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Pluralistic Extension Services for Smallholder Farmers in Developing Countries: A Bibliometric Review on Climate-Smart Agriculture Adoption

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ABSTRACT

Climate-smart agriculture (CSA) adoption remains low in developing countries due to resource constraints and weak extension systems. This bibliometric review examines how pluralistic extension services (PES) support smallholder farmers in adopting CSA practices between 1995 and 2023. We synthesized 389 documents from Scopus using Biblioshiny in R to identify publication trends, regional collaborations, emerging research themes, and institutional contributions. Findings highlight that PES plays a significant role in scaling CSA in resource-constrained environments through participatory, digital, and inclusive models. Despite exponential publication growth, adoption challenges remain due to coordination gaps, weak ICT infrastructure, and limited integration of local knowledge systems. The study concludes with insights for policymakers and researchers on strengthening PES to improve CSA uptake among smallholders in the Global South.

1. Introduction

Pluralistic Extension Services (PES) refer to multi-actor systems in which public, private, NGO, and community actors collaborate to deliver agricultural knowledge and innovation. Such systems are crucial for supporting smallholder farmers in developing countries, especially under increasing climate stress. This study explores how PES research has evolved in facilitating Cimate-Smart Agriculture (CSA) adoption, particularly among smallholders.

Several studies have highlighted the role of agricultural extension officers as key facilitators in decision-making and the promotion of CSA practices (Terblanche, 2008; Uzonna and Qijie, 2013; Mossie and Meseret, 2015; Maka et al., 2019). These officers equip farmers with the knowledge and tools to improve productivity, sustainability, and the adoption of CSA practices (Ampt et al., 2015). Traditionally, government agencies were the primary providers of these services, but pluralistic models have gained traction. These models integrate multiple actors, including government agencies, private sector players, NGOs, research institutions, community-based organizations, and Information and Communication Technologies (ICT) platforms (Halal, 2001). In this case, PEAS has emerged as a promising approach to enhance CSA's effectiveness by fostering innovation, expanding resource access, and making extension services more responsive to the dynamic needs of farmers adapting to climate change (Albert, 2006; Davis et al., 2020). However, identifying the key stakeholders and their specific contributions within PEAS is essential to address gaps in CSA adoption effectively.

Although research has examined PEAS and CSA adoption among smallholder farmers, significant knowledge gaps remain (Anang, 2022; Dowsing and Cardey, 2020; Makate et al., 2019). Research institutions and universities, in particular, are crucial in catalyzing collaboration among various actors to advance CSA adoption (Dawes et al., 2004; Ricardo et al., 2012). However, better coordination among stakeholders is essential to achieve meaningful progress. Without effective coordination, PEAS can overwhelm farmers, hindering their learning and consistent adoption of CSA practices (Mark et al., 2011). Smallholder farmers (SHF) often struggle to absorb and apply new knowledge introduced through PEAS (Klerkx et al., 2016). This challenge underscores the importance of fostering collaborations to create CSA materials that build on existing efforts. Addressing these gaps requires a bibliometric analysis to facilitate better coordination and disseminate actionable knowledge.

This study is guided by the following research questions: (1) What are the publication and collaboration trends in PES and CSA research for smallholder farmers in developing countries? (2) Who are the most influential authors, institutions, and countries in this space? (3) What are the key thematic clusters and knowledge gaps in the literature on PES and CSA? The paper concludes with evidence-informed recommendations for stakeholders working to enhance PES effectiveness.

Pluralistic stakeholder theory

This study is grounded on pluralistic stakeholder theory which has several aspects as presented in Table 1. The Agricultural Pluralistic Extension Stakeholder Theory (APES) posits that agricultural Extension and Advisory Services (EAS) operate within a complex web of stakeholders, each with diverse interests and power dynamics (Birner et al., 2009; Faure et al., 2012). The APES recognizes the importance of integrating multiple knowledge sources and acknowledging the value of both scientific and local knowledge systems. It emphasizes the need to bridge the gap between research and practice by promoting the co-creation of context-specific and relevant solutions for farmers (Röling and Jiggins, 1998). This pluralistic approach to knowledge generation and dissemination empowers farmers to actively participate in the innovation process, fostering a sense of ownership and agency (Pretty and Smith, 2004). As primary beneficiaries, farmers seek knowledge and support to enhance their livelihoods and adapt to the challenges posed by climate change (Birner et al., 2013). However, they often lack the resources and influence needed to access and shape EAS that adequately meets their needs (Davis et al., 2010).

Power dynamics and equity considerations are central to the APES. The theory underscores the importance of addressing power imbalances among stakeholders, empowering, and promoting inclusivity and fairness (Chambers, 1994; Davis and Sulaiman, 2014). Additionally, APES recognizes the dynamic nature of agriculture and the need for EAS to be adaptive and resilient. In the face of climate change and other challenges, EAS must evolve and innovate, equipping with knowledge and skills to navigate uncertainties and build sustainable livelihoods (FAO, 2012). collaboration and partnerships are vital to the success of pluralistic EAS. APES advocate for the formation of strong networks and alliances among stakeholders, leveraging diverse resources and expertise to co-deliver effective EAS and advance climate-smart agriculture (Klerkx et al., 2012). Hence, APES fosters collaboration, inclusivity, empowerment, and adaptability and provides a framework for navigating the complexities of agricultural extension in climate change. These collaborative approaches promote knowledge exchange, innovation, and collective action toward sustainable agricultural development (Leeuwis and Aarts, 2011). This requires creating platforms for meaningful farmer participation, ensuring marginalized groups have equal access to EAS, and promoting the equitable distribution of benefits (Rivera and Qamar, 2003). A representation of the conceptual framework of pluralistic stakeholder theory applied to EAS is shown in Figure 1. The conceptual framework reflects the dynamics common in Sub-Saharan Africa and other developing regions.

Table 1. Critical aspects of pluralistic stakeholder theory

Aspect	Description	References
Multiplicity of Stakeholders	Recognizes many stakeholders beyond shareholders, including employees, customers, suppliers, communities, governments, and NGOs.	Freeman (1984); Donaldson and Preston (1995)
Diverse Interests and Values	Acknowledges that stakeholders have different, sometimes conflicting, goals, values, and ethical concerns, which the organization must consider.	Jones et al. (2007); Clarkson (1995)
Collaborative and Conflicting Dynamics	Organizations must navigate cooperation and conflict among stakeholders, balancing competing interests to maintain productive relationships.	Mitchell et al. (1997); Frooman (1999)
Ethical and Moral Responsibility	Organizations have broader societal responsibilities, maximizing profits and considering ethical impacts on various stakeholder groups.	Freeman (1984); Phillips, Freeman and Wicks (2003)
Deliberative Processes	Decision-making should involve open dialogue and deliberation with stakeholders to ensure their perspectives are considered, promoting transparency and legitimacy.	Habermas (1990); Matten and Crane (2005)

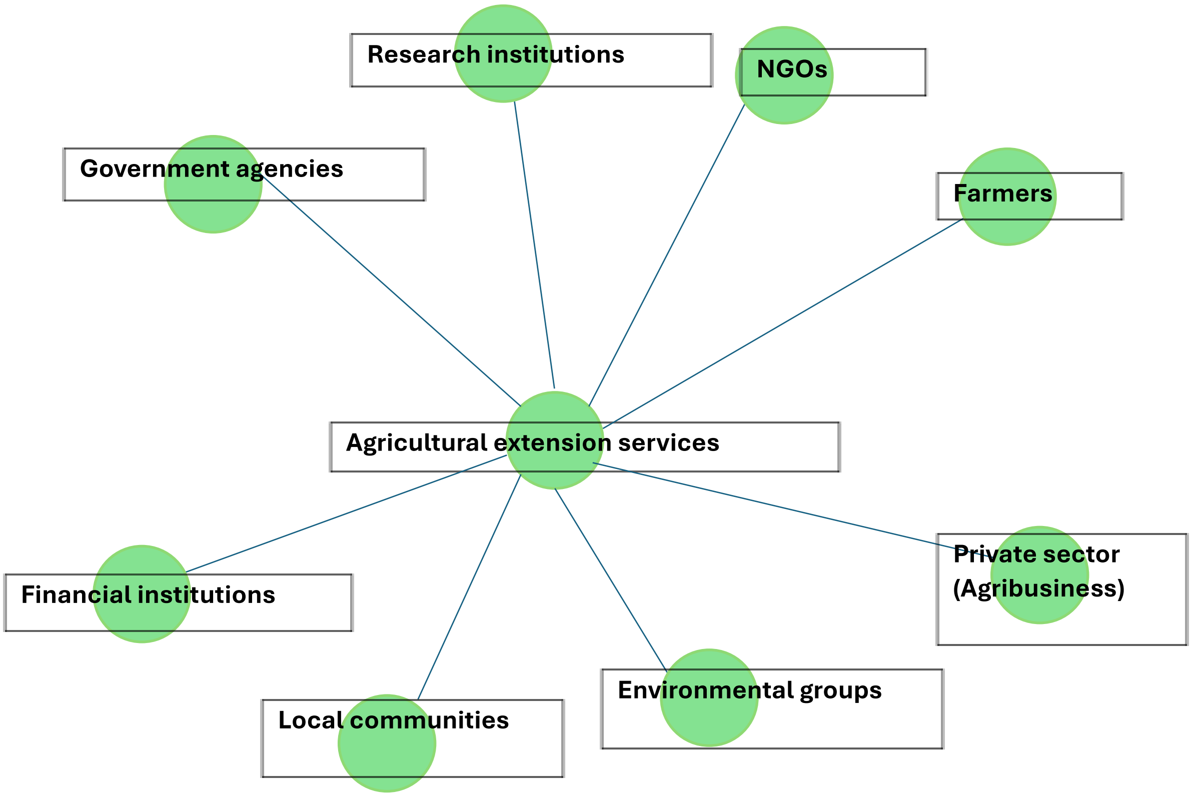

Figure 1: Conceptual framework pluralistic stakeholder theory in agricultural extension and advisory services. The conceptual framework reflects the dynamics common in Sub-Saharan Africa and other developing regions.

The conceptual framework in Figure 1 highlights the crucial need for Agricultural Extension and Advisory (EAS) to be pluralistic, stakeholder-driven, inclusive, and ethically accountable. Given the tendencies and rising subjects in climate-smart agriculture, EAS should have interactions with a various range of stakeholders, consisting of authorities' businesses, research institutions, NGOs, private zone actors, and smallholder farmers. These collaborations are essential for fostering sustainable agricultural development that balances economic, social, and environmental pursuits, especially within the context of adapting to weather trade. The framework also emphasizes the need for EAS to facilitate two-way communication, making sure that smallholder farmers are each recipient and contributors of information, particularly in implementing climate-smart practices. The conceptual framework reflects the dynamics common in Sub-Saharan Africa and other developing regions.

2. Materials and Methods

2.1. Bibliometric Analysis

Bibliometric analysis examines relevant literature within a specific domain to extensively assess the research status by analyzing existing publications, including keywords, citations, sources, and the geographical distribution of contributions (Almas et al., 2022; Fauzi, 2025). It evaluates a subject's developmental path and future direction (Yan et al., 2022). The primary advantage of bibliometric analysis is its ability to transform abstract, unstructured literature into an organized and manageable format, making it easier to identify patterns and trends within the field (Yao et al., 2022; Fauzi et al., 2025). Authorship, citation, co-authorship, co-citation, and co-word analyses are standard methods in bibliometric research (Fauzi et al., 2022). Citation analysis quantifies referenced articles based on the number of citations received by their authors, which is crucial for identifying significant contributions. Co-authorship patterns are analyzed by examining authors' interactions, affiliations, and countries to uncover collaboration networks (Tamala et al., 2022). Co-citation analysis tracks simultaneous citations, using co-citation counts to gauge reference similarity (Fauzi, 2025). Exploring research themes involves structuring academic literature to reveal coherence and evolutionary trends within a field. Keyword analysis assesses the prevalence of keywords across papers and examines correlations among them to highlight impactful topics and emerging research areas.

2.2. Data and Research Design

The data were collected from the Scopus database. Table 2 outlines the literature exploration and screening criteria of studies in bibliometric analysis. Scopus is preferred for bibliometric analysis due to its accuracy and comprehensive coverage. As one of the most widely used and reliable academic literature repositories, it provides access to high-quality research worldwide, making it an invaluable resource for bibliometric studies. The documents that were retrieved for analysis were 389. Biblioshiny, an R package, was used to run a bibliometrix analysis of the searched literature. The search outcomes from Scopus were input into the Biblioshiny app in Comma-Separated Value (CSV) CSV file format. The biblioshiny app provides a web interface for bibliometrix, and it was used to generate the knowledge map and provide insights on how far PEAS and CSA were researched.

Table 2: Criteria for literature inclusion for the intersection of PEAS and CSA practices Region: Developing countries and the Global South

Criteria	Measures
Period	Include documents from 1995 to December 2024
Search field	TITLE-ABS-KEY
Search keywords	("pluralistic extension" OR "extension advisory services" OR "agricultural extension" OR "farmer advisory services" OR "extension systems") AND ("smallholder farmers" OR "small-scale farmers" OR "family farmers") AND ("climate-smart agriculture" OR "climate-smart practices" OR "climate change adaptation" OR "sustainable agriculture" OR "resilient agriculture") AND ("adoption" OR "uptake" OR "implementation" OR "participation")
Citation Topics Meso	ALL
Document Type	Article
Languages	English

3. Results and Discussion

3.1. Publication Trends

The bibliometric analysis covers 389 documents published between 1995 and 2024, authored by 1,453 individuals from 19 countries (Table 3). The research exhibits an annual growth rate of 14.28%, with an average of 18.34 citations per document. Over time, the number of publications has increased significantly, particularly showing exponential growth in the past decade (Fig. 2), coinciding with a global shift towards sustainable agricultural practices in response to climate change. For instance, publications on Climate-Smart Agriculture (CSA) surged notably after the Food and Agriculture Organization (FAO) introduced the concept in 2010 (FAO, 2013; Campbell et al., 2014). This growth reflects the influence of global organizations and initiatives in shaping research priorities. FAO's introduction of CSA was a significant turning point that accelerated academic interest and contributions to the field.

Table 3: Summary information on retrieved PEAS and CSA studies

Description	Results
Scopus	Counts and rates
Timespan	1995:2024
Sources (Journals, Books, etc)	164
Documents	389
Annual Growth Rate %	14.28
Document Average Age	3.94
Average citations per doc	18.34
References	23647
DOCUMENT CONTENTS	
Keywords Plus (ID)	794
Author's Keywords (DE)	1261
AUTHORS	
Authors	1453
Authors of single-authored docs	25
AUTHORS COLLABORATION	
Single-authored docs	28
Co-Authors per Doc	4.2
International co-authorships %	44.22
DOCUMENT TYPES	
Article	389

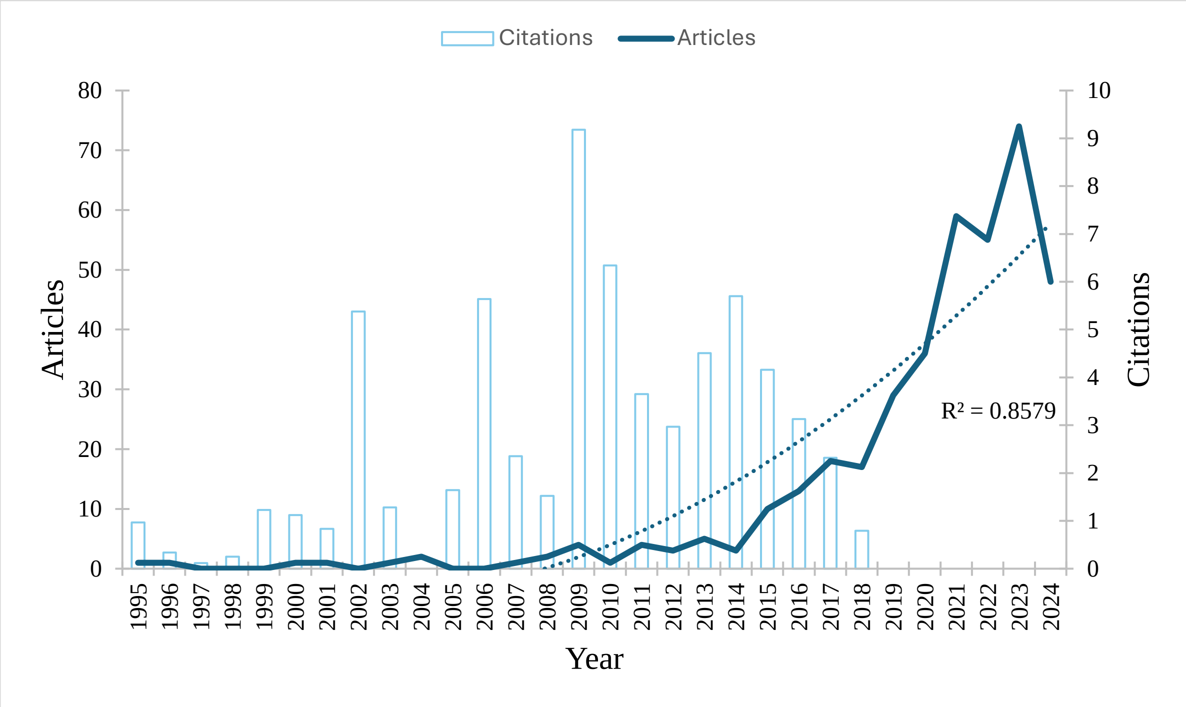

Figure 2: PEAS and CSA articles publication and citation trends as from 1995 to 2024

The exponential increase in publications (Fig. 2), especially in the past decade, suggests that CSA has gained substantial traction among researchers and in policy discussions on sustainable agricultural practices (Aggarwal et al., 2018; Blesh et al., 2019). However, the trend in citation does not follow a similar pattern (Fig. 2). The average citation rate of 18.34 citations per document further emphasizes the impact of these studies, indicating that CSA research is highly relevant within the scientific and policy-making communities. This growing body of work, concentrated particularly after the FAO's intervention, highlights the importance of CSA as a strategic response to climate-related agricultural challenges. Additionally, the trend aligns closely with global movements such as the United Nations Sustainable Development Goals (SDGs), prioritizing sustainable agriculture, climate resilience, and food security (Leal Filho et al., 2017; Rockström et al., 2017). The rise in CSA research reflects the increasing awareness of the need for integrating climate-resilient practices into agricultural systems, particularly as these relate to achieving global sustainability targets. This connection between research output and the SDGs suggests that CSA is viewed as a critical component in the broader movement towards achieving long-term sustainability goals, influencing both academic research and international development strategies.

A notable aspect of this growth is the focus on smallholder farmers in the Global South, particularly in regions like Sub-Saharan Africa (SSA). These areas are highly vulnerable to climate shocks, and CSA offers practical strategies to enhance resilience and food security. The prominence of Pluralistic Extension and Advisory Services (PEAS) in driving community CSA research in SSA regions reflects the pressing need for adaptive agricultural practices that mitigate the adverse effects of climate change (Kibwika et al., 2009; Huyer et al., 2015). The emphasis on smallholder farmers also highlights the role of CSA in addressing socio-economic challenges in agriculture-dependent economies, where building resilience to climate change is critical for sustaining livelihoods. Therefore, the regional focus on SSA and the Global South is especially significant, as these regions are more prone to climate-related risks, such as droughts, floods, and shifting weather patterns, which directly impact food production and security. The rapid increase in CSA-related research in these vulnerable regions underscores the urgency of finding practical, sustainable solutions to mitigate these impacts. As CSA becomes more widely recognized as a key strategy for enhancing climate resilience, it will likely play an increasingly important role in developing region-specific agricultural policies and practices.

3.2. Citation Analysis

3.2.1. Documents

A threshold of 10 citations, 170 documents from the 389 studies were included in the analysis. Table 4 presents the top 10 PEAS and CSA research documents ranked by citation. The top three most cited documents include pivotal works such as Abid et al. (2015), which examines how smallholder farmers in Punjab perceive climate change, adapt to it, and the factors influencing their capacity to implement adaptation strategies. The second most cited document, Makate et al. (2016), highlights crop diversification as a crucial strategy for smallholder farmers in Zimbabwe to improve livelihoods and build resilience against environmental changes, including climate variability. Lastly, the Abid et al. (2016) study explores the adaptation strategies employed by farmers in rural Pakistan to cope with climate change. It assesses the impact of these strategies on food productivity and crop income, while also identifying challenges and opportunities for enhancing adaptation efforts in the agricultural sector. These studies underscore the role of Climate-Smart Agriculture (CSA) in fostering agricultural resilience and are frequently cited for their comprehensive frameworks on operationalizing CSA practices in diverse agricultural contexts. Makate et al. (2016) effectively outline the key components of CSA sustainability, productivity, and resilience offering a structured approach for implementing these practices in both developed and developing regions. The global influence of these studies underscores their importance in shaping the discourse on CSA in the smallholder sector as a strategy for climate adaptation and food security.

Table 4:Top 10 documents ranked by citation

No.	Author	Title	Total citations	Links
1	Abid et al. (2015)	Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan	349	7
2	Makate et al. (2016)	Crop diversification and livelihoods of smallholder farmers in Zimbabwe: adaptive management for environmental change	224	0
3	Abid et al. (2016)	Adaptation to climate change and its impacts on food productivity and crop income: Perspectives of farmers in rural Pakistan	201	6
4	Masud et al. (2017)	Adaptation barriers and strategies towards climate change: Challenges in the agricultural sector	161	4
5	Truelove et al. (2015)	A socio-psychological model for analyzing climate change adaptation: A case study of Sri Lankan paddy farmers	145	1
6	McCord et al. (2015)	Crop diversification as a smallholder livelihood strategy within semi-arid agricultural systems near Mount Kenya	141	0
7	Ojo and Baiyegunhi (2020)	Determinants of climate change adaptation strategies and its impact on the net farm income of rice farmers in south-west Nigeria	138	0
8	Emmanuel et al. (2016)	Impact of agricultural extension service on adoption of chemical fertilizer: Implications for rice productivity and development in Ghana	128	1
9	Speelman et al. (2008)	A measure for the efficiency of water use and its determinants, a case study of small-scale irrigation schemes in North-West Province, South Africa	126	1
10	Gao et al. (2020)	Influence of a new agricultural technology extension mode on farmers' technology adoption behavior in China	121	0

Figure 3 illustrates the impact and influence of key authors within bibliometric networks, focusing on research related to precision agriculture and climate-smart agriculture (PEAS and CSA) in the smallholder farming sector. The color density on the map represents the strength of influence or connectivity among authors, with red areas signifying the highest density of co-citations or collaborations and highlighting significant contributors in the field. Abid et al. (2015, 2016) rank first, with seven and six links, respectively, underscoring their pivotal role in this research area. In bibliometric analyses, links represent citations or co-citations, which reflect the interconnectedness of an author's work within the broader research network. This high ranking suggests that Abid et al.'s findings are extensively integrated into the field and provide foundational insights into sustainable practices for smallholders.

Masud et al. (2017) follow with four links, indicating a strong but comparatively lesser influence. While Masud et al.'s contributions are significant, the greater engagement and recognition of Abid et al.'s work highlight their central role in shaping research on PEAS and CSA.

The density analysis effectively maps the intellectual hubs within the scholarly discourse, identifying authors whose work serves as critical nodes in advancing agricultural innovations for smallholders. These rankings further emphasize the importance of their research outputs in enhancing our understanding of sustainable agricultural practices and adaptation strategies to address climate change impacts.

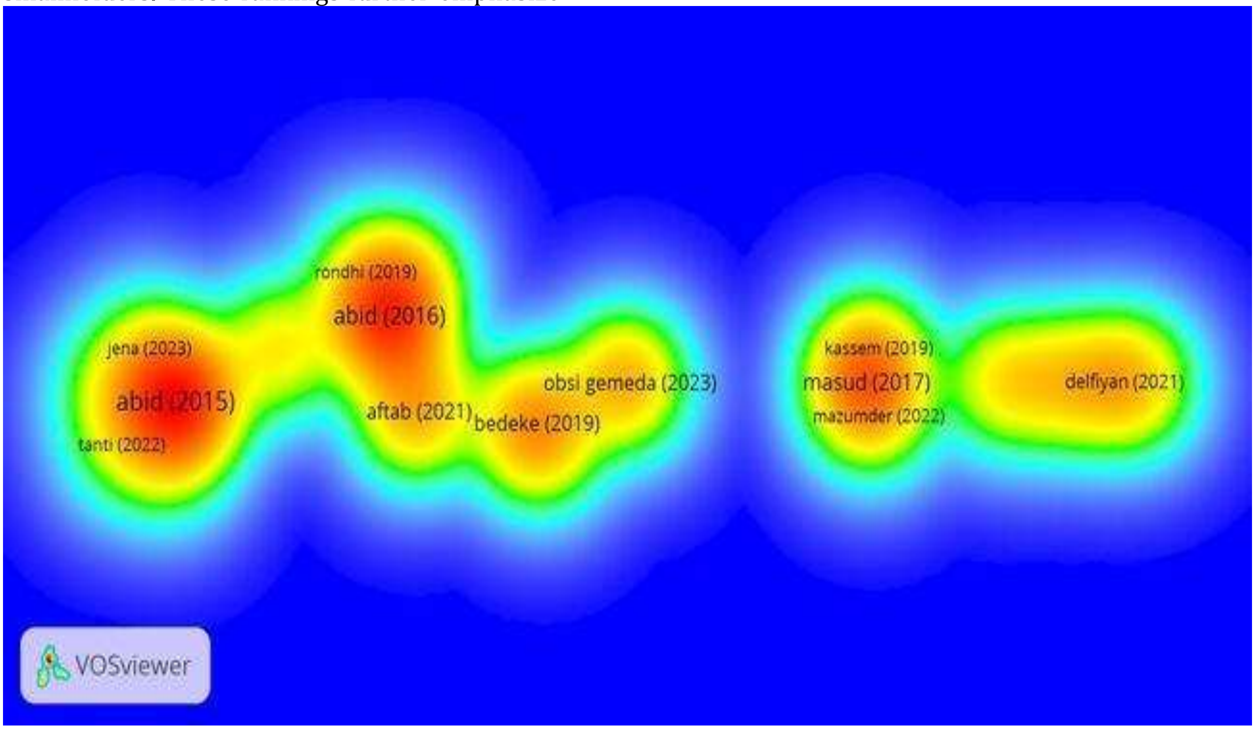

Figure 3: The density visualization of document citation analysis

3.2.2. Sources

Table 5 shows the top 10 sources ranked by average citation, which provides insights into the high-impact journals contributing significantly to research on PEAS and CSA. Based on their citation strength, these journals play a vital role in shaping academic discourse on sustainable agricultural practices, particularly for smallholders. At the top of the list, *Earth Systems Dynamics* (European Geosciences Union), despite only one publication, has garnered 349 citations, demonstrating its high impact per article. This suggests that research published here is highly influential, likely addressing critical environmental and systemic factors in CSA. *Springer Plus* and *Global Environmental Change* similarly represent high-impact platforms that attract attention for their interdisciplinary approaches to climate issues, environmental change, and sustainable development.

The *NJAS-Wageningen Journal of Life Sciences* has both a high total strength (324 citations) and significant total influence due to multiple publications. This is indicative of its consistent contribution to life sciences research that intersects with agricultural sustainability. *Development Studies Research* and *Land Use Policy* further emphasize policy-driven and socio-economic factors influencing CSA adoption, critical for scaling extension services to benefit smallholders. Elsevier's dominance, as seen with multiple journals such as *Applied Geography* and *Crop Protection*, reflects its prominence in publishing high-impact research that spans environmental, geographical, and agronomic sciences. Meanwhile, *World Development* and *Sustainability (MDPI)* is vital for promoting interdisciplinary research that addresses global challenges of food security, environmental resilience, and climate adaptation strategies in smallholder contexts

Table 5:Top 10 sources ranked by average citation

No.	Source	Publisher	Publication	Citation	Total link strength	Average citation
1	Earth Systems Dynamics	European Geosciences Union	1	349	9	349
2	Springer Plus	Springer Nature	1	224	0	224
3	Global Environmental Change	Elsevier	1	145	2	145
4	NJAS-Wageningen Journal of Life Sciences	Elsevier	3	324	8	108
5	Development Studies Research	Taylor and Francis	1	83	1	83
6	Land Use Policy	Elsevier	8	606	5	75.8
7	Environmental Research Letters	IOP Science	1	67	0	67
8	Applied Geography	Elsevier	1	56	0	56
9	Crop Protection	Elsevier	1	53	0	53
10	World Development	Elsevier	4	205	3	51.3
9	Internation Journal of Agricultural Sustainability	Taylor and Francis	13	326	13	25.1
10	Sustainability	MDPI	24	359	9	15

Figure 4 illustrates the density of citations, with red areas indicating highly cited sources. Prominent journals, such as *Sustainability (Switzerland)* and *Journal of Cleaner Production*, highlight a growing focus on sustainability and climate resilience in agriculture. Strong clusters around the *Journal of Agricultural Education* and the *Journal of Rural Studies* emphasize interdisciplinary research combining social sciences, climate studies, and technology. Emerging themes include equity in ICT adoption, with studies addressing barriers like infrastructure, costs, and digital literacy, particularly in marginalized communities. Journals like *Agriculture and Human Values* contribute to understanding the social dimensions of these challenges.

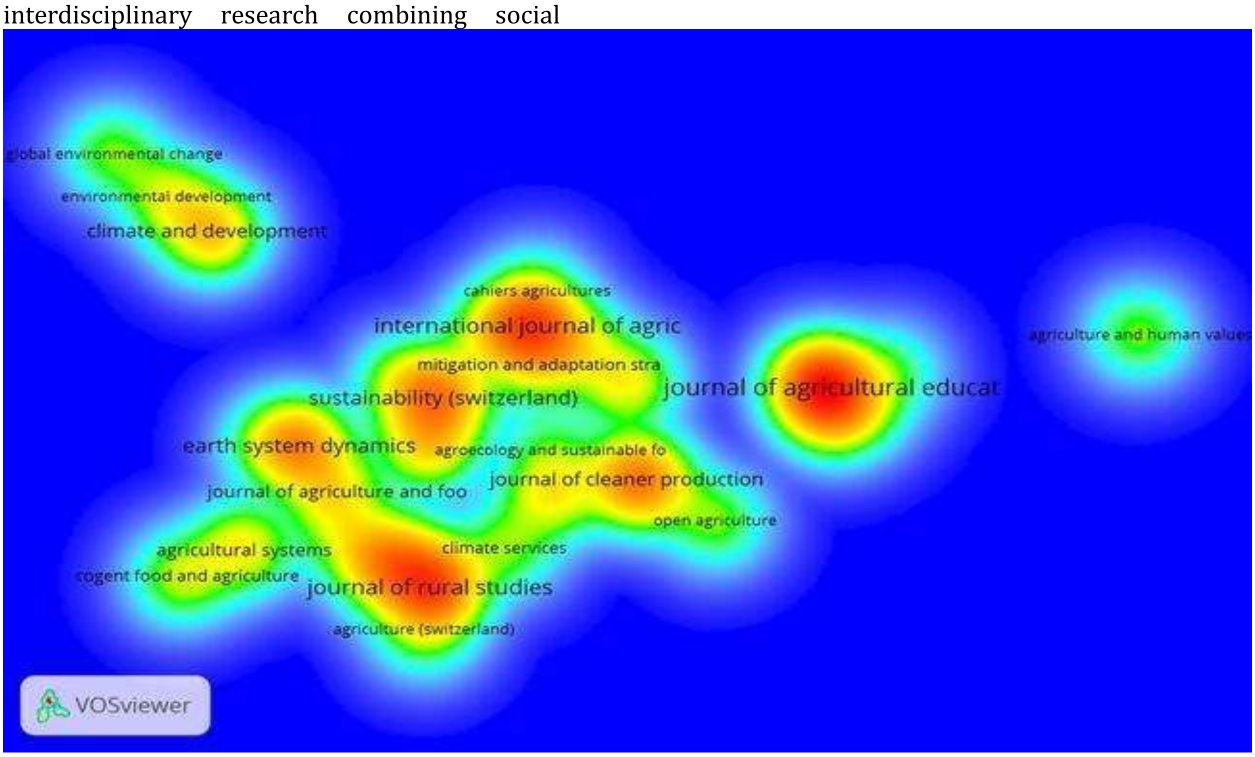

Figure 4:The density visualization of sources citation analysis

3.2.3. Organizations

The analysis identified 29 key institutions from 1104 organizations, with at least two publications and two citations each. Table 6 highlights the top 10 institutions ranked by average citation count. Leading the list is the University of Hamburg, Germany, with 275 citations from two publications, followed by the University of New York, USA (117.5 citations), and the University of Fort Hare, South Africa (70.5 citations). Other notable institutions include Wageningen University and Research, renowned for agricultural innovation, and CIMMYT, with contributions to sustainability in developing regions. These institutions reflect a geographically diverse network driving advancements in climate-smart agriculture.

Table 6:Top 10 institutions ranked by average citation

No.	Institution	Country	Publication	Citation	Total link strength	Average citation
1	University of Hamburg	Germany	2	550	2	275
2	University of New York	United States of America	2	235	0	117.5
3	University of Fort Hare	South Africa	2	141	1	70.5
4	Wageningen University and Research	Netherlands	2	89	2	44.5
5	International Maize and Wheat Improvement Centre	Ethiopia	2	71	2	35.5
6	International Maize and Wheat Improvement Centre	Kenya	2	50	2	25
7	China Agricultural University	China	2	46	0	23
8	University of Adelaide	Australia	2	45	0	22.5
9	Wageningen University and Research	Netherlands	2	41	0	20.5
10	Haramaya University	Ethiopia	2	39	0	19.5

Figure 5 displays a density analysis of organizations ranked by citation strength. Wageningen University Livestock Research leads with 89 citations, emphasizing its key role in agricultural and climate research. CIMMYT in Ethiopia and Kenya follows with 71 and 50 citations, highlighting their contributions to innovation and resilience. The Department of Agricultural Economics also features, albeit with lower citation density. This distribution showcases the collaborative and geographically diverse nature of agricultural research, with institutions from developed and developing regions working together to address global challenges like climate adaptation in agriculture.

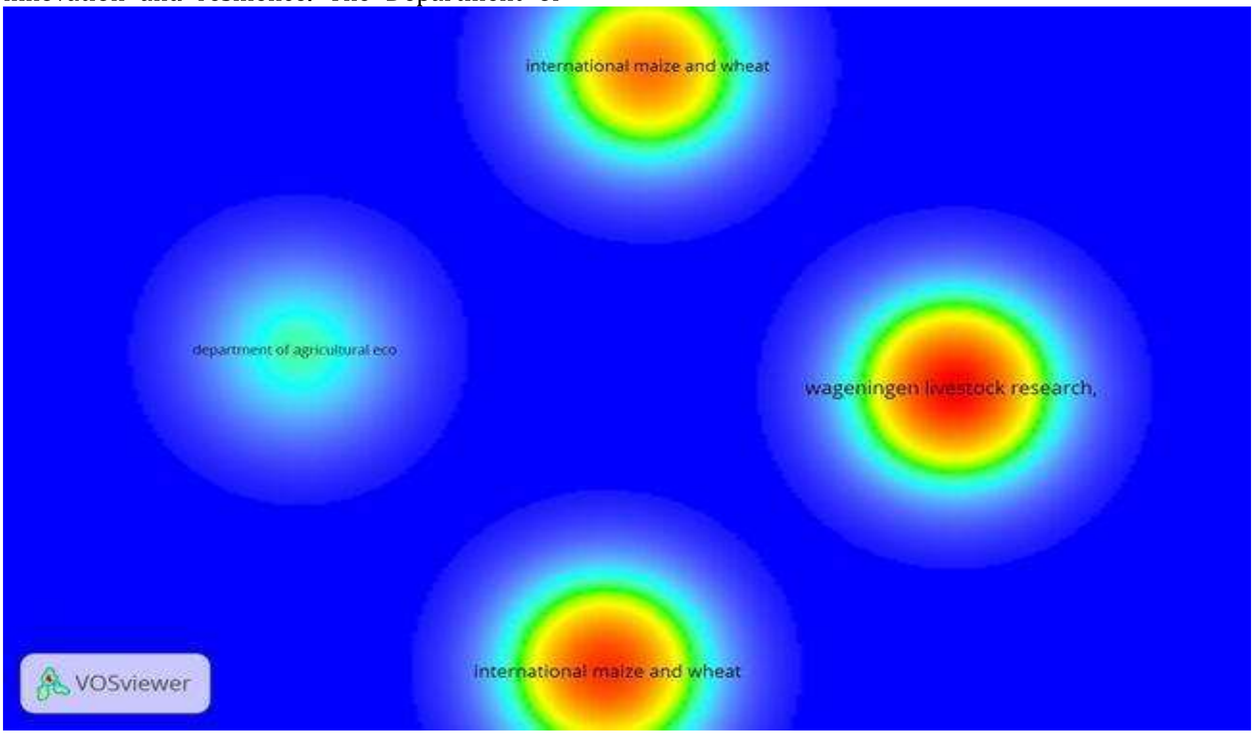

Figure 5: The density visualization of organizations' citation analysis

3.2.4. Countries

The analysis identified 79 countries with at least one publication and one citation. Table 7 ranks these countries by average citation count, revealing their research impact. Pakistan tops the list with an average of 83.1 citations across five publications, reflecting its strong contributions to Pluralistic Extension Advisory Services (PEAS) and Climate-Smart Agriculture (CSA). Germany follows with 51.9 citations from 14 publications, highlighting its role in agricultural innovation and climate adaptation. New Zealand ranks third, averaging 51 citations from three publications, emphasizing its focus on sustainability. Fiji and Malaysia also rank highly, with averages of 50 and 46.3 citations, respectively. This ranking highlights the global scope of PEAS and CSA research, with impactful contributions from both developed and developing countries addressing smallholder farming challenges worldwide.

Table 7: Top 10 countries ranked by average citation

No.	Country	Publication	Citation	Total link strength	Average citation
1	Pakistan	5	416	17	83.1
2	Germany	14	726	34	51.9
3	New Zealand	3	153	1	51
4	Fiji	1	50	3	50
5	Malaysia	4	185	7	46.3
6	Costa Rica	3	130	27	43.3
7	Ireland	4	160	6	40
8	Mexico	6	227	10	37.8
9	Spain	4	148	4	37
10	Saudi Arabia	7	222	14	31.7

Figure 6 illustrates the ranking of countries based on total link strength, providing a unique perspective on research collaboration and influence. Kenya stands out as the top-ranking country with a total link strength of 47, signifying its strong connections and collaborations in agricultural and climate research, particularly in areas related to Climate-Smart Agriculture (CSA) and Pluralistic Extension Advisory Services (PEAS). The Netherlands follows closely in second place with a total link strength of 43, reinforcing its long-standing contribution to global agricultural innovation and sustainability research. Ethiopia ranks third with a total link strength of 40, further highlighting its key role in advancing agricultural practices and resilience in the face of climate challenges. Other notable countries, such as Germany, Australia, and the United States, also feature prominently, reflecting the global and collaborative nature of research in CSA and PEAS.

Emerging trends in PEAS and CSA research include the growing use of Information and Communication Technologies (ICTs) to improve decision-making processes for SHF, particularly in communal farming systems. This includes mobile applications, remote sensing, and precision agriculture tools that provide real-time climate information, soil data, and crop monitoring. Furthermore, sustainability and resilience-building strategies are gaining traction, particularly in African nations like Kenya and Ethiopia, where research focuses on climate adaptation and food security through sustainable land management and integrated farming systems. Another emerging topic is gender-inclusive climate adaptation, exploring the role of women in communal farming and how access to CSA technologies can bridge the gender gap in agricultural productivity. These trends underscore the increasing interdisciplinary nature of CSA and PEAS research, which combines technological, social, and environmental approaches to address the complex challenges faced by smallholder farmers worldwide

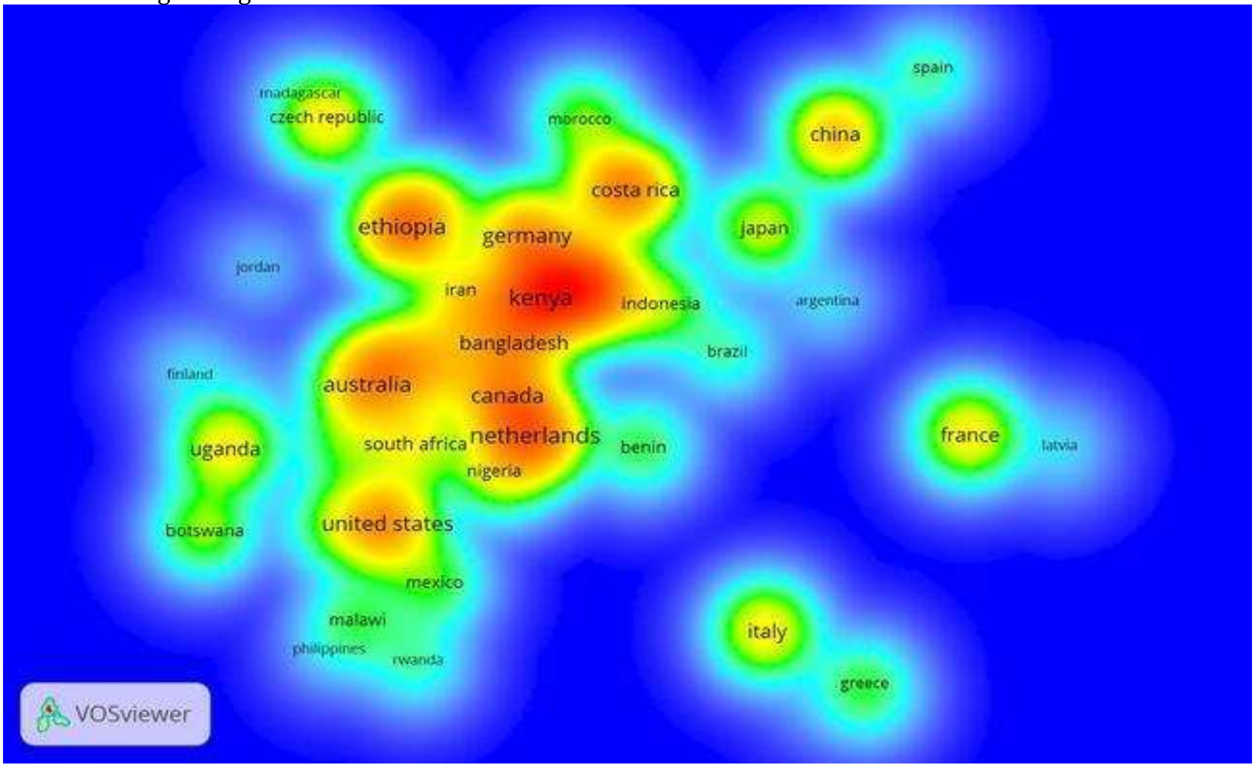

Figure 6: The density visualization of countries' citation analysis

3.3. Co-authorship Analysis

3.3.1. Authors co-authorship analysis

Out of the 1489 authors analyzed, 111 were selected based on the criteria of having at least two publications and an average of two citations per author. Table 8 highlights the top 10 authors ranked by their average citation count, shedding light on their scholarly impact within the fields of Climate-Smart Agriculture (CSA) and Pluralistic Extension Advisory Services (PEAS). Leading the list is Mango Nelson, with an impressive average citation of 117.5 across two publications, followed by Ojo T.O., who has an average citation of 112.5. Makate Clifton and Makate Marshall both have a high citation count of 259 across three publications, with an average of 86.3 citations, underscoring their significant contributions to agricultural and climate resilience research. Other notable authors include Owusu Victor (52.3 average citations) and Klerkx Laurens (44.3 average citations), whose works are widely referenced in the field. Additionally, Steinke Jonathan and Van De Gevel Jeske show strong collaborative influence, with a total link strength of 9, demonstrating their extensive research networks. These rankings provide a glimpse into the leading scholars driving innovation and thought leadership in CSA and PEAS, reflecting a growing body of impactful research that addresses climate challenges in agricultural systems.

Emerging trends in PEAS and CSA include the increasing use of digital technologies and ICTs in precision agriculture to help SHF adapt to climate variability. Researchers like Mango Nelson and Ojo T.O. are advancing the understanding of how mobile applications, remote sensing, and data analytics can provide real-time climate information and crop management tools, thus improving decision-making at the farm level. Another emerging topic is resilience-building and sustainability, particularly in regions vulnerable to climate change, such as SSA. Scholars are exploring integrated farming practices and climate-resilient crops as part of CSA strategies, aimed at improving food security while reducing greenhouse gas emissions. Moreover, there is growing attention on gender-inclusive approaches in CSA, emphasizing the role of women in communal farming and how targeted interventions can empower them to adopt new technologies. These trends illustrate a dynamic shift towards integrating social, technological, and environmental factors in addressing the challenges posed by climate change in agriculture.

Table 8: Top 10 authors ranked by average citation

No.	Author	Publication	Citation	Total link strength	Average citation
1	Mango Nelson	2	235	4	117.5
2	Ojo T. O	2	225	0	112.5
3	Makate Clifton	3	259	5	86.3
4	Makate Marshall	3	259	5	86.3
5	Owusu Victor	3	157	0	52.3
6	Klerkx Laurens	3	133	3	44.3
7	Steinke Jonathan	3	130	9	43.3
8	Van De Gevel Jeske	3	130	9	43.3
9	Simane Belay	4	163	4	40.8
10	Yazdanpanah Masoud	4	161	3	40.3

Figure 7 displays a co-authorship map based on the authors' collaborations. Cluster 1, the largest cluster, consists of five interconnected authors: Susannah M. Sallu, Christian Thierfelder, John Recha, Andrew J. Dougill, and Stephen Whitfield. These authors exhibit strong collaborative relationships, indicating shared research interests and potentially frequent co-authored publications, particularly in the fields of Climate-Smart Agriculture (CSA) and Pluralistic Extension Advisory Services (PEAS). The map also reveals interconnections between these researchers, suggesting a network of collaboration focused on topics such as climate resilience, agricultural sustainability, and technology-driven farming solutions.

In contrast, Cluster 2 includes only one author, Daniel Adu Ankrah, positioned slightly apart from the primary group. His isolated placement suggests less collaboration within this specific network, although the color gradient indicates his research activity is more recent, peaking around 2023. This may imply that Ankrah is either an emerging scholar or focusing on niche research areas that are yet to establish broader collaborative ties with the larger group.

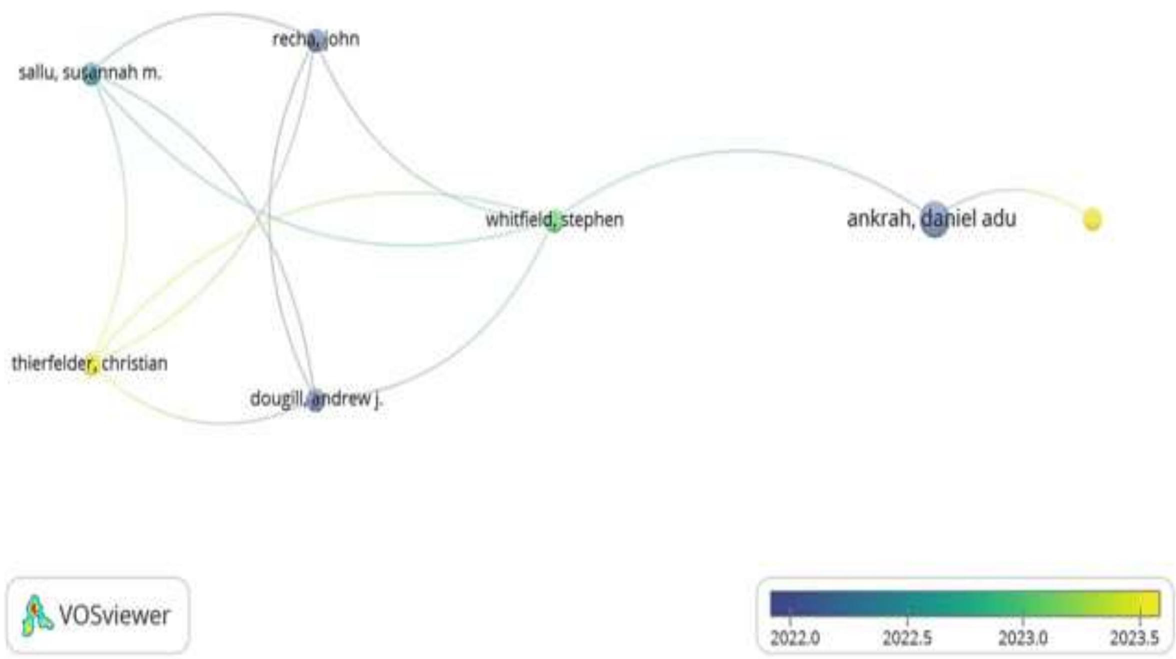

Figure 7. The overlay visualization of authors' co-authorship analysis

3.3.2. Organizations co-authorship analysis

Out of the 528 institutions analyzed, each having at least one publication and ten citations, several were found to be disconnected from the primary network. Ultimately, 12 groups formed across four distinct clusters, creating a co-authorship network among institutions. Figure 8 visualizes this network, highlighting the collaborative relationships between various research organizations. Notably, the Chinese Ministry of Agriculture and Wageningen University and Research stand out as the two most collaborative institutions, engaging in co-authorship with eight other organizations. These institutions play a pivotal role in driving international research efforts related to Climate-Smart Agriculture (CSA) and Pluralistic Extension Advisory Services (PEAS), bridging geographical and institutional gaps to foster global collaboration. Other institutions, such as the Lancaster Environment Centre and Agro-Environmental Protection Institute, also show significant participation in this network, contributing to the growing body of knowledge focused on sustainability, agricultural resilience, and climate adaptation strategies. The visualization illustrates not only the density of collaborations but also the evolving nature of these partnerships over time, with recent growth in research activity around 2023–2024, signaling an increasing focus on innovative solutions for climate challenges.

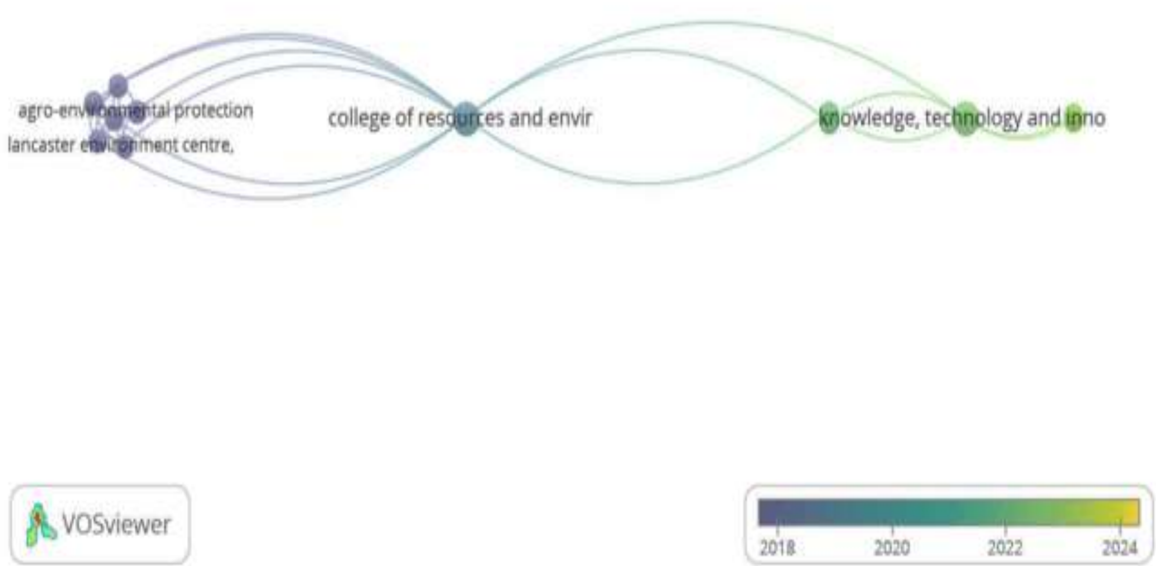

Figure 8: The network visualization of organizations' co-authorship analysis

In the Purple cluster, we see prominent universities from the UK, such as Warwick University, the University of London, Lancaster University, and the University of Nottingham, working alongside international partners like the Ministry of Agriculture (China) and Northwest AandF University. This cluster represents a strong collaboration between UK institutions and Chinese agricultural bodies, likely contributing research on policy, environmental sustainability, and agricultural innovations to improve smallholder resilience.

The Green cluster highlights key global agricultural research institutions such as China Agricultural University, Wageningen University, and the International Institute of Tropical Agriculture (IITA). These organizations, along with the Alliance of Biodiversity-CIAT and the Chinese Academy of Agricultural Sciences, focus heavily on biodiversity, tropical agriculture, and sustainability. Their collaboration indicates an international focus on adapting CSA practices for diverse agro- ecological regions, particularly within tropical and subtropical climates.

Table 9: Organizations co-authorship clusters

Cluster	Number	Organizations
1 (Purple)	6	Warwick University, University of London, Lancaster University, University of Nottingham, Ministry of Agriculture (China), Northwest AandF University
2 (Green)	6	China Agricultural University, Wageningen University, Chinese Academy of Agricultural Sciences, Alliance of Biodiversity- CIAT, International Institute of Tropical Agriculture, Northwest AandF University

3.3.3. Countries co-authorship analysis

As some countries were not connected with others in PEAS and CSA research, the final national co-authorship network comprised 79 countries, organized into eleven clusters. As Figure 9 illustrates, England, the U.S.A., and Ethiopia were the top three countries with the most collaborations, co-authoring with 38, 37, and 22 countries, respectively. Table 8 provides a list of the countries that fall within each of these clusters.

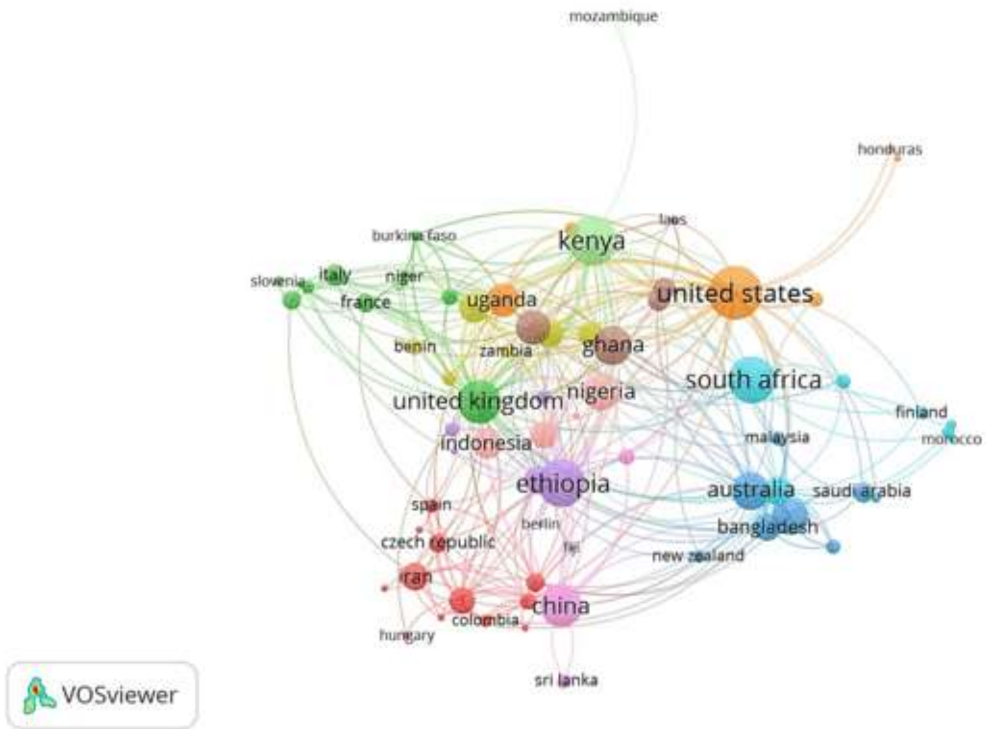

Figure 9: The network visualization of countries' co-authorship analysis

Table 10: Countries co-authorship clusters

Cluster	Number	Countries
1 RED	12	Albania, Austria, Belgium, Colombia, Czech Republic, Estonia, Hungary, Iran, Mexico, Portugal, Slovakia, Spain
2 GREEN	11	Burkina Faso, Burundi, France, Greece, Italy, Latvia, Niger, Norway, Philippines, Slovenia, United Kingdom
3 LIGHT BLUE	8	Australia, Bangladesh, Egypt, India, Malaysia, Nepal, New Zealand, Saudi Arabia
4 ORANGE	7	Benin, Bolivia, Malawi, Senegal, Tanzania, Zimbabwe
5 PURPLE	7	Berlin, Cote D'ivoire, Ethiopia, Fiji, Germany, Madagascar, Rwanda
6 DARK BLUE	7	Canada, Finland, Ireland, Jordan, Morocco, South Africa, Tunisia
7 YELLOW	6	Botswana, Brazil, Honduras, Liberia, Uganda, United States of America
8 GREENISH YELLOW	6	Ghana, Laos, Netherlands, Switzerland, Thailand, Vietnam
9 LIGHT GREEN	4	China, Pakistan, Sri Lanka, Sweden
10 PINK	4	Budget andAmp, Japan, Nigeria
11 LIGHT GREEN	3	Costa Rica, Kenya, Mozambique

3.4. Emerging Trends: Keywords, word clouds, and thematic mapping

The most frequent keywords in the literature (Figure 10) and the word cloud (Figure. 11) reveal dominant terms such as "*climate-smart agriculture*," "*smallholder farmers*," "*adoption*," and "*extension services*." These keywords have become increasingly prominent over the past decade, reflecting a growing focus on the resilience of smallholder farming systems in the face of climate variability. The prominence of these terms indicates that CSA and the role of extension services in its adoption are central concerns in contemporary agricultural research, particularly as they relate to supporting smallholder farmers in adapting to climate change. Additionally, recent studies have increasingly emphasized keywords such as "*participation*" and "*sustainability*," signifying a shift toward more inclusive and long-term strategies in agricultural extension systems. This shift is well-illustrated in the keyword trend over time (Figure 12), where participatory approaches have gained traction (Simpson et al., 2018). These approaches place farmers at the center of decision-making processes, promoting active involvement in designing and implementing extension services. Such participatory models have improved the adoption of climate-smart practices, as they account for farming communities' local knowledge and needs, thereby aligning extension services with smallholder farmers' specific needs and conditions.

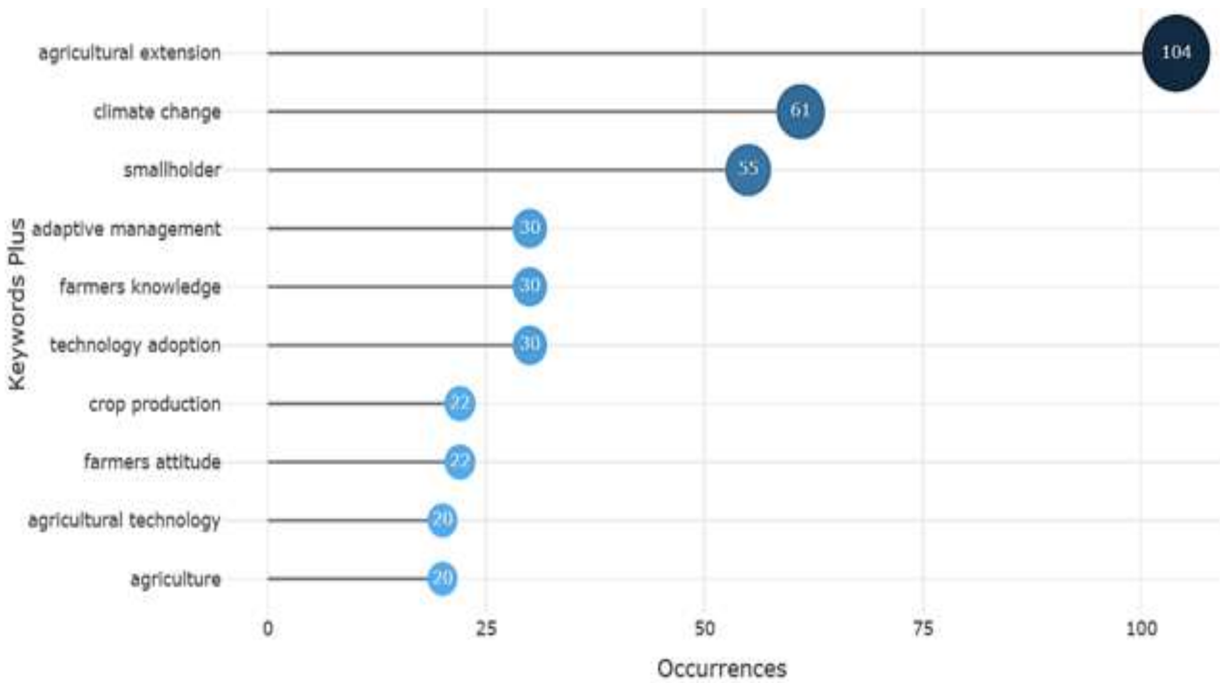

Figure 10. Most frequent words

Figure 11. Word cloud

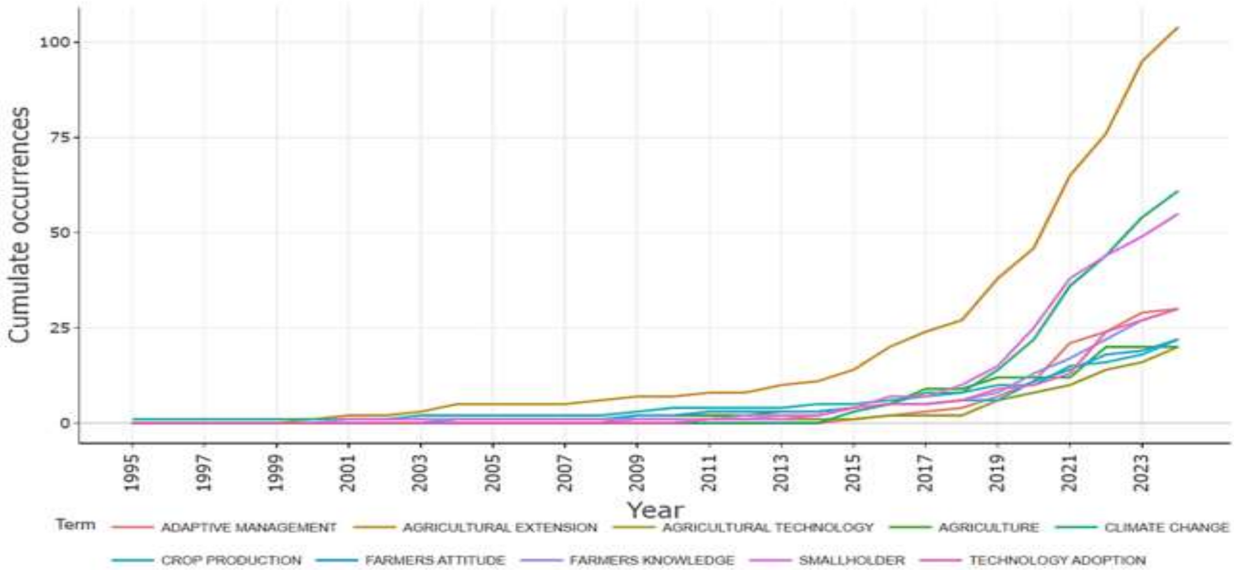

Figure 12: Word frequency over time

The Thematic Map (Figure 13) further illustrates key clusters in the literature, such as "*adoption of sustainable practices*," "*participatory extension models*," and "*climate resilience strategies*." These clusters align with recent research that emphasizes farmer-driven approaches to agricultural adaptation. For example, Jat et al. (2020) demonstrated the effectiveness of participatory extension models in India, where the engagement of local farmers in designing and implementing CSA practices significantly increased the adoption of sustainable techniques like water-efficient irrigation and agroforestry. Such models are proving to be essential in ensuring that climate-smart technologies are not only accessible to farmers but also tailored to their specific environmental and socio-economic conditions.

The implications of these emerging trends suggest that future research will continue to prioritize participatory models and localized adaptation strategies, with a growing focus on how extension services can better address the specific needs of smallholder farmers. As climate challenges become more pronounced, extension systems must adopt flexible, inclusive approaches that integrate scientific innovations and local farmer knowledge. Gender inclusivity and digital extension tools are also gaining prominence in literature. Recent studies have shown that these tools can enhance access to CSA practices by reaching marginalized groups, such as women farmers, and improving the scalability of extension services in rural areas.

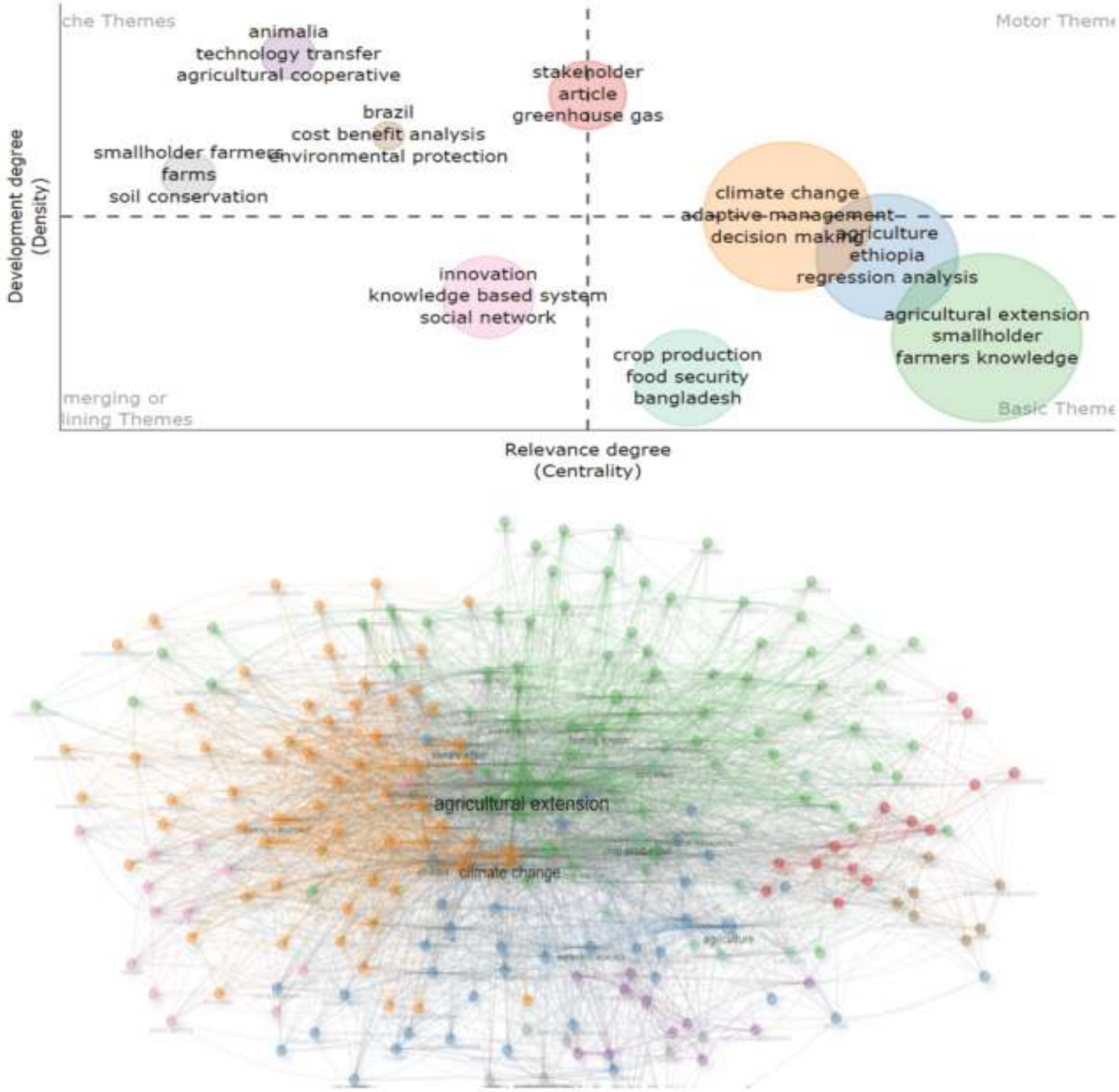

Figure 13. Thematic map

4. Conclusions and Recommendations

4.1. Conclusions

This bibliometric analysis reveals that research on Pluralistic Extension Advisory Services (PEAS) and their role in promoting climate-smart agriculture (CSA) for smallholder farmers has grown significantly over the last two decades. The increasing attention to CSA practices highlights its crucial role in addressing climate change challenges, particularly for smallholder farmers in vulnerable regions. The four thematic cluster-climate change adaptation, extension systems, CSA adoption, and sustainability undertake the breadth of research conducted to improve agricultural resilience and food security. Emerging topics such as gender inclusivity, digital extension services, and participatory approaches signal a shift towards more inclusive, technology-driven, and sustainable agricultural practices. Moreover, the global collaboration between countries and institutions reflects the importance of collective efforts in tackling climate change and promoting sustainable agriculture. The analysis also identifies critical gaps in existing research, such as the need for better coordination among stakeholders, integration of local knowledge, and the need to address digital divides in rural and marginalized communities.

4.2. Recommendations

Promote Gender-Inclusive Approaches: Future policies and programs should prioritize gender inclusivity in agricultural extension services. Women, often the backbone of smallholder farming, must have equitable access to CSA technologies, training, and resources to bridge the gender gap in agricultural productivity. This recommendation is directed at national policymakers and NGOs working in rural development.

Leverage Digital Technologies: Governments, research institutions, and NGOs should continue to invest in digital extension tools, including mobile apps, precision agriculture, and ICTs, to improve real-time access to climate information, soil data, and crop management techniques. These technologies should be tailored to meet the needs of smallholder farmers and ensure widespread accessibility. Governments, ICT developers, and rural extension agencies should lead implementation efforts.

Enhance Coordination Among Stakeholders: There is a need for stronger partnerships between public and private sectors, NGOs, research institutions, and local communities to ensure that extension services are well-coordinated and responsive to the diverse needs of farmers. Collaborative models that foster innovation and resource-sharing should be encouraged. Research institutions and public-private partnerships are key actors here.

Invest in Participatory Extension Systems: Participatory approaches that involve smallholder farmers in decision-making processes should be expanded. Extension services must incorporate local knowledge and context-specific solutions to increase the relevance and adoption of CSA practices. Extension departments and local governments should facilitate participatory model design and deployment.

Focus on Sustainability and Agro ecology: Future research and extension services should prioritize sustainability in agricultural practices. Efforts to integrate agro ecological principles, such as soil health, biodiversity, and sustainable water management, will help build long-term resilience in farming systems.

Support CSA Adoption in Vulnerable Regions: Policymakers and development organizations should focus on scaling CSA practices in regions most affected by climate change, such as Sub-Saharan Africa and South Asia. Tailored interventions that address specific regional challenges can help smallholder farmers build resilience to climate shocks. International donors, regional governments, and community-based organizations should prioritize region-specific programs.

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