Mapping climate change adaptation scholarship in smallholder farming systems across Sub-Saharan Africa: A bibliometric analysis

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ABSTRACT

This study presents a bibliometric analysis of climate change adaptation research in smallholder farming systems across Sub-Saharan Africa (SSA) between 2015 and early 2025. Anchored in the knowledge production systems perspective, which conceptualizes scientific research as shaped by institutional structures, funding architectures, and collaboration networks, the study examines how adaptation scholarship in SSA has evolved within the broader research ecosystem. Drawing on peer-reviewed journal articles indexed in the Scopus database, the analysis examines temporal publication trends, thematic priorities, disciplinary distribution, geographic representation, institutional collaboration networks, and funding structures. A total of 31 Scopus-indexed peer-reviewed articles met the inclusion criteria and were analyzed using Bibliometrix and VOSviewer. The findings indicate a gradual increase in scholarly output, particularly after 2019, reflecting growing international attention to climate-resilient agriculture. However, the indexed literature remains modest in volume and exhibits pronounced structural imbalances. Research is concentrated in agricultural and environmental sciences, with comparatively limited social science integration. Geographic representation is concentrated in a small number of countries, particularly Kenya, South Africa, Ethiopia, Zimbabwe, and Ghana, while parts of Central and West Africa remain underrepresented. Institutional collaboration networks are similarly concentrated, and funding support is predominantly sourced from international donors. Keyword evolution reveals continued emphasis on climate-smart agriculture and food security, alongside emerging attention to participatory approaches and digital agriculture. Overall, the analysis suggests that adaptation scholarship in SSA's smallholder systems is shaped not only by thematic priorities but also by structural factors related to research visibility, funding architecture, and institutional capacity. The study highlights the need for broader disciplinary integration, improved geographic equity, diversified institutional participation, and strengthened domestic research investment to enhance inclusive and context-responsive climate adaptation research in the region.

Keywords: Bibliometric Analysis, Climate Change Adaptation, Research Capacity, Smallholder Farmers, Sub-Saharan Africa

I. INTRODUCTION

Climate change poses escalating risks to agricultural productivity and food security worldwide, with Sub-Saharan Africa (SSA) widely recognized as one of the most vulnerable regions. The region's heavy reliance on rainfed agriculture, combined with limited adaptive capacity and increasing climatic variability, heightens exposure to systemic shocks (Afokpe et al., 2022; Amede et al., 2023). Within this context, smallholder farming systems responsible for the majority of food production in SSA face acute constraints, including limited access to capital, insecure land tenure, inadequate infrastructure, and restricted access to climate-smart technologies (Chavula & Turyasingura, 2021; Jellason et al., 2022).

Since the adoption of the Paris Agreement in 2015, adaptation has gained renewed prominence within international climate governance, reinforced by the United Nations 2030 Agenda for Sustainable Development and the African Union's Agenda 2063. These frameworks have catalyzed expanded funding, institutional programming, and research initiatives focused on climate-resilient agriculture across SSA. Despite growing scholarly attention, the research landscape remains fragmented across disciplines, institutions, and geographic contexts, complicating synthesis and coordinated policy application (Kombat et al., 2021; Tesfuhuney & Mbeletshie, 2021).

Bibliometric analysis offers a systematic approach to mapping such fragmented research domains by examining temporal publication trends, thematic priorities, institutional collaboration networks, geographic representation, citation structures, and funding dynamics (Akinyi et al., 2021; Autio et al., 2021). While numerous empirical studies assess localized adaptation practices, fewer investigations have evaluated the structural configuration of adaptation scholarship

itself within SSA's smallholder farming systems. Understanding how research output has evolved, which themes dominate, how disciplines intersect, and how geographic and institutional participation is distributed is essential for identifying structural gaps and informing future research investment.

This study addresses that gap by conducting a bibliometric analysis of peer-reviewed literature indexed in Scopus between 2015 and early 2025. It examines temporal trends, thematic configurations, disciplinary distribution, geographic patterns, institutional collaboration networks, and funding structures in order to reveal the structural dynamics shaping adaptation scholarship in SSA's smallholder systems. By doing so, the study aims to provide evidence-based insights that can strengthen research coordination, enhance policy alignment, and support the development of more inclusive and regionally responsive climate-resilient agricultural strategies.

The remainder of the paper is organized as follows. The next section outlines the methodological approach used for data collection and analysis. The results section presents findings on publication trends, thematic evolution, collaborative networks, and citation patterns. The discussion interprets these results in light of structural imbalances and knowledge visibility dynamics, and the conclusion offers recommendations for advancing adaptation research and policy in SSA.

1.1 Research Objectives

This study addresses the identified research gap by conducting a bibliometric analysis of peer-reviewed literature on climate change adaptation in smallholder farming systems across Sub-Saharan Africa between 2015 and early 2025. Using publications indexed in the Scopus database, the study systematically examines the structure and evolution of adaptation scholarship within this research domain. By mapping temporal publication trends, thematic priorities, disciplinary engagement, geographic representation, institutional collaboration networks, and funding patterns, the study provides a structured overview of how adaptation knowledge related to smallholder farming systems has developed within the region's scientific literature.

The primary objective of this study is to map and assess the development of climate change adaptation research in smallholder farming systems across Sub-Saharan Africa. Specifically, the study pursues the following objectives: (i) to analyze temporal trends in scholarly publications on climate change adaptation in smallholder farming systems across Sub-Saharan Africa between 2015 and early 2025; (ii) to identify dominant research themes and emerging keywords shaping the climate adaptation research landscape within the region; (iii) to examine the geographic and institutional distribution of research output and patterns of collaboration among authors and institutions; and (iv) to assess the funding structures and institutional collaboration networks influencing the development and visibility of adaptation scholarship in Sub-Saharan Africa. By addressing these objectives, the study contributes to a deeper understanding of how adaptation knowledge is produced, distributed, and supported within the region. The findings aim to inform future research investment, strengthen interdisciplinary collaboration, and support the development of more inclusive and context-responsive climate adaptation strategies for smallholder farming systems in Sub-Saharan Africa.

II. THEORETICAL FRAMEWORK

This study is grounded in the knowledge production systems perspective, which conceptualizes scientific research as the outcome of interactions among institutional structures, funding mechanisms, collaboration networks, and publication infrastructures that collectively shape how knowledge is generated, disseminated, and utilized. According to this perspective, scientific output does not emerge in isolation but is embedded within broader social, institutional, and economic systems that influence research agendas, disciplinary orientations, and the visibility of scholarly contributions. Foundational work by Gibbons et al. (1994) and Nowotny et al. (2001) highlights the evolving nature of knowledge production, emphasizing that contemporary research increasingly occurs within distributed networks involving universities, international organizations, and policy institutions.

In the context of Sub-Saharan Africa, the structure of knowledge production systems is strongly influenced by disparities in research capacity, institutional resources, and funding availability. Studies on African research systems have shown that international development agencies and global research institutions play a significant role in shaping research priorities and knowledge visibility within the region (Arvanitis et al., 2022). As a result, patterns of scientific publication often reflect broader structural dynamics related to institutional collaboration, funding architecture, and integration into global academic publishing networks. These dynamics can influence not only the quantity of research output but also the thematic focus and geographic representation of scholarly work.

Applying the knowledge production systems framework provides an analytical lens for interpreting the bibliometric patterns identified in this study. Indicators such as publication trends, disciplinary distribution, institutional collaboration networks, geographic representation, and funding sources can be understood as manifestations of underlying structural conditions within the regional research ecosystem. By situating bibliometric findings within this theoretical perspective, the study moves beyond descriptive mapping of publications and instead highlights how

structural factors shape the development and visibility of climate change adaptation scholarship in smallholder farming systems across Sub-Saharan Africa. This theoretical perspective therefore provides the conceptual foundation for examining publication trends, collaboration networks, and funding structures shaping climate adaptation scholarship in SSA.

III. METHODOLOGY

3.1 Study Design and Approach

This study employed a bibliometric approach to examine peer-reviewed literature on climate change adaptation in smallholder farming systems across Sub-Saharan Africa (SSA). The methodological process was organized into four interrelated stages: database selection and search strategy formulation, eligibility screening, data extraction and preparation, and bibliometric analysis and visualization.

3.2 Database Selection and Timeframe Justification

The Scopus database was selected for its extensive coverage of high-quality peer-reviewed literature across disciplines relevant to this study, including agriculture, environmental science, and development research. All data collection and analysis were conducted exclusively within the Scopus platform to ensure consistency and replicability. The search was limited to journal articles and review papers published between January 2015 and February 2025.

This ten-year window was selected to capture recent developments in climate adaptation scholarship during a period of intensified global policy engagement. Beginning with the adoption of the Paris Agreement in 2015, adaptation gained renewed prominence within international climate governance frameworks. The timeframe also aligns with the implementation of the United Nations 2030 Agenda for Sustainable Development and the African Union's Agenda 2063, both of which emphasize agricultural resilience and climate-responsive development. During this period, international research institutions and development agencies including FAO, IPCC, and CGIAR expanded adaptation-focused programming across SSA.

While a decade may not be sufficient to establish long-term historical trends, it provides a focused lens on contemporary research dynamics within a policy-relevant era. The selected timeframe therefore prioritizes analytical relevance to current climate governance frameworks rather than offering a comprehensive historical account of adaptation scholarship in the region.

3.3 Search Strategy

A structured search strategy using Boolean logic was applied within the Scopus database. The final search string was:

TITLE-ABS-KEY

(("Climate change adaptation" OR "climate adaptation" OR "adaptation to climate change")

AND

("Smallholder" OR "small-scale farmer" OR "subsistence farmer" OR "peasant farmer")

AND ("Sub-Saharan Africa" OR "SSA"))

This formulation was developed following preliminary scoping searches to identify commonly used terminology within the adaptation literature. The inclusion of both "climate change adaptation" and "climate adaptation" ensured capture of studies that refer to adaptation processes with or without explicit repetition of the term "climate change." The smallholder-related terms were selected to reflect dominant descriptors in agricultural development and adaptation scholarship within SSA. While alternative terminology such as "family farmer" or "resource-poor farmer" is occasionally used, preliminary scoping indicated that such terms are more frequently associated with broader rural development or livelihood studies and are less consistently employed in explicitly climate adaptation-focused research within SSA. The selected search string therefore prioritized conceptual precision and thematic relevance to maintain analytical coherence. The search was restricted to English-language publications, reflecting the dominant language of indexed scientific publishing within the region.

3.4 Eligibility Criteria and Screening Process

Following the application of the search strategy within the Scopus database, the initial query returned a total of 257 documents. Titles, abstracts, and keywords of these records were manually screened to determine their relevance to the research objectives. Documents were included if they (i) were published between January 2015 and February 2025, (ii) were peer-reviewed journal articles, review papers, or book chapters, and (iii) explicitly addressed climate change adaptation in smallholder farming systems within Sub-Saharan Africa.

Documents were excluded if they (i) focused exclusively on climate mitigation, (ii) addressed large-scale, industrial, or commercial agriculture, (iii) examined regions outside Sub-Saharan Africa, (iv) were not published in English, or (v) consisted of conference proceedings, editorials, opinion pieces, or other non-peer-reviewed materials.

The relatively small final corpus (n = 31) reflects the highly specific conceptual intersection defined by the inclusion criteria, which required publications to explicitly address climate change adaptation in smallholder farming systems within Sub-Saharan Africa, while also being indexed in Scopus and published in English-language peer-reviewed journals during the 2015–early 2025 period. In bibliometric research, precision in search strategy and conceptual delimitation is essential to ensure thematic coherence and analytical validity (Donthu et al., 2021). Narrowing the dataset to a clearly defined thematic and geographic intersection is consistent with established systematic review and bibliometric protocols that emphasize transparency, replicability, and rigor in eligibility screening (Page et al., 2021). Although broader searches of climate adaptation research in agriculture yield substantially larger bodies of literature, the strict conceptual intersection applied in this study deliberately focuses on a narrower and policy-relevant research niche. Similar focused bibliometric analyses examining tightly defined thematic intersections have reported relatively modest datasets when stringent inclusion criteria are applied. The restricted corpus therefore reflects the analytical precision of the search strategy rather than a lack of research activity in the broader field of climate adaptation. The document selection process is summarized in Figure 1, which presents a PRISMA flow diagram illustrating the stages of screening and exclusion.

3.5 Quality Control Procedures

To ensure methodological rigor, screening was conducted by two independent reviewers using a standardized template to maintain consistency. Any discrepancies were resolved through discussion, and when necessary, by consulting a third reviewer. An exclusion log was maintained to document decisions. Bibliographic metadata were cleaned before analysis to remove duplicates, correct inconsistencies in author and institutional names, and normalize keyword variants (e.g., singular versus plural forms), improving the accuracy of network and co-occurrence analysis.

3.6 Data Extraction and Processing

All bibliographic data were extracted directly from Scopus in RIS and CSV formats. The datasets were processed using three tools: Bibliometrix, an R package for advanced bibliometric analysis; VOSviewer, used for visualizing co-authorship networks, keyword clusters, and institutional linkages; and Microsoft Excel was used for managing summary tables and basic descriptive statistics.

3.7 Analytical Indicators and Visualization

The bibliometric analysis focused on several key indicators, including annual publication output, citation metrics, keyword co-occurrence, author collaboration networks, institutional affiliations, geographic distribution of publications, and funding acknowledgment patterns. Visualizations were produced to map collaboration structures, research themes, and institutional and regional contributions. These analytical outputs provided a structured overview of the research landscape in climate change adaptation for smallholder farming systems across SSA.

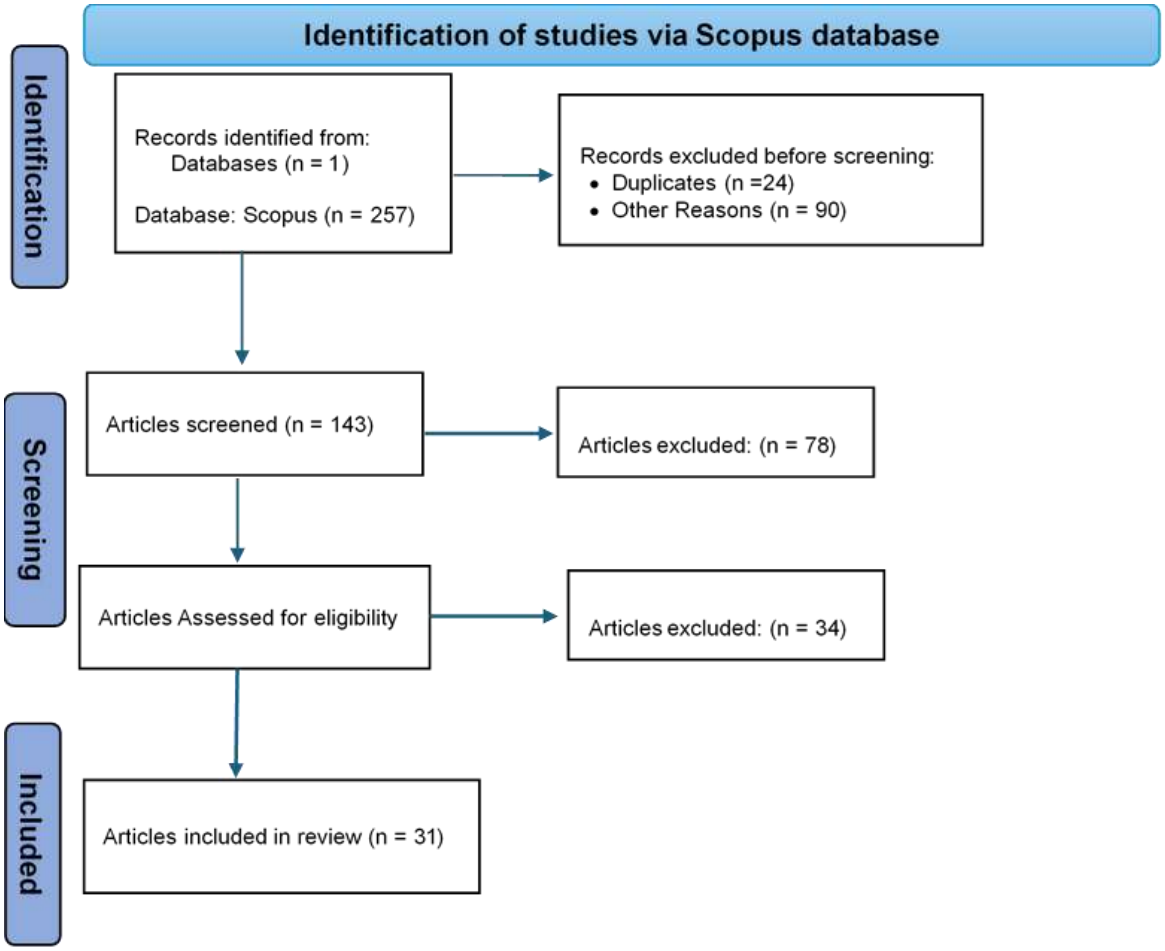

Figure 1
PRISMA Flow Diagram for Article Selection Process
Note. Adapted from Page et al. (2021)

IV. FINDINGS & DISCUSSION

4.1 Findings

4.1.1 Publication Trends

The annual distribution of publications (Figure 2) demonstrates a gradual but uneven upward trajectory in scholarly output on climate change adaptation in smallholder farming systems across Sub-Saharan Africa between 2015 and early 2025. During the initial period (2015–2018), publication activity remained sporadic, with one to three articles per year and no publications recorded in 2016 and 2018. From 2019 onward, however, a clearer growth pattern emerges, with output increasing steadily through 2022 and reaching a pronounced peak in 2024 (n = 10), the highest annual contribution within the dataset.

The post-2019 acceleration suggests expanding research attention to smallholder-focused adaptation, potentially reflecting the consolidation of funding cycles and the operationalization of global climate policy frameworks. The slight decline observed in 2025 (n = 2) should be interpreted cautiously, as the year was incomplete at the time of data extraction. Overall, despite the upward trend, the cumulative volume of publications (n = 31) remains modest relative to the scale and urgency of climate adaptation challenges in SSA, indicating both emerging momentum and persistent underrepresentation within internationally indexed scholarship.

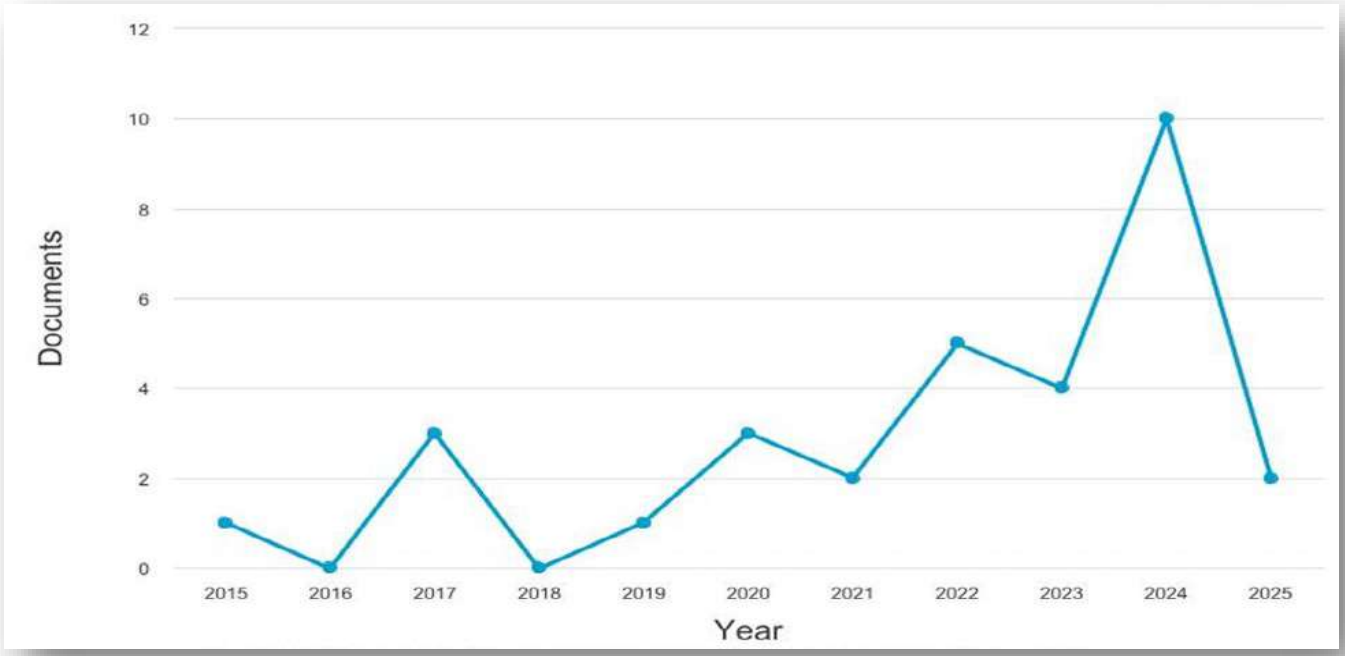

Figure 2
Publication Trends

4.1.2 Document Types and Subject Areas

Among the 31 selected publications, original research articles constitute the largest share (58.1 percent), followed by review papers (29.0 percent) and book chapters (12.9 percent). This distribution indicates a healthy balance between empirical evidence generation and broader thematic synthesis. In terms of disciplinary classification, the publications are predominantly indexed under Agricultural and Biological Sciences (34.5 percent) and Environmental Science (25.9 percent). Social Sciences contribute 10.3 percent, while Economics, Engineering, and Multidisciplinary Sciences each account for approximately 6.9 percent. A few entries also fall under categories such as Business, Management, and Earth Sciences, reflecting the interdisciplinary nature of adaptation research in the SSA context (Figure 3 & 4).

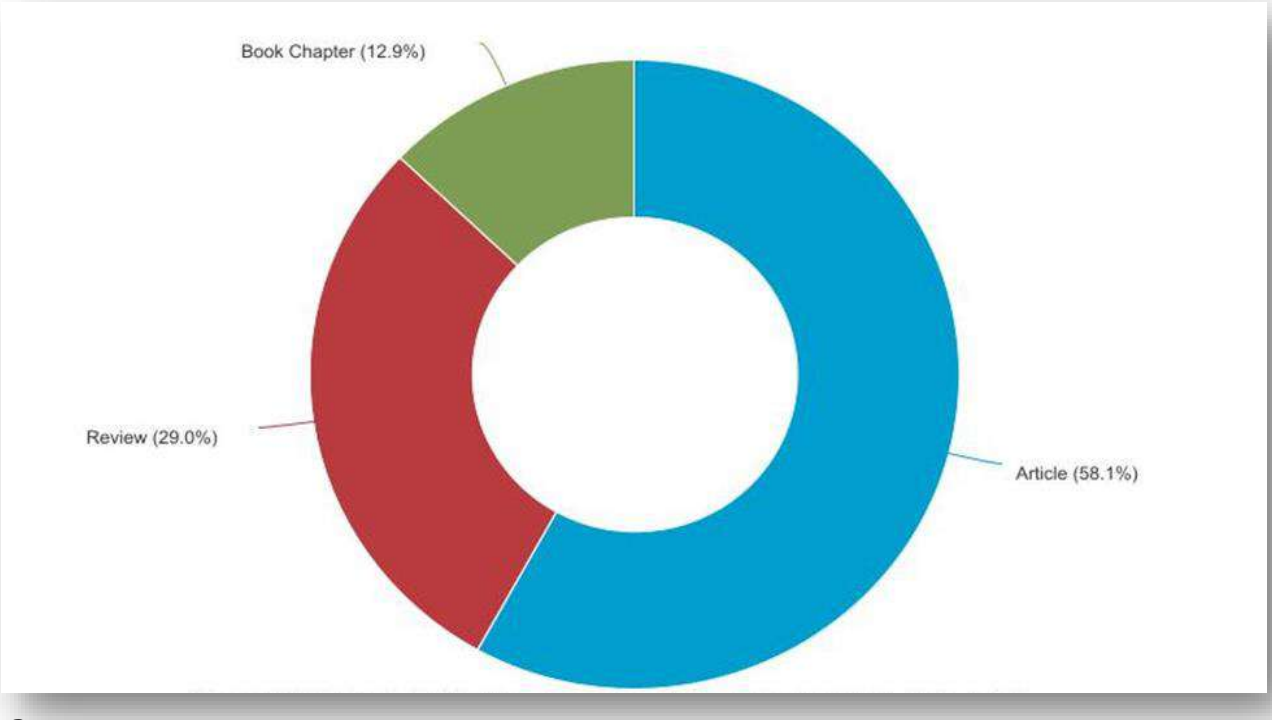

Figure 3
Documents by Publication Type.

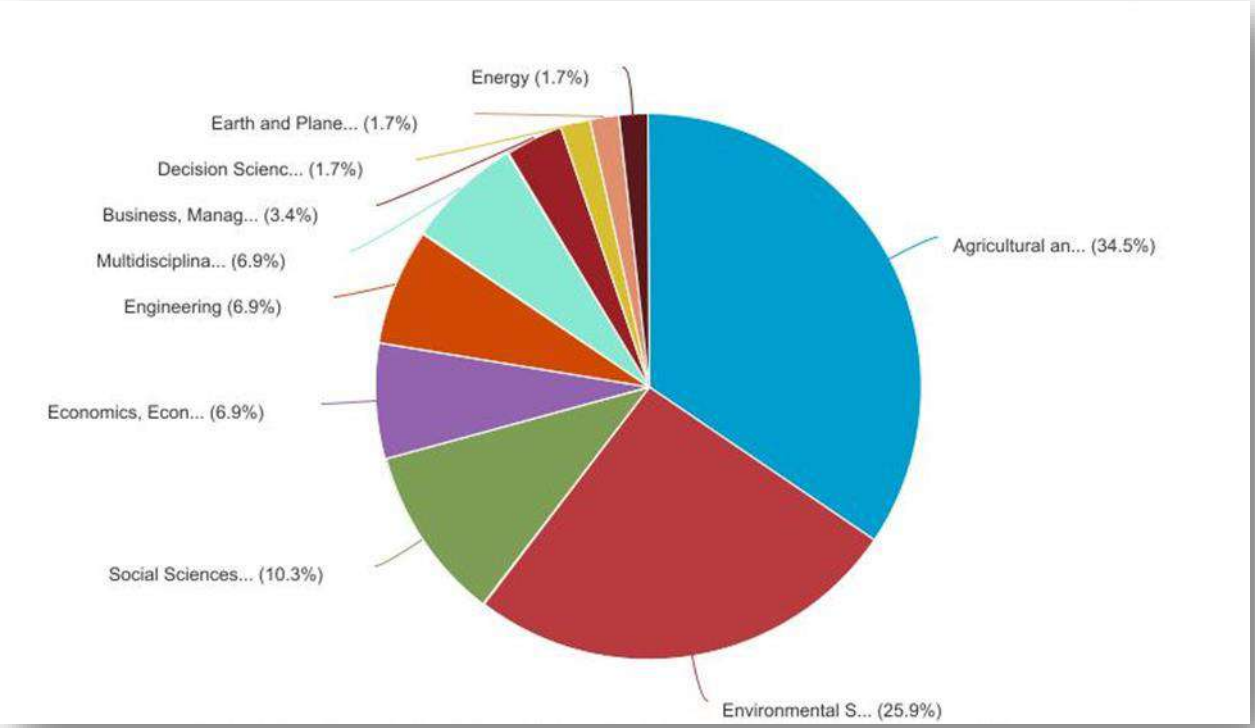

Figure 4
Documents by Subject Area

4.1.3 Geographic Distribution of Research

An analysis of author affiliations shows that research output is concentrated in a limited number of SSA countries. Kenya is the most frequently represented, with 11 documents, followed by South Africa (7), Zimbabwe (6), Ethiopia (5), and Ghana (2). These five countries together account for the majority of SSA-based contributions. Many of the studies include multi-country affiliations, suggesting active regional and international collaboration. However, countries in Central and parts of West Africa are notably underrepresented, pointing to geographic disparities in research capacity and visibility (Figure 5).

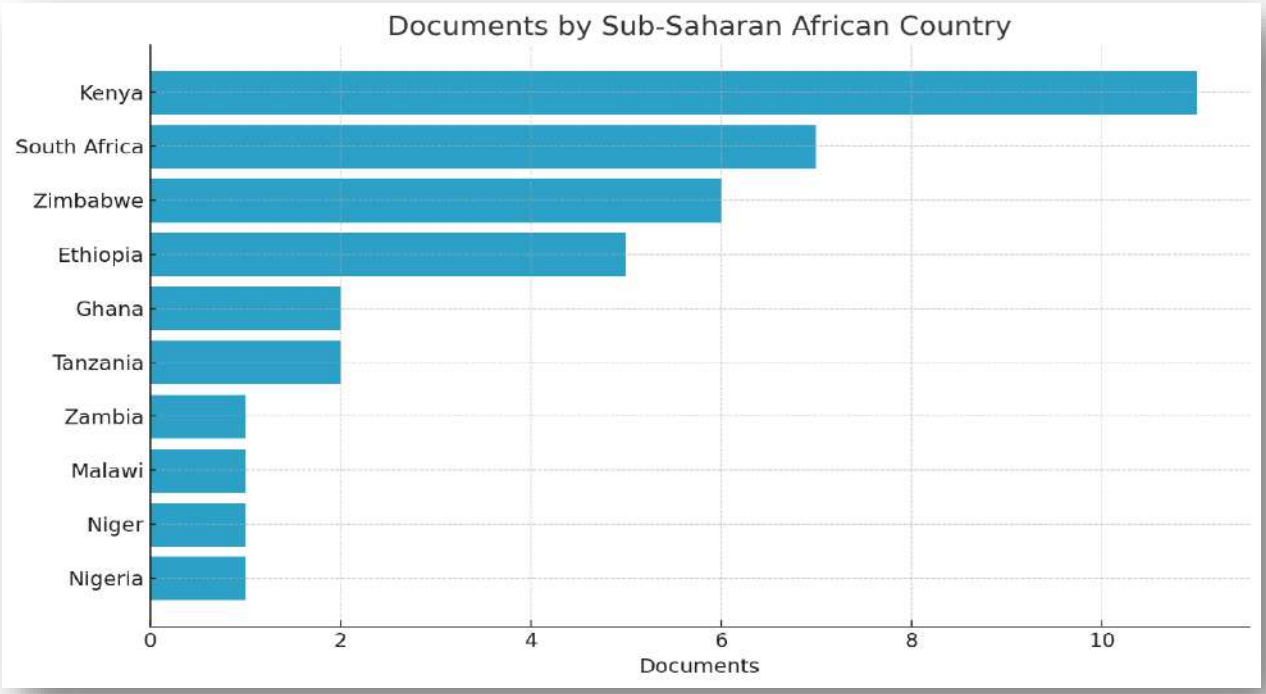

Figure 5
Documents by Country or Territory

4.1.4 Institutional Contributions

Research activity is similarly concentrated among a small group of institutions. The University of KwaZulu-Natal and the University of Zimbabwe each contributed four publications, making them the most prolific institutions in the dataset. They are followed by the University of Nairobi (3), and several others including the International Centre of Insect Physiology and Ecology, Kenyatta University, and the International Livestock Research Institute, each contributing two articles. Additional contributors include the University of Embu, the International Potato Center, and CGIAR-affiliated programs. The presence of both national universities and international research organizations highlights a blend of local and global participation in SSA climate adaptation scholarship (Figure 6).

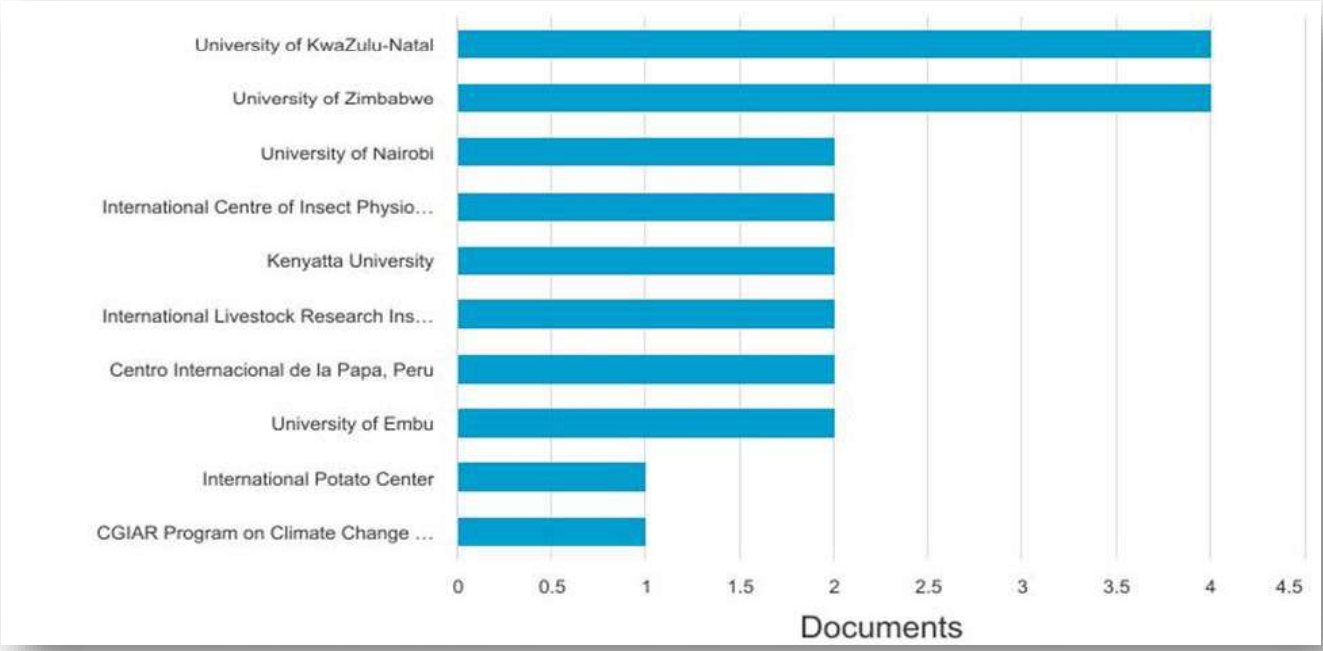

Figure 6

Documents by Affiliated Institution.

4.1.5 Research Themes and Keyword Analysis

The keyword co-occurrence analysis, conducted using VOSviewer, identified several frequently used terms across the dataset. Core terms include "climate change," "climate-smart agriculture," "smallholder farmers," "food security," and "climate change adaptation." These keywords formed thematic clusters that emphasize technical and agronomic approaches to adaptation. Additional keywords such as "resilience," "sustainable development," "agroforestry," "vulnerability," and "conservation agriculture" reflect broader ecological and sustainability concerns.

A temporal overlay revealed that newer terms such as "digital agriculture," "climate variability," and "participatory approaches" have gained traction in recent years, especially between 2018 and 2024. This suggests an evolving interest in innovation, governance, and farmer-centric adaptation strategies. Keyword frequency analysis also indicates that the terms “climate-smart agriculture,” “food security,” and “smallholder farmers” became especially prominent from 2022 onwards, pointing to growing scholarly attention to resilience-building practices in smallholder systems (Figures 7 and 8).

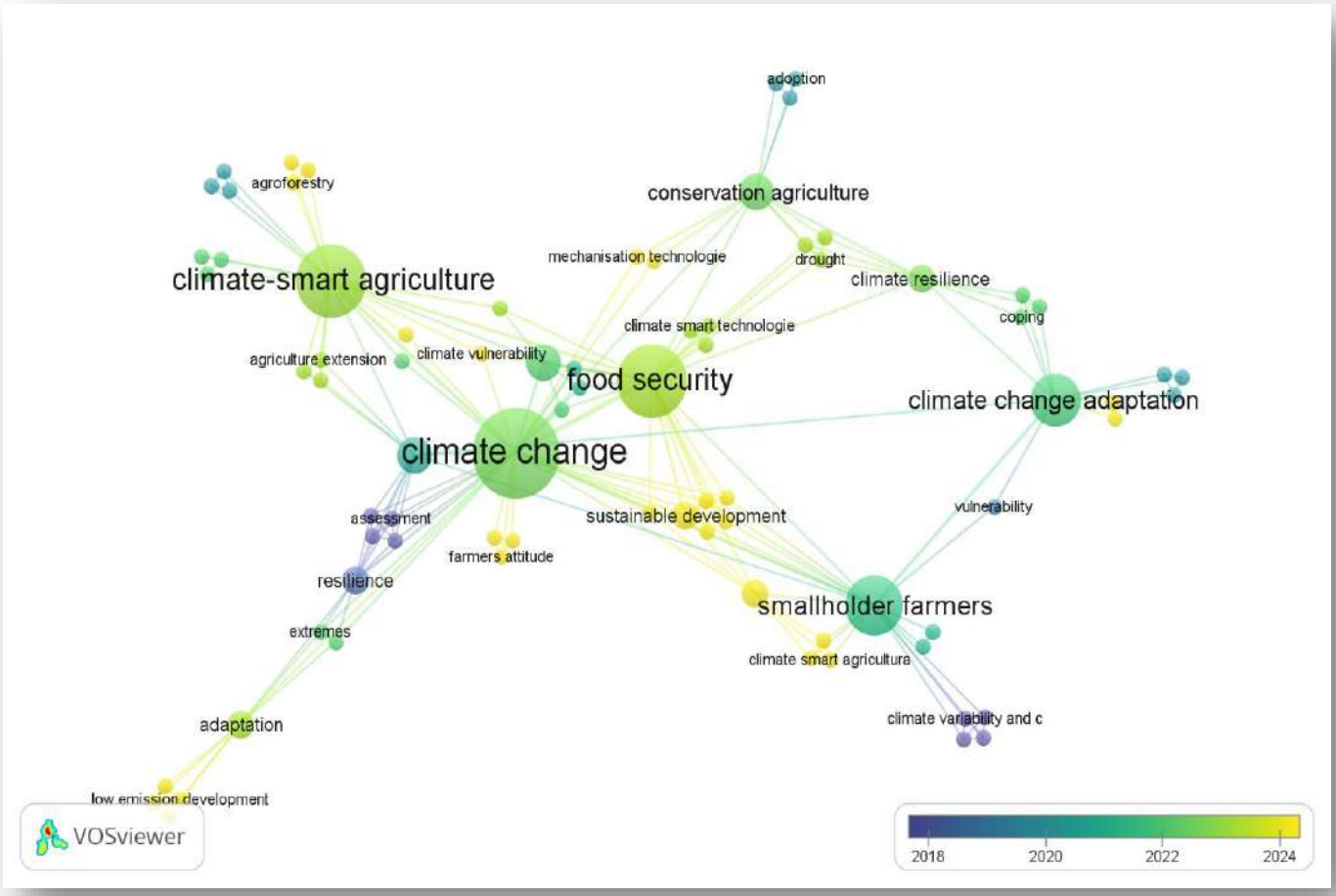

Figure 7
Keyword Co-Occurrence Network Map

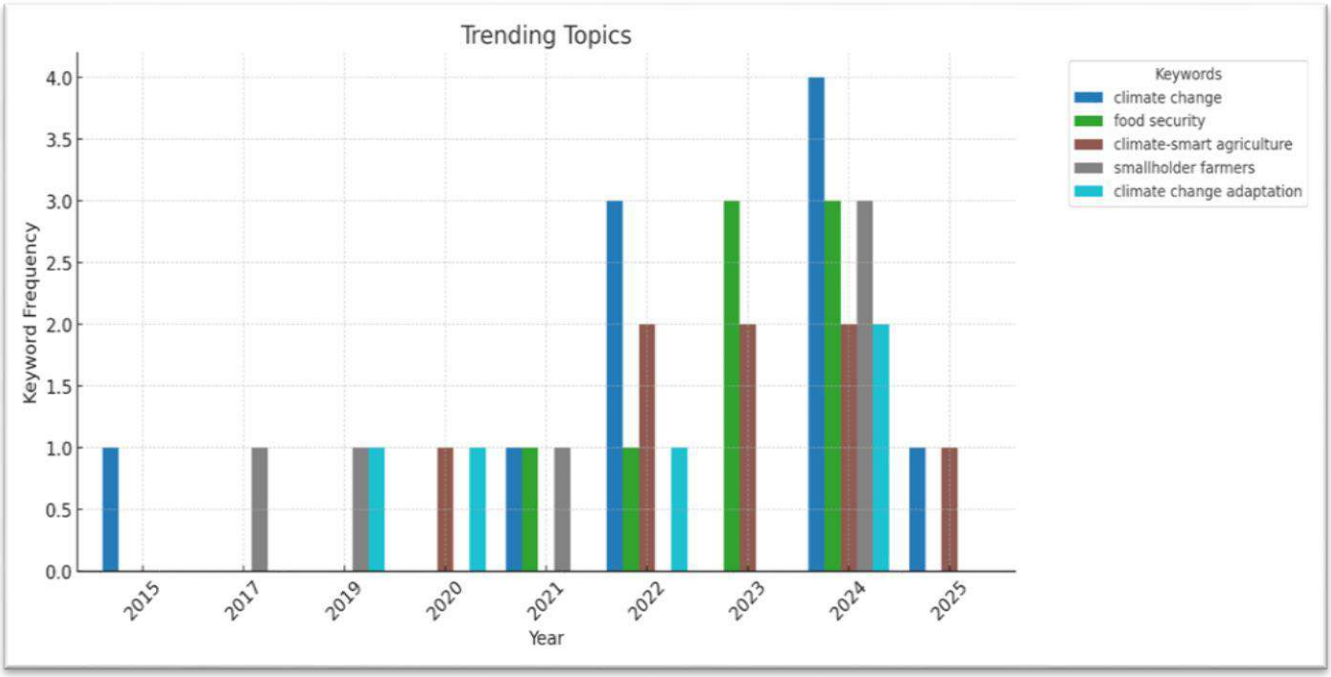

Figure 8
Trending Keywords by Year.

4.1.6 Core Journals and Source Distribution

An assessment of publication sources using Bradford's Law identified a core group of journals contributing the most to the field. These include *Frontiers in Sustainable Food Systems*, *Agriculture (Switzerland)*, *Heliyon*, and the *Journal of Agriculture and Environment for International Development*. These journals specialize in interdisciplinary research at the intersection of agriculture, environment, and rural development. Their prominence reflects a preference for accessible, open-access platforms that are widely read by both academic and practitioner audiences (Figure 9).

Figure 9
Core sources by Bradford's Law

4.1.7 Influential Articles and Citation Mapping

Citation mapping using a Sankey diagram revealed a set of highly influential publications, primarily addressing themes such as climate-smart agriculture, smallholder resilience, and food security. The diagram illustrates connections among key contributing authors, core references, and dominant research domains. Most frequently cited works are empirical studies or reviews situated within East and Southern African contexts, highlighting a concentration of scholarly influence in specific sub-regions (Figure 10).

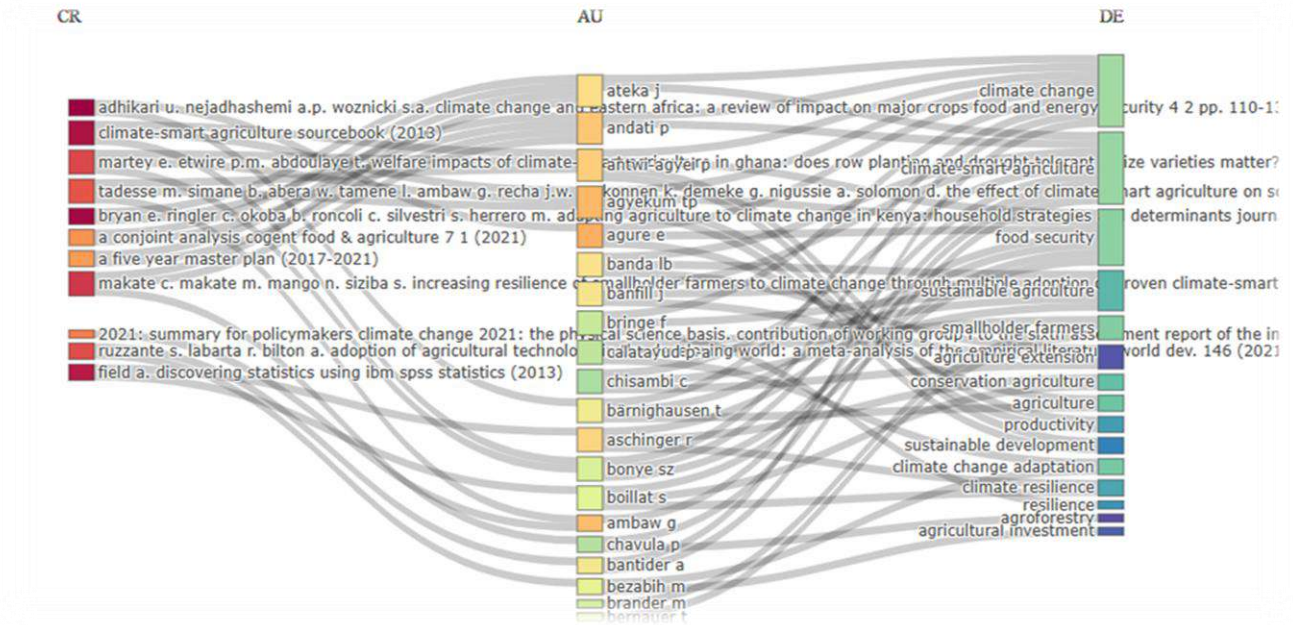

Figure 10
Sankey Diagram

4.1.8 Funding Sources

Funding analysis indicates that the majority of studies were supported by large international donors. The Consortium of International Agricultural Research Centers (CGIAR) appears most frequently, followed by the World Bank Group, the International Fund for Agricultural Development (IFAD), and the Bill and Melinda Gates Foundation. European donors such as GIZ and the Swedish International Development Cooperation Agency (SIDA) also feature prominently. The dominance of external funding sources underscores the strong influence of international development actors in shaping the research agenda for climate adaptation in SSA (Figure 11). Notably, domestic funding from SSA governments or local agencies is almost entirely absent, raising concerns about long-term sustainability and local ownership of research priorities.

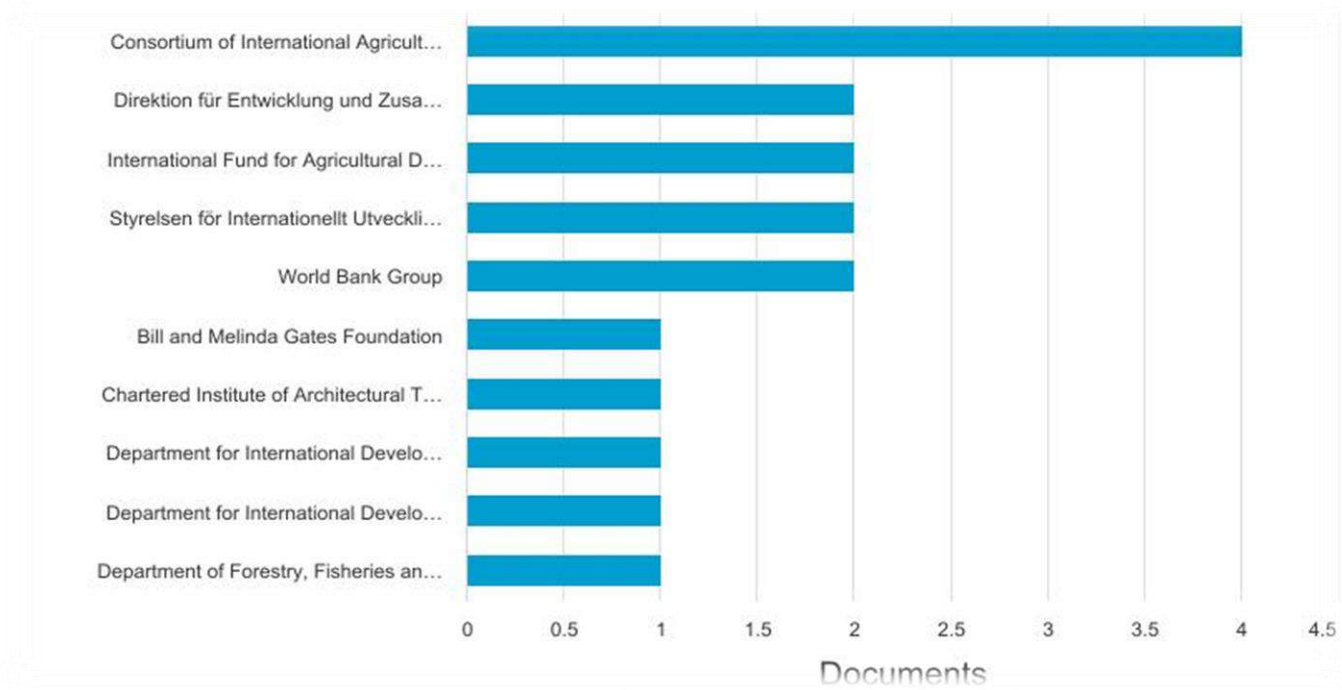

Figure 11
Documents by Funding Sponsor.

4.2 Discussion

The bibliometric analysis of climate change adaptation research in smallholder farming systems of Sub-Saharan Africa reveals several significant patterns and gaps that merit deeper examination. This discussion interprets these findings within the broader context of climate science, agricultural development, and research capacity in the region.

4.2.1 Temporal Evolution and Research Momentum

The publication trajectory between 2015 and early 2025 indicates a gradual but discernible increase in scholarly engagement with climate change adaptation in smallholder farming systems across Sub-Saharan Africa. The acceleration observed from 2019 onward coincides with key developments in global climate governance, including the operationalization of the Paris Agreement and the strengthening of adaptation commitments within international climate negotiations (Arnott et al., 2021). This temporal pattern suggests that international policy frameworks and funding priorities may have stimulated research investment and scholarly attention in this domain.

The publication peak in 2024 may reflect the maturation of multi-year research initiatives initiated in the late 2010s, as well as heightened international emphasis on climate-resilient agriculture within the Sustainable Development Goals agenda. However, despite this upward trend, the overall corpus remains modest (n = 31), indicating that smallholder-focused adaptation research within internationally indexed literature remains underdeveloped relative to its critical importance for regional food security and climate resilience. Similar patterns of limited adaptation scholarship in developing regions have been documented in broader global assessments of climate adaptation research (Nalau & Verrall, 2021; Berrang-Ford et al., 2021).

Importantly, this temporal growth should be interpreted within the structural constraints discussed earlier, including database selection, language restrictions, and funding asymmetries. The observed increase therefore reflects trends in indexed research visibility rather than definitive measures of total adaptation research activity across SSA.

4.2.2 Disciplinary Integration and Knowledge Structures

The predominance of original research articles (58.1%) indicates a strong emphasis on empirical evidence generation within the field. However, the disciplinary distribution reveals both strengths and structural limitations in the adaptation research landscape. The concentration in Agricultural and Biological Sciences (34.5%) and Environmental Science (25.9%) demonstrates robust natural science foundations. In contrast, the comparatively lower representation of Social Sciences (10.3%) suggests potential gaps in addressing socioeconomic, behavioral, institutional, and governance dimensions of adaptation. Given that smallholder adaptation operates at the intersection of technology, policy, land tenure, gender relations, and local knowledge systems, limited social science engagement may constrain the development of context-sensitive and institutionally grounded adaptation strategies (Nightingale et al., 2020; Nakagawa & Saijo, 2021)

This disciplinary imbalance has important implications for how adaptation challenges are framed and addressed. A research landscape dominated by agronomic and environmental perspectives may prioritize technical interventions, climate-smart agricultural practices, and productivity-enhancing solutions, while comparatively underexamining structural inequalities, power relations, implementation barriers, and governance dynamics. Scholars have cautioned that technocratic framings of climate adaptation risk overlooking social vulnerability, institutional capacity constraints, and political economy dimensions that shape adaptive outcomes (Canosa et al., 2021; Nightingale et al., 2020). Consequently, disciplinary composition may influence not only the types of research questions asked, but also the policy narratives and development pathways that emerge from adaptation scholarship.

At the same time, the observed imbalance may partially reflect structural publication and indexing dynamics rather than the absence of social science research within SSA. Social science scholarship is frequently disseminated through regional journals, policy reports, development agency publications, and institutional working papers that may not be comprehensively indexed in Scopus. Furthermore, interdisciplinary and development-focused research may appear in venues with lower international visibility. The disciplinary distribution observed in this study should therefore be interpreted as indicative of patterns within indexed literature, rather than a definitive measure of overall disciplinary engagement in smallholder adaptation research across Sub-Saharan Africa.

4.2.3 Geographic and Institutional Concentration

The pronounced geographic concentration of research in Kenya, South Africa, Zimbabwe, Ethiopia, and Ghana carries important implications for regional knowledge equity within Sub-Saharan Africa. Several structural factors may help explain this concentration. These countries host some of the region's most established agricultural research institutions and universities, many of which maintain long-standing collaborations with international research organizations and development partners. In addition, stronger integration into global academic publishing networks and the predominance of English-language scholarship may facilitate higher visibility of research outputs originating from these contexts. The underrepresentation of Central and parts of West Africa may reflect structural disparities in research capacity, infrastructure, funding access, and international publication integration (Elouaourti et al., 2025). Such geographic imbalance risks generating adaptation knowledge that does not fully capture the region's diverse agroecological and socioeconomic realities, a concern echoed in broader assessments of African research ecosystems (Ezeh et al., 2021). If adaptation strategies are predominantly informed by evidence from a limited number of national contexts, their broader applicability across SSA may be constrained.

However, these patterns must be interpreted with caution. The observed concentration may not solely indicate uneven research production, but also disparities in indexed research visibility. The reliance on Scopus, while methodologically appropriate for bibliometric consistency, inherently privileges journals embedded within global citation infrastructures. This dynamic tends to favor Anglophone countries and institutions with established international publication networks, while potentially underrepresenting scholarship disseminated through regional, non-indexed, or non-English outlets (Amano et al., 2016; Erick et al., 2025). Distinguishing between research production and indexed research visibility is therefore critical, as publication infrastructure, language policies, and collaborative networks significantly shape global scholarly representation.

Institutional concentration further reinforces these dynamics. The dominance of a relatively small group of universities and internationally connected research centers suggests limited democratization within the indexed literature. While collaboration between national institutions and global research organizations demonstrates productive partnerships, the prominence of established institutions may constrain the visibility of perspectives emerging from smaller or less internationally integrated entities (Graham, 2020; Chigudu, 2024). These patterns align with broader challenges in diversifying climate science leadership across the Global South (Kilungo et al., 2024) and underscore the importance of strengthening inclusive publication infrastructures to enhance equitable representation in climate adaptation scholarship.

Thematic Focus and Emerging Trends: The keyword analysis reveals a research landscape that has traditionally emphasized technical and agronomic approaches to adaptation. The prominence of terms like "climate-smart

agriculture," "food security," and "smallholder farmers" since 2022 reflects alignment with global development frameworks, particularly the Sustainable Development Goals (Oyelami et al., 2023). The temporal evolution toward terms such as "digital agriculture," "climate variability," and "participatory approaches" signals promising shifts toward innovation and farmer-centered methodologies, mirroring evolving priorities in agricultural development literature (McCampbell et al., 2021). However, the relative absence of keywords related to indigenous knowledge systems, gender dimensions, policy implementation, and economic aspects of adaptation suggests potential blind spots in current research (Huntington et al., 2021). These gaps may limit the practical applicability and inclusivity of adaptation strategies being developed, a concern raised by critical scholars.

*Funding Dynamics and Research Agenda Setting***:** Funding analysis indicates that the majority of studies were supported by large international donors, particularly CGIAR, the World Bank Group, IFAD, and the Bill and Melinda Gates Foundation. European development agencies such as GIZ and SIDA also feature prominently. The dominance of external funding sources stresses the strong influence of international development actors in shaping the climate adaptation research landscape within SSA. Notably, domestic funding from SSA governments or local agencies appears minimal within the indexed literature, reflecting broader structural funding gaps documented in African research systems (Arvanitis et al., 2022; Mdoe et al., 2025). Similar financial capacity constraints have been observed in agricultural enterprise contexts, where managerial financial literacy and financial management practices significantly influence performance and investment potential (Mang'ana, 2026; Mang'ana et al., 2024).

Beyond simple funding concentration, these patterns may have substantive implications for research orientation and thematic emphasis. Several of the dominant keywords identified in the analysis particularly "climate-smart agriculture," "resilience," and "food security" align closely with programmatic frameworks promoted by CGIAR and multilateral development institutions. While such alignment reflects important global development priorities, existing scholarship suggests that funding architectures can influence research agendas, conceptual framings, and methodological preferences (Barrett et al., 2020; Canosa et al., 2021). Donor-driven funding mechanisms often emphasize measurable, scalable, and technically framed adaptation interventions, which may partially explain the predominance of agronomic and technological themes within the dataset (Nightingale et al., 2020).

These dynamics raise broader questions concerning research sovereignty and agenda-setting power within SSA adaptation scholarship. Heavy reliance on international funding may orient research priorities toward externally defined development frameworks rather than locally determined knowledge needs (Arvanitis et al., 2022). Although international collaboration and financial support remain essential for advancing climate resilience, strengthening domestic research investment and regional funding mechanisms could enhance contextual responsiveness, diversify research perspectives, and support more locally grounded adaptation strategies (Ochieng et al., 2018; Barrett et al., 2020).

Implications for Future Research and Policy: The findings of this study indicate a research domain that is gaining scholarly momentum yet remains structurally constrained by geographic concentration, institutional clustering, disciplinary imbalance, and funding asymmetries. Addressing these structural limitations is essential for strengthening the knowledge base underpinning climate adaptation in smallholder farming systems across Sub-Saharan Africa (Mdoe et al., 2025b).

First, expanding geographic representation should be prioritized through targeted capacity-building initiatives, regional research networks, and strengthened collaboration with institutions in underrepresented countries (Erick et al., 2025). Enhancing research infrastructure and publication support in Francophone and Lusophone regions is particularly critical to improving equitable scholarly visibility. Second, greater disciplinary integration is needed to complement strong agronomic foundations with deeper engagement from social sciences, governance studies, and political economy perspectives (Nightingale et al., 2020; Canosa et al., 2021). Such integration would enable more holistic adaptation frameworks that account for institutional constraints, power relations, and socioeconomic inequalities shaping smallholder resilience.

Third, diversifying institutional participation beyond a small group of internationally connected universities and research centers could democratize knowledge production and foster context-specific innovation (Ezeh et al., 2021). Strengthening domestic and regional funding mechanisms is equally important. While international donor support remains vital, balancing external investment with national and regional funding commitments would enhance research sovereignty, sustainability, and alignment with locally defined priorities (Barrett et al., 2020). Finally, broadening thematic emphasis to include adaptation governance, indigenous knowledge systems, gender dynamics, and economic dimensions would contribute to more inclusive and implementation-oriented adaptation strategies (Huntington et al., 2021).

The future trajectory of climate adaptation research in SSA will significantly influence policy effectiveness and practical resilience outcomes (Nalau & Verrall, 2021; Berrang-Ford et al., 2021). As climate impacts intensify, closing structural gaps in knowledge production and visibility becomes increasingly urgent. Strengthening equity in research representation, disciplinary integration, and funding architecture will be critical to advancing evidence-based adaptation

pathways that are locally grounded, socially responsive, and regionally inclusive across diverse African smallholder farming systems.

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusion

This bibliometric analysis examined the structural configuration of climate change adaptation research in smallholder farming systems across Sub-Saharan Africa between 2015 and early 2025. By systematically mapping publication trends, thematic priorities, geographic representation, institutional collaboration networks, and funding dynamics, the study provides a structured overview of how climate adaptation knowledge related to smallholder farming systems has evolved within internationally indexed scientific literature during the Paris Agreement era. The analysis reveals that although scholarly engagement with smallholder-focused climate adaptation has increased in recent years, the overall body of indexed literature remains relatively modest. Moreover, the research landscape is characterized by notable structural imbalances in geographic representation, disciplinary integration, institutional participation, and funding architecture.

The findings indicate that the effectiveness of climate adaptation policy in Sub-Saharan Africa will depend not only on generating additional research, but also on transforming the ways in which knowledge is produced, funded, and disseminated. The study therefore contributes to the emerging literature on climate adaptation knowledge systems by highlighting how structural factors such as publication infrastructure, funding architecture, and institutional collaboration networks shape the visibility and direction of adaptation scholarship in the region. As climate impacts intensify and the vulnerability of smallholder farming systems deepens, addressing structural inequities in research visibility and capacity becomes increasingly critical. Without broader geographic inclusion, stronger integration of social science perspectives, and more diversified funding mechanisms, adaptation scholarship risks reinforcing existing structural asymmetries rather than supporting regionally responsive resilience strategies.

5.2 Recommendations

Based on the findings of this study, several priorities emerge for strengthening climate change adaptation research related to smallholder farming systems in Sub-Saharan Africa. First, expanding research capacity and publication support in underrepresented regions particularly in Central and West Africa as well as in non-Anglophone countries is essential for improving geographic equity in climate adaptation scholarship. Strengthening research infrastructure, training opportunities, and publication support mechanisms can enhance the visibility of locally grounded knowledge and broaden regional representation in international research databases.

Second, greater interdisciplinary integration is needed to complement the strong presence of agricultural and environmental sciences with deeper engagement from social sciences, governance studies, and political economy perspectives. Such integration would enable a more comprehensive understanding of the socioeconomic, institutional, and policy dynamics that shape smallholder adaptation processes. Third, rebalancing research funding structures is critical for improving long-term sustainability and research sovereignty in the region. Increasing domestic and regional investment in climate adaptation research alongside continued international collaboration would help align research agendas more closely with locally defined priorities and development needs.

Finally, future bibliometric research should broaden database coverage, incorporate non-English scholarship, and integrate qualitative assessments of policy uptake and practitioner engagement. Expanding analytical approaches in this way would provide a more comprehensive understanding of how adaptation knowledge is generated, disseminated, and applied within smallholder farming systems across Sub-Saharan Africa.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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