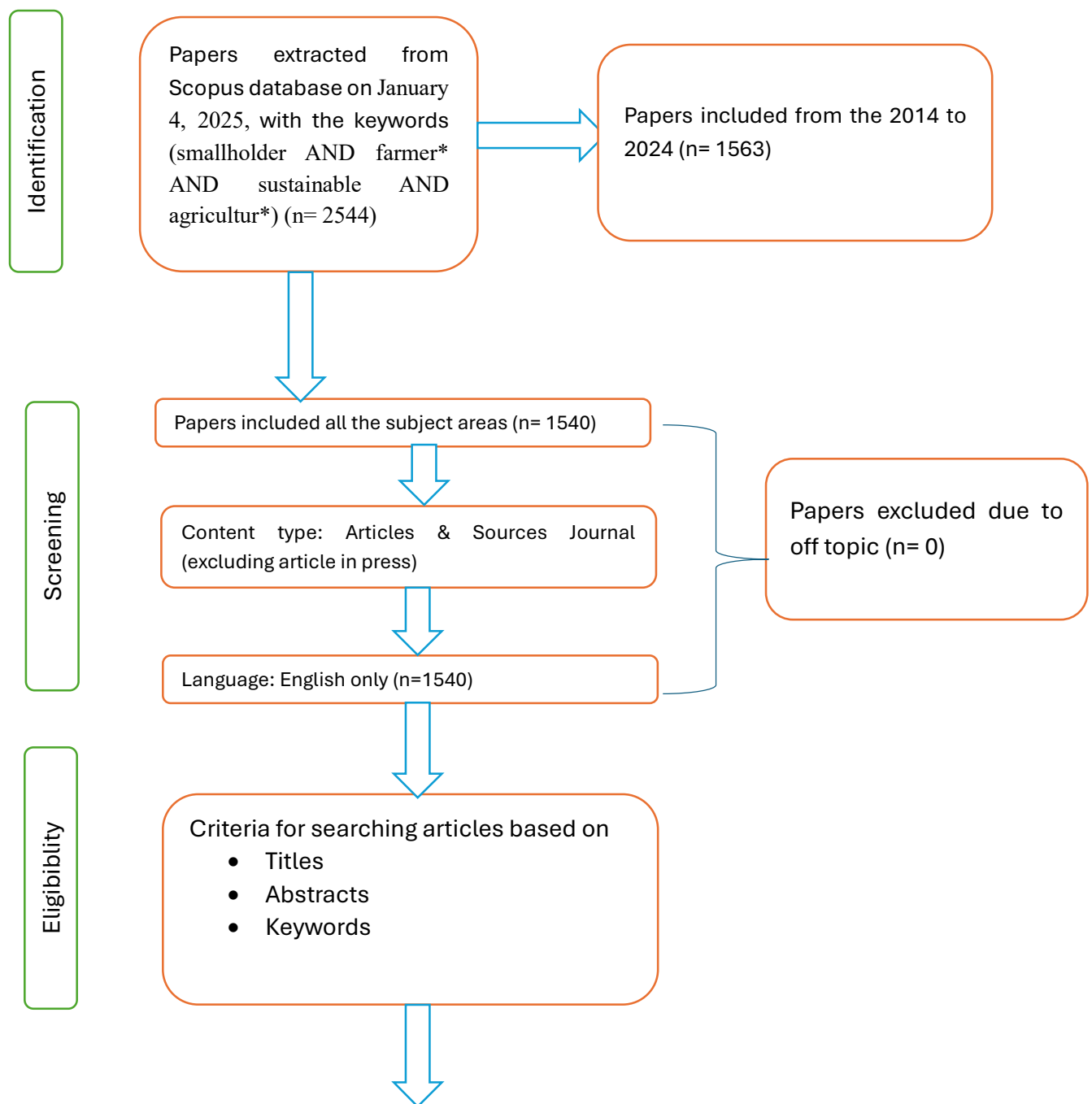
RQ5: Which areas remain underexplored, and what gaps in the literature should be addressed to support future research and policy efforts aimed at strengthening smallholder agriculture?
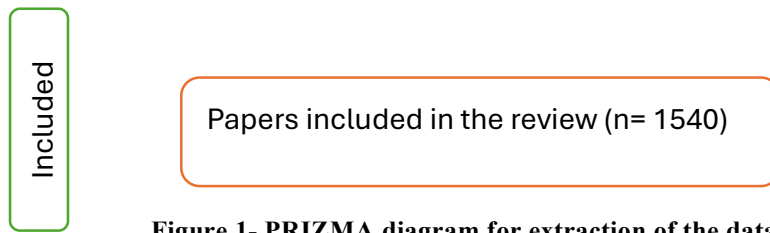
This empirical study provides an in-depth examination of the evolution and current status of research on the benefits and dangers of small-scale farmers in agricultural sustainability. It identifies noteworthy publications, authors, institutions, and approaches, as well as research gaps and prospective areas of collaboration. The paper is organized as follows: Section 2 describes the research technique used to gather, analyze, and process data, as well as a descriptive analysis. Section 3 presents the study's primary findings and highlights the key insights gained from the analysis. Sections 4 and 5 provide a full examination of these findings as well as the study's closing observations.

2. RESEARCH METHODOLOGY

In this study, the researchers applied a structured three-phase approach for sourcing and examining the relevant literature, as shown in Figure 1. Their methodology draws upon established frameworks proposed by (Siraj & Fayek, 2019; Osei-Kyei & Chan, 2015). This systematic approach facilitated both bibliometric

analysis and the categorization of significant benefits and risks associated with smallholder farmers and sustainable agriculture. As emphasized by (Dhamija & Bag, 2020), careful keyword curation is essential for ensuring the relevance of literature included in bibliometric reviews. Accordingly, this study identified relevant search terms based on prior literature and controlled vocabularies, focusing on combinations like *"smallholder"*, *"farmer"*, *"sustainable"*, *and "agricultur"* to capture variations across global contexts.

Identification

Papers extracted from Scopus database on January 4, 2025, with the keywords (smallholder AND farmer* AND sustainable AND agricultur*) (n= 2544)

→ **Papers included from the 2014 to 2024 (n= 1563)**

↓

Screening

Papers included all the subject areas (n= 1540)

↓

Content type: Articles & Sources Journal (excluding article in press)

↓

Language: English only (n=1540)

→ **Papers excluded due to off topic (n= 0)**

↓

Eligibility

Criteria for searching articles based on
- Titles
- Abstracts
- Keywords

↓

Included

Papers included in the review (n= 1540)

Figure 1- PRIZMA diagram for extraction of the data from Scopus database

2.1. Data Collection and Search Strategy

A thorough literature search was carried out on January 4, 2025, using the Scopus database, which is widely recognized for its extensive coverage of peer-reviewed research. Conducting the search on a single day helped ensure consistency and minimize any variations caused by ongoing indexing updates. The inclusion criteria specified English-language journal articles published across multiple subject areas, including **agricultural sciences, environmental studies, economics, social sciences, and business management**.

The initial search string targeted article titles, abstracts, and keywords. This returned **1,540 unique records**, after filtering journal articles only (excluding articles in press, conference papers, and books). These records were exported in CSV format for further analysis. Keywords similar to those used by (Safruddin et al., 2024) were adopted to ensure thematic alignment with current literature on smallholder livelihoods and sustainable practices. These words enabled a thorough examination of scholarly engagement across several dimensions of sustainability, especially sustainable development, conservation of the environment, and equity in society.

2.2 Bibliometric Tools and Techniques

To analyze the collected data, the study utilized two leading bibliometric tools: RStudio's Bibliometrix package and VOSviewer.

1. Bibliometrix and Biblioshiny (RStudio) Bibliometrix is a powerful open-source R software designed for comprehensive scientometric evaluation. Developed by (Aria & Cuccurullo, 2017a), this tool enables the exploration of three core knowledge structures: conceptual (themes and topics), intellectual (citation and co-citation patterns), and social (collaborative networks). Its interface, Biblioshiny, facilitates easy visualization, keyword clustering, and thematic mapping without requiring advanced coding skills.

As noted by (Ding, 2025; Reyes-Gonzalez et al., 2016; Mohammed, 2024) Bibliometrix supports strategic analyses by integrating various statistical techniques with graphical outputs. This allows researchers to assess productivity by country, institution, journal, and author, while also detecting co-authorship and citation dynamics (Fakruhayat & Rashid, 2023).

2. VOS-viewer

First constructed by (Van Eck & Waltman, 2010) at Leiden University, VOSviewer is widely recognized for its capability to produce sophisticated visualizations of bibliometric networks. It supports **co-authorship, keyword co-occurrence, bibliographic coupling, and co-citation analysis**, displaying results in network, overlay, and density formats. This enables researchers to explore linkages among articles, authors, and concepts in a visually intuitive manner.

The combination of Bibliometrix and VOSviewer provides a holistic analytical framework, enabling both macro-level trend analysis and micro-level thematic exploration. These tools complement each other: Bibliometrix excels in theme evolution and conceptual structuring, while VOSviewer strengthens the visualization of network relationships (Arruda et al., 2022).

2.3. Data Cleaning and Refinement

After collecting the initial set of records, a careful screening process was carried out to ensure the quality and relevance of the data. Duplicate entries, unrelated publications, and any outliers were removed. The selection was further refined by focusing on specific subject areas such as Agricultural and Biological Sciences, Environmental Science, and Economics, and by limiting the scope to peer-reviewed journal articles. Only studies published in English were included.

The final dataset, consisting of 1,540 relevant publications, provided a solid base for exploring how research on sustainable agriculture and the development of smallholder farming has progressed over time. In line with the best practices in bibliometric research, this process ensures reliability and replicability, thus strengthening the validity of findings (Baraj et al., 2024). Moreover, the analyzed results contribute to identifying research gaps, influential contributors, regional productivity patterns, and underexplored themes in the domain of sustainable agriculture (Ajibade et al., 2023).

2.4. Contribution of Methodology

This study does more than track the volume of research on smallholder agriculture, it sheds light on the core ideas influencing the field, identifies emerging focus areas, and points out regional gaps in academic contributions. These findings are important not just for scholars, but also for policymakers and development practitioners working to design effective, context-sensitive strategies for small farmers. As global agriculture faces growing challenges from climate change and population pressures, such insights help reframe sustainability as an evolving, multidisciplinary concern that requires collaboration across sectors and regions.

Additionally, it has the potential to inform future digital and technological integration in small farm holder systems, aligning with recent developments in decentralized technologies (Safeer et al., 2024) and precision farming (Rejeb et al., 2024).

2.5. Descriptive statistics

2.5.1. Trend Analysis of Yearly Publications and Citation Counts

The descriptive statistics on smallholder farmers and related research topics, derived from the Scopus database, highlight key publication trends such as annual output, leading journals, prominent countries, and research applications. The yearly distribution of publications on small farm holder is shown comprehensively in **Figure 2**, with a notable rise in scholarly output during recent years. In particular, **2023 recorded 243 articles**, and **2024 marked the highest output with 288 articles**. These figures suggest a growing scholarly interest in promoting research on smallholder farmers and sustainable agriculture.
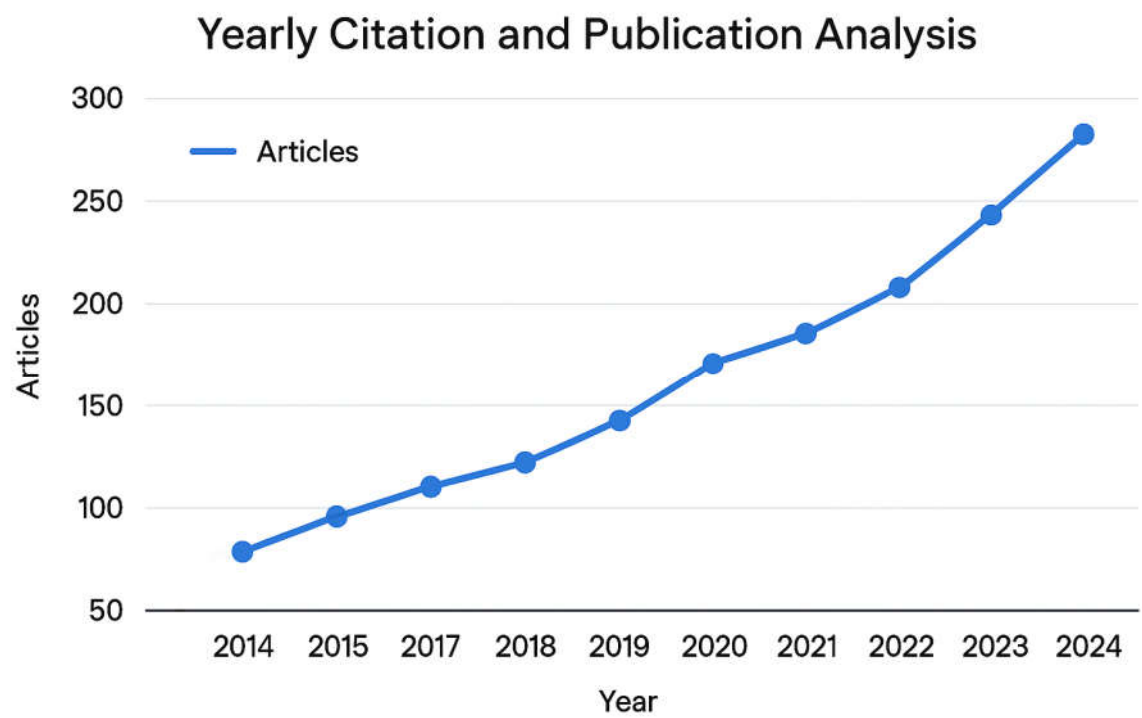

Figure 2- Scientific Publication Trends

We identified the top 10 journals with the most publications on smallholder farmers and sustainable agriculture in recent years, ordered by number of articles published in (Fig 3). Sustainability (Switzerland) leads with 106 publications, demonstrating its emphasis on interdisciplinary approaches to sustainable

practice. Similarly, Agricultural Systems (56 papers) and International Journal of Agricultural Sustainability (51 articles) emphasize novel approaches to sustainable agriculture. Frontiers in Sustainable Food Systems (43 papers) focusses on advances in sustainable food production, while Land Use Policy (33 articles) and Journal of Rural Studies (31 articles) deal with crucial policy and rural livelihood issues. Other publications, such as World Development, Agriculture, Ecosystems and Environment, Journal of Cleaner Production, and Land, contribute significantly, each with 24-25 articles that examine global challenges and strategies for sustainable development and environmental management.
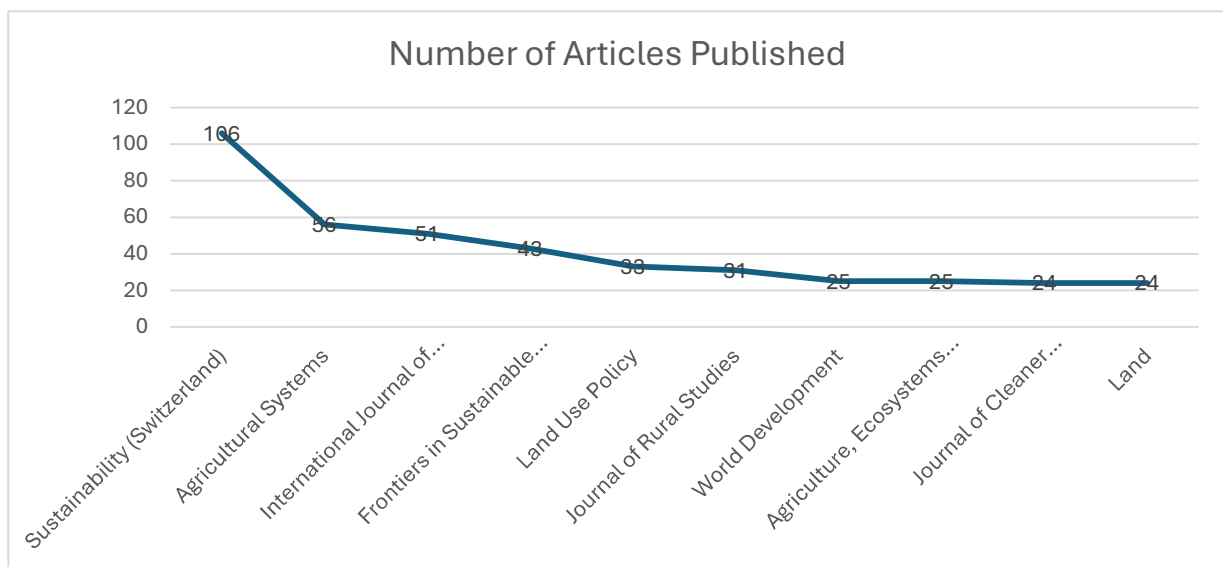
Figure 3- Prominent publications

For researchers and academics, the regional or country-wise distribution of articles provides fascinating insights. This section highlights the leading countries in scientific output that have made notable contributions to research on smallholder farmers and sustainable agriculture (Table 1; Fig. 4).

The world map (Fig. 4) of scientific production, complemented by the frequency table, highlights the global distribution of research output, revealing both traditional leaders and emerging contributors in the field. As presented in (Table 1) **China**, with the highest publication count (759), and the **United States** (576) continue to dominate global research, reflecting their established infrastructure, funding, and institutional strength. However, the notable presence of **Kenya (400), India (379), South Africa (335), and Ethiopia (322)** signifies a shifting research landscape where countries from the Global South are making significant strides, particularly in areas aligned with their regional needs such as agriculture, sustainable development, and public health. European nations like **Germany (312), Netherlands (297), and the United Kingdom (294)** also maintain strong positions, driven by their collaborative research cultures and focus on sustainability and innovation. The map visually emphasizes this distribution, with darker shades in countries

with higher research productivity. Importantly, the prominent appearance of African nations like **Kenya, Ethiopia, South Africa, and Ghana (266)** suggests growing academic engagement and the impact of international partnerships and development-focused research agendas. Overall, the data reflects a gradual diversification of global research production, with emerging economies and developing nations increasingly contributing to the scientific discourse, especially in critical areas addressing global and regional challenges.

**Table 1-** Countries with High Research Productivity

Country	Frequency
CHINA	759
USA	576
KENYA	400
INDIA	379
SOUTH AFRICA	335
ETHIOPIA	322
GERMANY	312
NETHERLANDS	297
UK	294
GHANA	266

Country Scientific Production
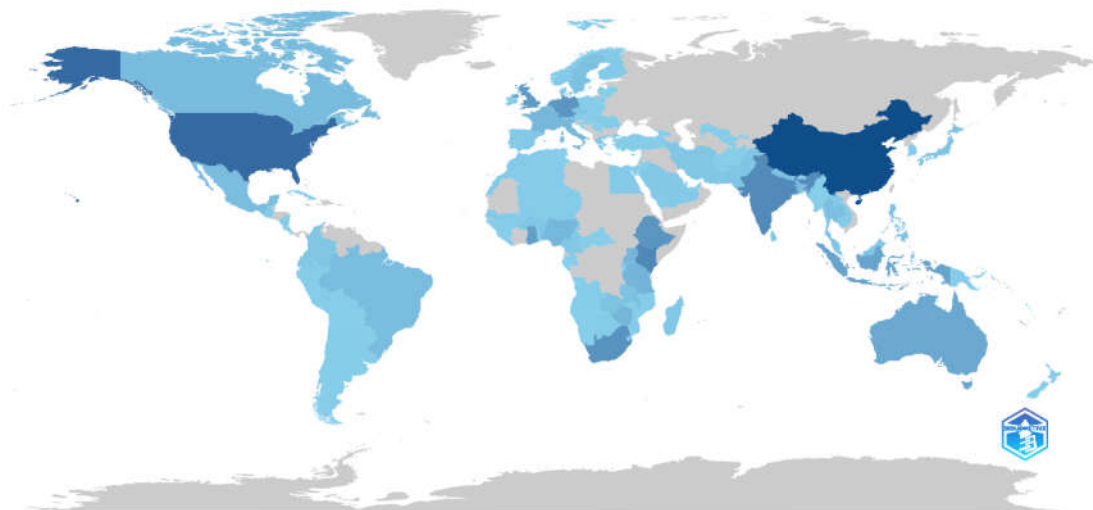
Figure 4- Top Research-Producing Nations

Given the growing global demand for research in this field, this analysis could serve as an eye-opener for other scholars and countries. Figure 5 shows country-specific citation statistics and average article counts, indicating a growing demand for research on smallholder farmers. China ranks highest with a total of 3,653 citations and an average of 27.70 citations per article. Other nations also have an important role in advancing research on smallholder farmers and sustainable agriculture (see figure 5 for more details).
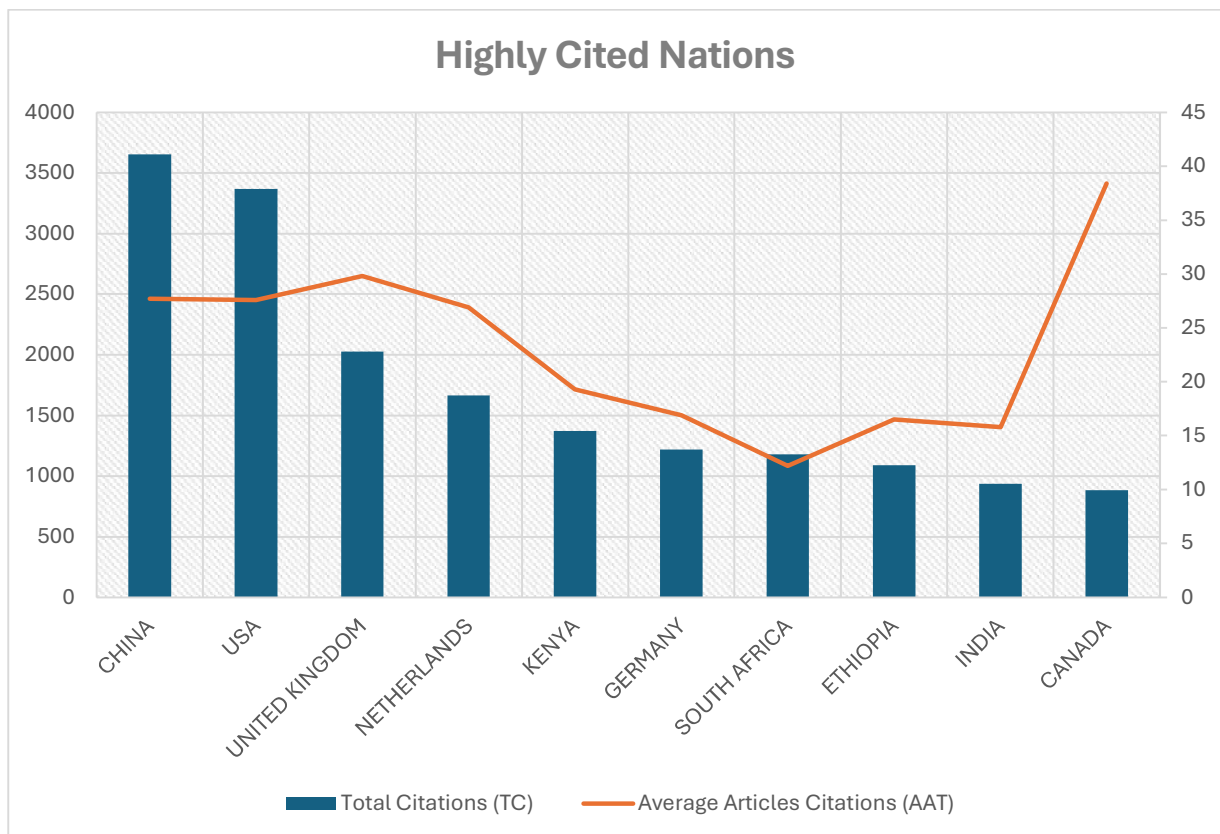
Figure 5- Top Referenced Countries

3- RESULTS AND FINDINGS

3.1. Bibliometric analysis

According to (Aria & Cuccurullo, 2017b) bibliometric evaluation can be conducted using different software tools, and we have selected "Biblioshiny: The Shiny App for Bibliometrix" due to its broad acceptance in academic research. To reach the study's goal, a bibliometric approach focusing on smallholder farmers has been utilized. This includes analyzing citations, co-citations, bibliographic coupling networks, and phrase co-occurrences using bibliographical data. These methods aim to explore research trends in smallholder farmers and sustainable agriculture and to uncover the foundational knowledge within this domain (Shacheendran V, 2023).

3.1.1. Keyword Trends Analysis and Frequently Used Keywords

This study performed an extensive bibliometric analysis based on 4,296 keywords extracted from 1,540 articles. Some terminologies have identical meanings, sometimes leading to mistakes. Unlike other bibliometric tools, the R-tool can consolidate keywords by grouping comparable sentences under primary representations, as shown in Figure 6. This approach enhances the accuracy and reliability of the keyword analysis.

Figure 6- Lexical Co-occurrence

Figure 6 illustrates the most used keywords, shedding light on the primary themes within the research. The keyword "smallholder" is the most prevalent, appearing 646 times, highlighting the significant focus on small-scale farmers and their contributions to agriculture. Other prominent terms include "alternative agriculture" (244 occurrences), which reflects an interest in innovative and non-traditional farming practices, "agriculture" (228 occurrences), encompassing the broader scope of the field, and "sustainable development" (196 occurrences), which emphasizes the integration of farming with environmental,

economic, and social sustainability. These patterns reveal a strong research emphasis on tackling the challenges faced by smallholder farmers while advancing sustainable and innovative agricultural practices.

3.2. Network analysis

Network analysis explores the connections among different research components (Baker et al., 2021; Ramos-Rodríguez & Ruíz-Navarro, 2004). This evaluation focuses on the intellectual connections and structural relationships within the investigation landscape. Science mapping employs scientific methodologies such as citation analysis, co-citation analysis, and keyword co-occurrence. When combined with network analysis, these tools disclose the bibliometric and intellectual structure of a study domain (Tunger & Eulerich, 2018).

3.2.1. Citation analysis

(Appio et al., 2014) in his study, citation evaluation is defined as a basic tool in scientific mapping, based on the assumption that citations signify intellectual linkages between publications, generated when one work refers to another. In this analysis, the influence of a publication is measured by the number of citations it accumulates. This approach helps identify the foremost impactful Articles in the research field. While other methods, like connection metrics, exist to assess the relevance of articles, citation count remains the simplest and most objective indicator of impact (Stremersch et al., 2007; Pieters & Baumgartner, 2002). After analyzing citation data from previous years, we selected the top ten writers mentioned in this paper.

The data (see table 2; figure 7) highlights key contributors to impactful research across various fields. CUI Z (2018) leads with 924 citations in Nature, reflecting significant influence in their domain. KUMAR D (2017) follows with 647 citations in Foods, showcasing notable contributions to food science. ZHANG W (2016) also features prominently with 490 citations in Nature. GRAEUB BE (2016) has 370 citations in World Development, emphasizing the relevance of their work in global development studies, while MARTIN-GUAY M-O (2018) accrued 366 citations in Science of the Total Environment, highlighting contributions to environmental science, and so on.

Table 2- Highly Referenced Global Publications

Paper	Total Citations	TC Per Year
CUI Z, 2018, NATURE	924	115.50
KUMAR D, 2017, FOODS	647	71.89
ZHANG W, 2016, NATURE	490	49.00
GRAEUB BE, 2016, WORLD DEV	370	37.00

|		
MARTIN-GUAY M-O, 2018, SCI TOTAL ENVIRON	366	45.75
PRETTY J, 2015, INSECTS	365	33.18
KASSIE M, 2015, LAND USE POLICY	360	32.73
VANLAUWE B, 2015, SOIL	267	24.27
MANDA J, 2016, J AGRIC ECON	252	25.20
ZEWELD W, 2017, J ENVIRON MANAGE	243	27.00
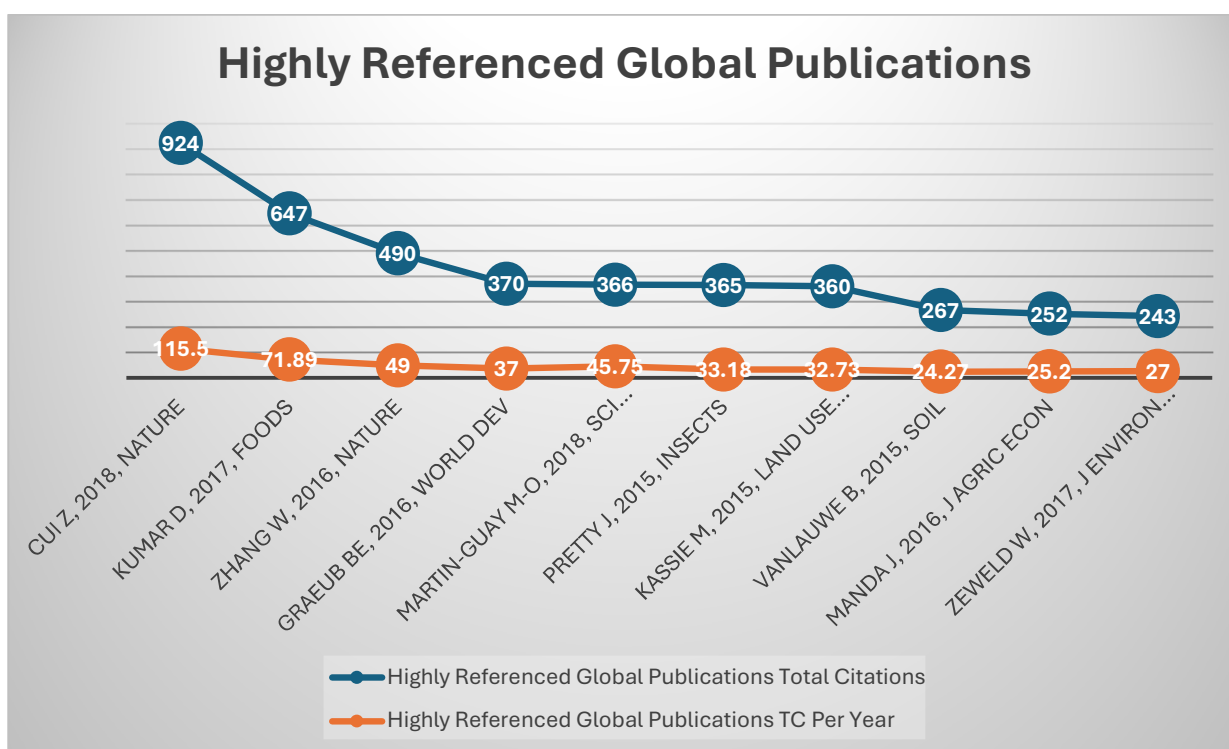
Figure 7- Highly Impactful Global Research Articles

3.2.2. Co-citation Investigation

Co-citation evaluation is a scientific mapping method based on the hypothesis that papers frequently cited together contain topic connections (Hjørland, 2013). This method helps reveal the conceptual structure of a study domain. (Rossetto et al., 2018), including its core themes (Liu et al., 2015). Researchers can apply co-citation analysis to a variety of pairings, such as authors and domains or journals and keywords. This study examines all conceivable combinations and uses co-citation analysis on journal papers to provide an analytical framework for comprehending specific fields of knowledge. In this framework, sustainable

agriculture is the focal point, showing sociological and ethical linkages amongst authors. The analysis uses VOSviewer, a strong network analysis tool (Valenzuela et al., 2017), to perform keyword co-occurrence and author coupling analyses, allowing for an in-depth examination of the intellectual structures within the field. A set of authors who are cited was created using VOSviewer, setting the minimum citation criterion is 20. for references. Out of 119115 cited references, 1634 met the inclusion criteria (Figure- 8).
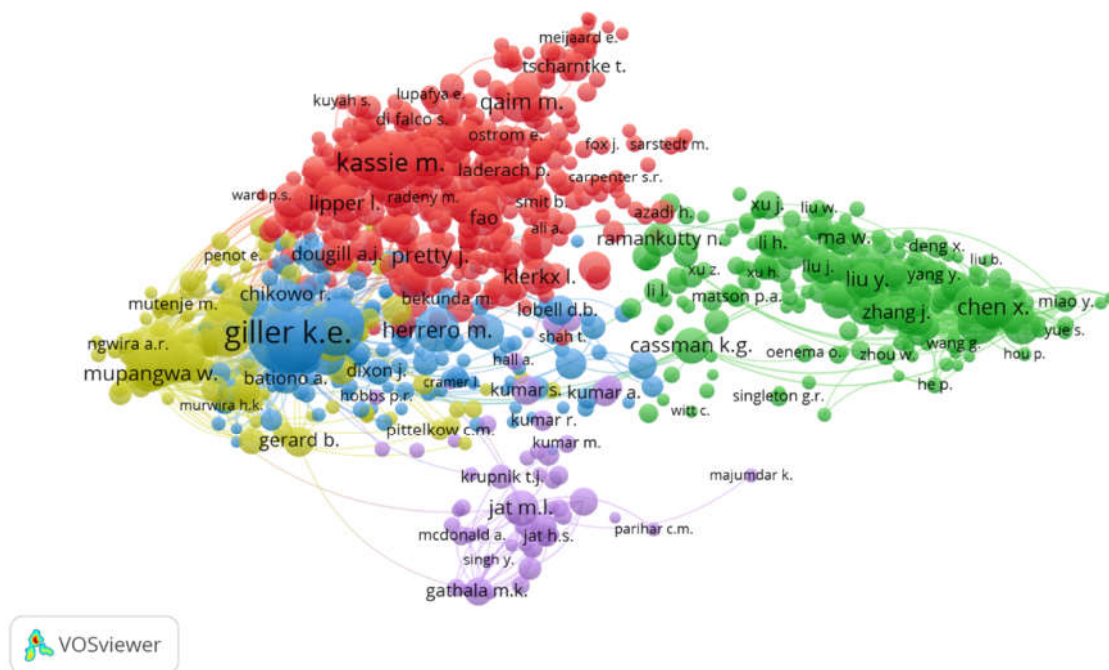

Figure 8- Citation Network Analysis

3.2.3. Keywords Co-occurring Analysis

Keyword relationship is the occurrence of distinctive terms occurring together in documents, indicating the frequency with which specific keywords are employed (Fang et al., 2018; Chen, Chen, et al., 2024). When keywords frequently appear across multiple documents, it signifies a strong correlation between them, providing helpful insights into the major study areas within a particular discipline (Chen, Hu, et al., 2024; Hu et al., 2024). In another word, keywords are used to define and summarize the main content and themes of a study. Analyzing the frequency of keyword occurrences provides insights into the primary research focus areas. A keyword co-occurrence network map for smallholder farmers and sustainable agriculture was created using VOSviewer software with all keywords, as illustrated in (Figure -9). In this map, the node size reflects the frequency with which specific keywords appear. We established the minimal threshold for keywords occurrences to '5.' As a result, out of 7,304 keywords, 725 met this criterion. The arrangement of

nodes and edges illustrates the process of cluster analysis, highlighting groups of densely interconnected nodes that stand out distinctly from other connected clusters.
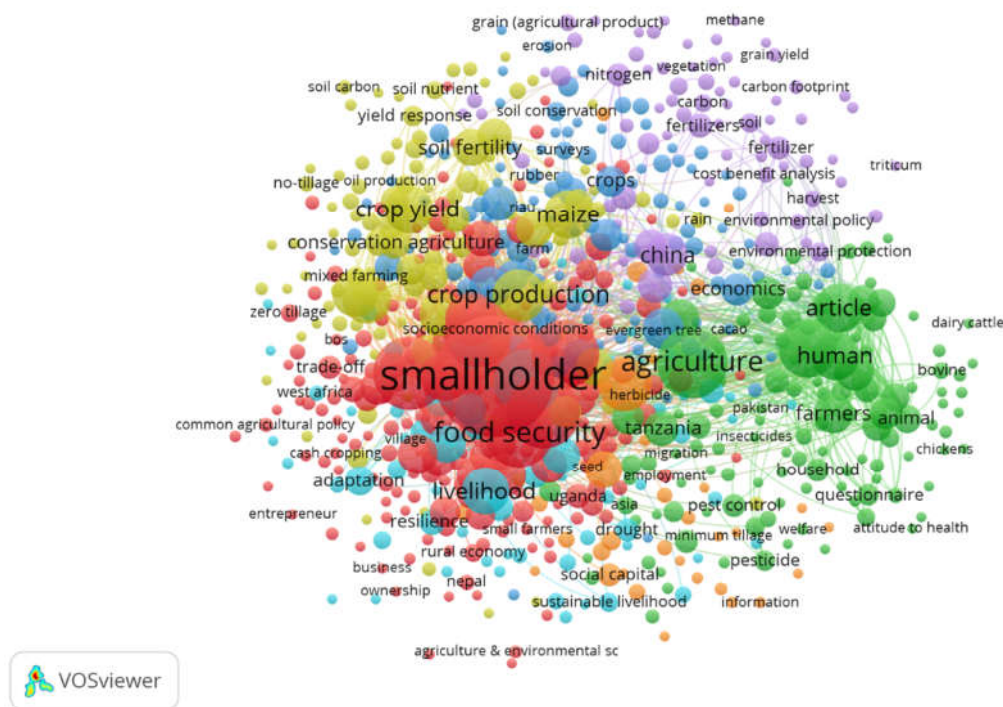
Figure 9- Keyword Network Mapping

4. CONCLUSION, IMPLICATIONS, AND FUTURE RESEARCH DIRECTIONS

This bibliometric study offers a comprehensive account of how scholarly interest in smallholder agriculture and sustainability has emerged over the past decade. By mapping patterns in academic publishing, it highlights key developments, recurring themes, and influential contributions that have shaped current understanding in the field. One notable trend is the growing emphasis on digital transformation in agriculture, especially through tools that aim to enhance productivity and ecological resilience for small-scale farmers. Technologies like precision farming, geospatial mapping, and remote sensing are increasingly being explored for their potential to improve land management, reduce input waste, and address the effects of climate change. Recent findings, including those from the FAO (2024), indicate that such innovations are especially valuable in low-resource settings, where smallholders often face significant operational and financial constraints. At the same time, there is increasing attention to agroecological approaches and the role of local institutions and governance in building sustainable farming systems. The study underscores that the sustainability of smallholder agriculture is shaped by a complex web of factors—

ranging from institutional support and cooperative models to inclusive policy frameworks and access to finance, knowledge, and capacity-building opportunities. This reflects a broader shift in the literature toward more interdisciplinary and systemic perspectives.

The thematic clusters identified through this analysis cut across environmental science, social sciences, and agricultural technology, showing how different academic disciplines are coming together to address the challenges faced by smallholder farmers. There is also a growing interest in the role of communication and digital tools—such as mobile-based advisory services, data platforms, and networked systems—in improving access to markets, weather and climate information, and farm-level decision-making. Moving forward, future research could explore how these technological and institutional innovations interact at the grassroots level, particularly in diverse agro-climatic and socio-economic contexts. There is also a need for more localized, participatory studies that capture the voices and experiences of smallholders themselves, ensuring that solutions are not only scalable but also inclusive and context sensitive. To achieve this comprehensive view, tools like RStudio Bibliometrix and VOSviewer were employed, allowing for detailed mapping of citation patterns, co-authorship networks, and thematic evolutions. Bibliometrix enables the tracking of conceptual and social structures within the literature, while VOSviewer provides graphical visualizations of emerging research networks. The synergy of these tools enhances the interpretability of complex data and helps to identify gaps in knowledge and future research priorities.

The study identifies several emerging themes: the role of climate-smart practices, participatory innovation systems, digital inclusion, and the resilience of food systems post-COVID-19. These themes not only reveal where academic attention is focused but also highlight critical areas for practical intervention, especially in the Global South, where smallholders play a vital role in national food security. In sum, the findings reinforce the idea that sustainable agriculture is a multidimensional concept, and that supporting smallholder farmers demands more than technological inputs—it requires institutional reform, knowledge exchange, and inclusive development models. The bibliometric results serve as a valuable roadmap for researchers, development practitioners, and policy stakeholders aiming to improve the livelihoods of smallholder communities through sustainable practices. Despite its comprehensive approach, this study is subject to certain constraints. Firstly, the dataset is exclusively sourced from the Scopus database. While Scopus is a robust and extensive repository of academic publications, omitting other databases like Web of Science, AGORA, or PubMed may lead to the exclusion of relevant work, particularly from health and development sectors that intersect with agriculture. Secondly, only publications written in English were considered. This decision, though practical for consistency, potentially filters out significant contributions published in regional languages—especially from Latin America, Francophone Africa, and South Asia— where smallholder agriculture remains central to economic and cultural life.

Thirdly, the analysis is limited to publications from the period 2014 to 2024, thereby excluding foundational studies that shaped early thinking on sustainable agriculture and smallholder engagement. As a result, some historical trajectories and shifts in scholarly perspective may not be fully captured. Finally, while bibliometric techniques are excellent for identifying patterns, trends, and network structures in academic publishing, they are inherently quantitative. This means that qualitative depth—such as the theoretical contributions, contextual depth, or policy implications of specific studies—might be underrepresented. Consequently, a bibliometric study should ideally be supplemented by in-depth content analysis or case-based reviews for a more nuanced understanding.

ETHICAL STATEMENT:

An ethical statement is not appropriate for this manuscript because it is solely concerned with "Smallholders and Sustainable Agriculture: A Comprehensive Bibliometric Mapping" and does not include any research on humans or animals, nor does it contain any data or information about vulnerable populations. All the data utilized in this study came from publicly available sources or were simulated for analysis. Any linked resources or datasets follow applicable ethical rules and legislation.

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