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Exploring Global Research Trends on Extension Advisory Services in Climate-Smart Agriculture

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HIGHLIGHTS

- Scientific publications on EAS and CSA have increased sharply since 2015, reflecting the global momentum in climate policy.
- Thematic evolution shows a shift from conceptual frameworks to applied studies on innovation, capacity building, and policy integration.
- EAS are pivotal in translating CSA knowledge into field-level climate resilience and sustainable farming practices.

ARTICLE INFO

Keywords: Bibliometric analysis, Climate-smart agriculture, Extension advisory services, Knowledge dissemination, Research collaborations, Sustainable agriculture.

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ABSTRACT

The study examines global research trends on the role of Extension Advisory Services (EAS) in advancing Climate-Smart Agriculture (CSA) from 1984 to 2024. Data retrieved from the Scopus database were analysed using VOS viewer and the R-based Bibliometrix package to map publication trends, citation influence, collaboration networks, and thematic evolution. The results show a sharp rise in research output after 2015, coinciding with global policy momentum following the FAO's CSA framework and the Paris Agreement. Collaboration networks reveal strong linkages between African and European institutions, reflecting an emphasis on participatory and farmer-oriented approaches. Keyword and thematic analyses indicate a transition from conceptual discussions on extension and adaptation toward applied research focused on capacity building, innovation systems, and behavioural change. The findings highlight the critical role of EAS in enabling sustainable agricultural transformation. Strengthening institutional capacity, digital integration, and regional collaboration remains essential for enhancing the effectiveness of EAS in building climate resilience. Overall, EAS functions as the operational backbone of CSA by translating knowledge into adaptive, farm-level actions.

INTRODUCTION

Climate change, alongside food and nutrition insecurity, continues to be among the most urgent global issues, demanding immediate and innovative solutions (Brooks & Loevinsohn, 2011; Kabato et al., 2025). With the world population expected to reach 9.7 billion by around 2050, increasing food demand will put significant pressure on already-strained agricultural systems. (UN, 2019). Without sustainable management, this expansion in food production will further intensify environmental degradation and resource depletion (Anuranj et al., 2024; McLaughlin & Kinzelbach, 2015). Current food systems are also the largest source of methane emissions (Kabato et al., 2025), underscoring the unsustainable nature of prevailing agricultural practices. These trends highlight the urgent need for transformative change in how food is produced, distributed, and consumed (IPBES, 2019). If unaddressed, emissions from food systems will continue to rise, threatening ecosystem stability and global food security (Abbasi & Zhang, 2024; Bajzelj et al., 2014). In this context, the adoption of climate-smart technologies and practices emerges as an essential strategy.

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Climate-Smart Agriculture (CSA) offers a holistic framework aimed at sustainably increasing productivity and income, enhancing resilience to climate change, and reducing GHG emissions (Barman & Neog, 2024; Bai et al., 2019). It has emerged as an effective strategy for restructuring and guiding agricultural development in response to the challenges posed by climate change (Yadav et al., 2025). Beyond technological interventions, CSA depends on the diffusion of knowledge, supportive policies, and targeted investments in agricultural research and innovation (Das et al., 2022; Prajapati et al., 2025). Empowering farmers with timely, relevant information remain central to the implementation of CSA, underscoring the indispensable role of Extension Advisory Services (EAS).

EAS connect research with field work, offering farmers tailored advice and support to boost productivity and sustainability (Kumar et al., 2022; Singh & Kaunert, 2023). These services aid technology transfer and decision-making on crops and resources (Kumar et al., 2021; Sharma et al., 2024) and bolster capacity to tackle cross-cutting issues such as climate adaptation, nutrition, and disaster response (Kingiri, 2020; Silici et al., 2021). Through participatory methods and farmer training, EAS build adaptive capacity and promotes resilient agriculture aligned with CSA (Mishra et al., 2025; Jellason et al., 2020). By encouraging sustainable practices, EAS reduces agriculture's environmental impact and supports food security and rural resilience (Rajesh et al., 2024; Gugissa et al., 2022). Initially focused on technology dissemination, EAS now also addresses climate change adaptation and mitigation (Ghosh, 2019), serving as key enablers for operationalising CSA and translating research into farm-level innovations (Raj & Garlapati, 2020).

Despite growing recognition of EAS within CSA, existing research remains fragmented and largely context-specific, with limited understanding of global trends, thematic evolution, and collaboration patterns. Bibliometric analysis serves this purpose effectively by mapping scholarly patterns, identifying collaboration networks, and revealing intellectual structures across domains (Akhtar et al., 2023; Phoong et al., 2022; Donthu et al., 2021). Therefore, this study conducts a bibliometric analysis to systematically map global research trends, thematic structures, and knowledge gaps concerning the role of EAS in advancing CSA.

METHODOLOGY

A bibliometric analysis was performed to explore the role of EAS in CSA. This bibliometric analysis aimed to evaluate the scientific literature on the role of extension in CSA using the Elsevier Scopus database, given its broad multidisciplinary coverage, strong representation of agricultural and social science journals, and compatibility with bibliometric analysis tools. The study was conducted by retrieving all relevant research articles published between 1984 and 2024. The search was executed using a comprehensive set of keywords related to the role of extension services, advisory services, and CSA, ensuring the inclusion of all relevant studies within this domain.

The initial search involved the use of keywords such as 'extension services,' 'advisory services,' 'climate-smart agriculture,' 'CSA,' and related terms. This search expression was developed to cover the broad, related areas linking EAS to CSA. The Scopus search string used included the terms related to extension systems ("Extension Advisory Services," "Agricultural Extension," "Extension Services," "Advisory Services," "Extension Education," "Extension Programs"), climate-smart agriculture ("Climate-Smart Agriculture," "CSA," "Climate-Smart Practices," "Sustainable Agriculture," "Climate-Smart Agriculture Practices," "Climate Adaptation in Agriculture"), and their perceived role ("Role," "Impact," "Effect," "Contribution," "Importance").

Using the AND and OR operators helped link the concepts and narrow the results to studies examining the relationship between extension and CSA. This approach ensured that the literature retrieved was comprehensive, relevant, and aligned to analyse how extension systems contribute to the development and adoption of CSA practices. The search strategy was carefully refined to include only peer-reviewed research articles, reviews, and conference papers, resulting in a preliminary set of articles. Duplicate records were manually identified and removed during data cleaning, and the data were subsequently screened for relevance and language. The final dataset comprised 230 research articles.

The dataset comprising the selected scholarly publications was analysed using VOSviewer and the Bibliometrix package integrated within the R environment, as commonly adopted in previous bibliometric studies (Roy et al., 2024; Bretas & Alon, 2021). These tools enabled both quantitative analysis and visual representation of research patterns, facilitating the examination of publication trends, thematic structures, and collaboration networks in the field of extension in CSA. This combination ensured a methodologically robust and visually supported understanding of the research landscape.

RESULTS

Trends in scientific production

The annual distribution of publications related to the role of EAS in CSA from 1984 to 2024 is presented in Figure 1. The temporal evolution of the scientific output reveals three distinct phases. The initial phase, extending from 1984 to 2005, was characterised by sporadic and low publication activity, indicating that research attention toward the nexus between EAS and CSA was minimal during this period. Only isolated studies appeared, often within broader discourses on agricultural development or rural communication, with limited integration of climate adaptation perspectives. The period from 2006 to 2016 shows a gradual increase in publications, reflecting growing global awareness of climate change impacts on agriculture and climate adaptation as a policy focus. The FAO's CSA Framework (2010) and global climate initiatives likely spurred research growth, with scholars viewing EAS as institutional mechanisms for resilience and sustainability.

A marked acceleration occurred in the third phase, beginning in 2017, with the publication rate rising sharply and peaking in 2022 at more than 30 publications per year. This pronounced surge indicates a maturing research domain driven by international policy commitments, such as the Paris Agreement (2015), and increased funding for climate-adaptive agriculture. It also reflects a growing awareness of the indispensable role that EAS play in scaling climate-smart technologies, farmer capacity building, and participatory adaptation. Despite minor fluctuations across individual years, the upward trend is sustained, confirming the establishment of this topic as a consolidated field of inquiry. Overall, the increasing volume of literature signifies both scholarly engagement and institutional endorsement of EAS as pivotal actors in facilitating climate-resilient agricultural transitions.

Citation impact

The citation trend across the analysed period, as illustrated in Figure 2, reveals the maturation and intellectual influence of the field. Prior to 2005, the number of citations per publication was negligible, reflecting the absence of foundational literature that explicitly linked extension systems to climate resilience. From 2010 onwards, the average number of citations per year began to rise markedly, aligning with the period when seminal conceptual and empirical works started to emerge. These influential papers provided the theoretical grounding and methodological frameworks that connected advisory systems with the CSA paradigm.

Two notable peaks are observed around 2016 and 2018. These coincide with the publication of high-impact studies that introduced integrative approaches, combining technical innovation, institutional strengthening, and participatory communication, to promote CSA adoption. Such works were frequently cited in policy documents and global assessments, suggesting their influence beyond academia. A moderate decline in average citations is noted after 2020. This trend can largely be attributed to citation lag, where recently published papers have not yet accumulated substantial citations. Another plausible factor is the diversification of publication outlets, as the field expanded into interdisciplinary domains, diluting citation concentrations. Nevertheless, the general trajectory of increasing citation frequency signifies the growing scholarly and practical influence of research in this area.

Geographical distribution and international collaboration

The global distribution of research and collaboration networks, as depicted in Figure 3, highlights the international dimension of EAS-CSA. Research activity is widely dispersed, with significant contributions from both developed and developing countries. The United States, the United Kingdom, and select European nations emerge as central hubs of collaboration, maintaining strong linkages with African and Asian counterparts. This North-South collaborative pattern reflects the global research agenda's emphasis on supporting smallholder adaptation and the role of advisory services in low-income, climate-vulnerable regions.

In Africa, countries such as Kenya, Ethiopia, Malawi, and Tanzania stand out for their consistent research contributions. These nations have benefited from sustained international funding and capacity-building initiatives focusing on EAS and CSA. Their

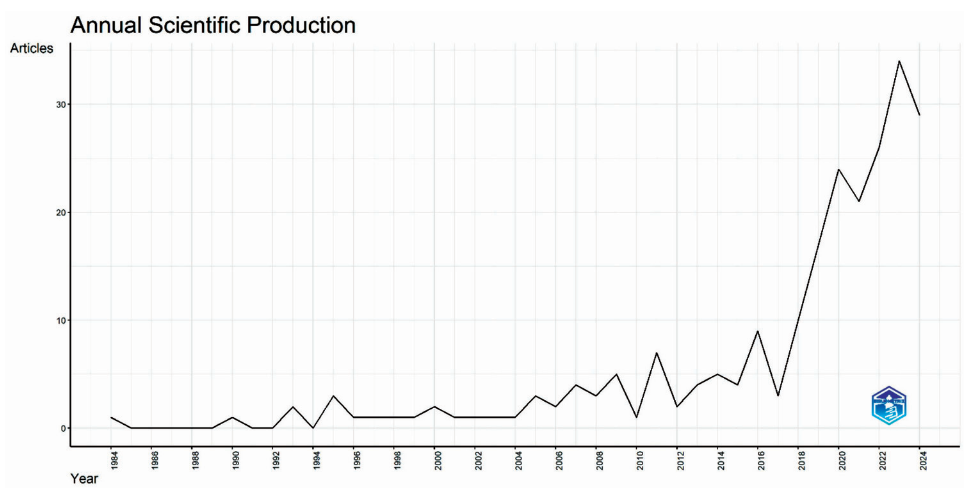

Figure 1. Annual scientific production on EAS in CSA (1984 to 2024).

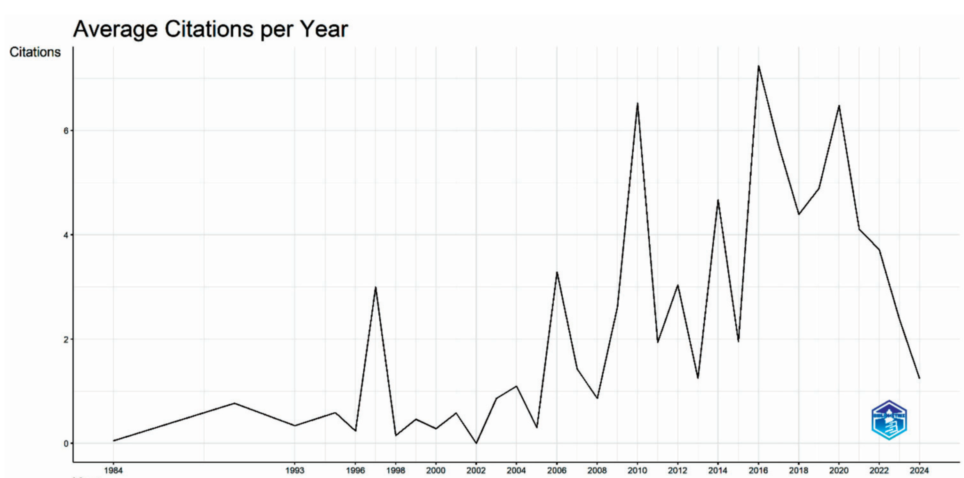

Figure 2. Average article citation per year on EAS in CSA (1984 to 2024).

prominence suggests that empirical work on extension-driven adaptation is disproportionately concentrated in contexts where smallholder farming is predominant. Additionally, collaborations between African and European institutions, often supported by multilateral programs, have facilitated the co-production of knowledge and context-specific extension models. South Asian countries, including India, Bangladesh, and Nepal, also appear as emerging contributors, though with comparatively weaker collaborative linkages. Conversely, regions such as Latin America and Southeast Asia are underrepresented, suggesting geographic imbalances in the research landscape. Overall, the international collaboration network underscores the field's global relevance while highlighting the importance of continued investment in transnational research partnerships to enhance knowledge sharing and policy translation.

The co-authorship network in Figure 4 highlights author collaborations within the field, showing distinct yet connected research communities. The red cluster, led by Susannah M. Dougil and Andrew J. Whitfield, centres on climate adaptation, institutional learning, and advisory reform. The blue cluster, led by John Recha and Krista Heiner, focuses on climate information, participatory methods, and farmer advisory systems in East Africa. The orange and green clusters, involving Christian Thierfelder, Innocent Pangapanga-Phiri, and Daniel Adu-Ankrah, relate to conservation agriculture, sustainable intensification, and participatory extension studies. The clusters show moderate network density, with some authors bridging clusters for cross-disciplinary collaboration in CSA. This highlights opportunities for greater consolidation via research groups, journal issues, or global networks.

Keyword co-occurrence and thematic structure

The keyword co-occurrence network shown in Figure 5 captures the conceptual and thematic architecture of research on EAS in CSA. The clustering structure reveals four dominant thematic groups. The first cluster (red) is dominated by keywords such as *role*, *research*, *agricultural extension*, *sustainable agriculture*, *challenge*, *program*, and *problem*. This cluster represents the conceptual and evaluative core of the literature, focusing on understanding the role of extension systems, sustainability challenges, and research-based assessments of extension programmes within the broader climate change context. The second cluster (green) centres on terms including *access*,

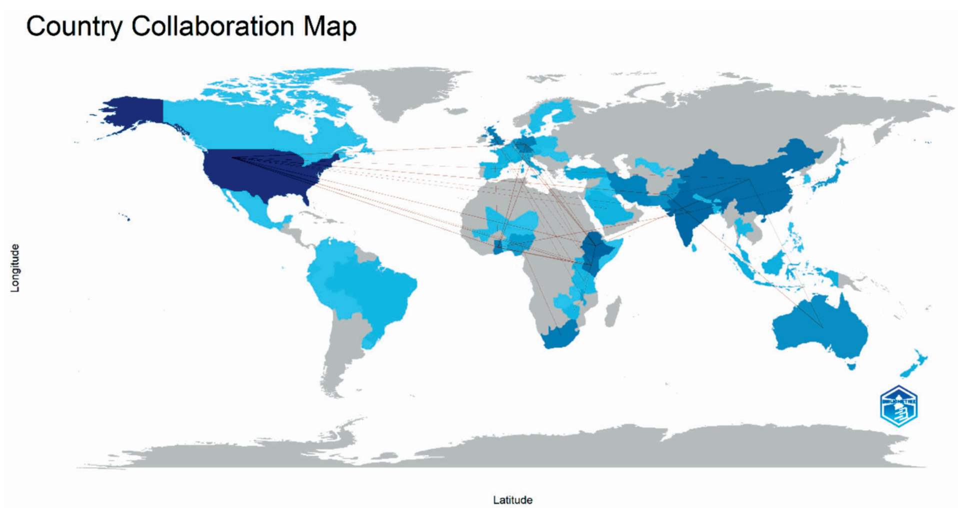

Figure 3. Country collaboration map depicting international research networks in EAS and CSA.

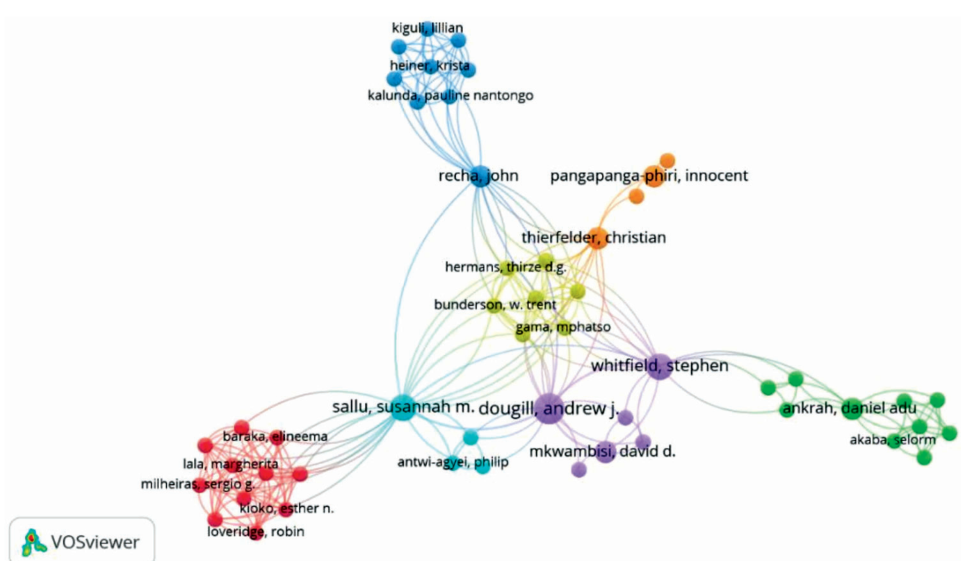

Figure 4. Co-authorship network among authors publishing on EAS in CSA.

climate-smart agriculture, *CSA*, *smallholder farmer*, *household*, *income*, *livelihood*, *credit*, and *crop*. This cluster reflects a farmer-centric and livelihood-oriented strand of research, emphasising access to CSA practices, household-level outcomes, and the socio-economic dimensions of extension and advisory interventions. The third cluster (blue) includes keywords such as *innovation*, *case study*, *uptake*, *community*, *process*, and *context*. This cluster encompasses implementation-oriented and learning-based studies that examine how CSA innovations are introduced, adapted, and adopted through community engagement, participatory processes, and context-specific extension approaches.

Together, these three clusters illustrate the multidimensional nature of EAS-CSA research, linking conceptual inquiry into extension roles, practical concerns regarding farmer access and livelihoods, and process-oriented studies of innovation uptake and community engagement. The central positioning of terms such as *role*, *access*, and *CSA* indicates their bridging function across the thematic structure.

The temporal evolution of research themes shown in Figure 6 illustrates how EAS-CSA research has developed from 1984 to 2024. During the early phase, studies largely focused on broad and foundational themes such as agricultural extension, sustainable agriculture, and regional contexts. This period was characterised by exploratory research examining the general role of extension systems in agricultural development and early climate adaptation efforts, with limited emphasis on adoption or livelihood outcomes. From around 2017 onwards, the thematic focus shifted toward more applied and farmer-centric concerns. Keywords related to access, smallholder farmers, households, income, and climate-smart agriculture gained prominence, indicating increased attention to adoption processes and socio-economic dimensions of CSA. This shift reflects a growing recognition of the importance of advisory services in enabling farmers to access resources, make informed decisions, and improve livelihood resilience under changing climatic conditions.

In later years, themes such as innovation, uptake, capacity building, and CSA practices became more visible, indicating a shift

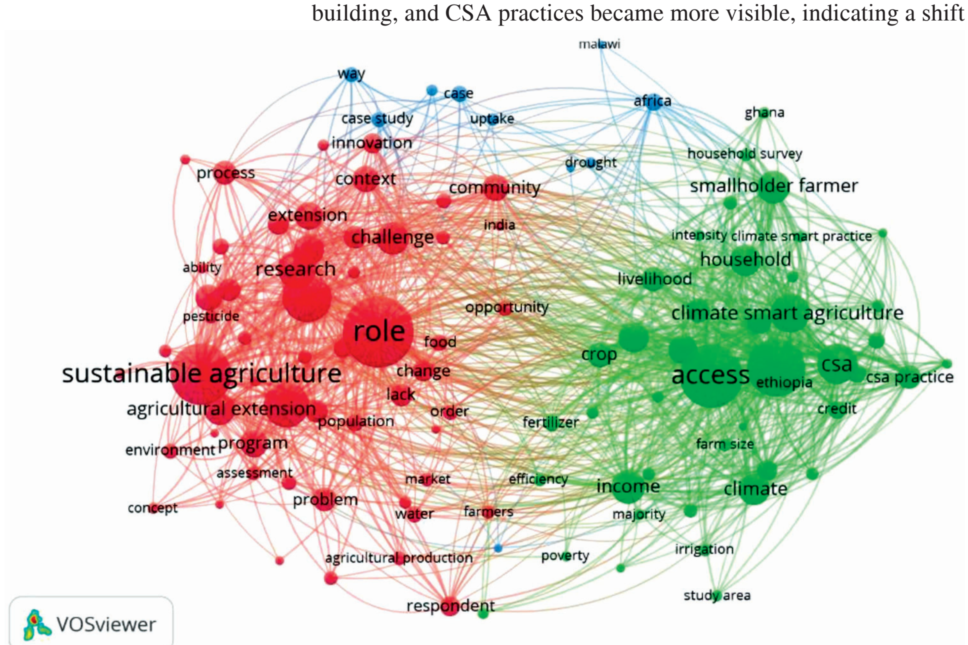

Figure 5. Keyword co-occurrence network showing thematic clusters in EAS-CSA research.

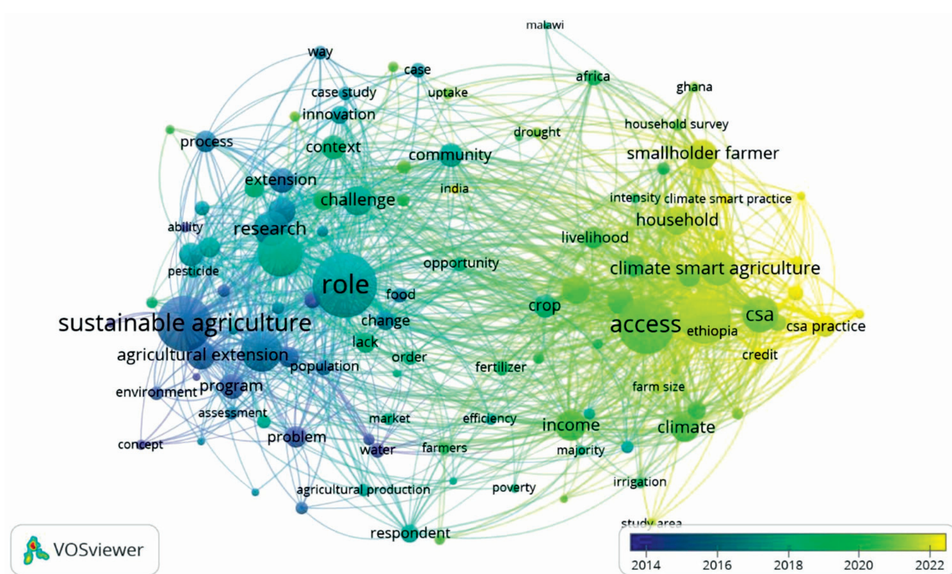

Figure 6. Temporal evolution of major research themes in EAS-CSA literature (2014 to 2022).

Table 1. Evolution of Extension Advisory Focus in Climate-Smart Agriculture Research

Period	Extension Advisory Focus	Evidence from Bibliometric Results
Before 2016	Conceptual extension and sustainability focus	Frequent use of agricultural extension and sustainable agriculture.
2017-2019	Participatory approaches and CSA access	Rising prominence of access, smallholder farmers, household, livelihood, and adoption-related terms
Beyond 2020	Advisory-led CSA implementation	Strong visibility of CSA, CSA practices, income, credit, innovation, and capacity building

Table 2. Notable insights from the study

Figure No.	Title/content	Notable insight
Figure 1	Annual scientific production	Rapid growth after 2015 indicates an increasing research focus on the EAS-CSA linkage
Figure 2	Average citations per year	Peaks from 2016 to 2018 indicate influential conceptual papers
Figure 3	Country collaboration map	Strong collaborations between Africa, Europe, and the U.S.
Figure 4	Co-authorship network	Moderate author connectivity with a few leading researchers
Figure 5	Keyword co-occurrence clusters	Four thematic areas: adaptation, participation, sustainability, and adoption
Figure 6	Evolution of keywords over time	Shift from conceptual to applied, policy-oriented research

toward implementation-oriented research. The close spatial positioning of clusters suggests strengthening linkages between extension systems, socio-economic factors, and climate outcomes. Overall, the temporal pattern demonstrates a progression from conceptual discussions of extension roles to applied, policy-relevant research focused on supporting farmer-level adaptation and sustainable agricultural transitions.

The comprehensive bibliometric analysis reveals that research on the role of EAS in CSA has expanded substantially over the past four decades (Table 1). The acceleration in publication output after 2015, accompanied by a rise in global collaborations, reflects the integration of extension discourse into mainstream climate and agricultural development research.

In summary, the results affirm that EAS serve as pivotal intermediaries in the operationalisation of CSA principles, bridging scientific innovation with local adaptation practices. The steady increase in research activity and the diversification of themes indicate a vibrant and expanding scholarly community committed to understanding and strengthening the role of advisory systems in climate-resilient agriculture (Table 2).

DISCUSSION

This bibliometric analysis shows that research on Extension and Advisory Services (EAS) and Climate-Smart Agriculture (CSA) has become increasingly important for policy beyond academia. The sharp rise in studies after 2015 reflects how global policy milestones, such as the FAO's CSA framework and the Paris Agreement, have pushed extension research to focus more on climate-resilient farming and knowledge systems (Lipper & Zilberman, 2017). At the same time, this raises a practical concern: global priorities may not always translate easily into locally relevant extension support.

The increase in publications after 2017 suggests that EAS is now widely seen as a key link between climate science and farmers' actions. While many studies highlight the role of institutional innovation in shaping farmers' adaptive behaviour (Chander & Rathod, 2020; Ranjan et al., 2025), they also reveal a gap between ambitious climate goals and the actual capacity of extension systems on the ground. Recent conceptual work (Dougill et al., 2021; Prajapati et al., 2025) therefore points to the need for extension services to move beyond information delivery and take on stronger facilitation and coordination roles.

Collaboration patterns show both progress and imbalance. Much of the research focuses on Africa and South Asia, where climate risks are high, but is often led by institutions from Europe and North America. While such partnerships support shared learning and innovation (Bhatta et al., 2015; Nkiaka et al., 2019; Pathak et al., 2024), they also underline the need for greater leadership from local institutions to ensure solutions are context-specific and practically useful.

The co-authorship networks highlight the increasingly interdisciplinary nature of this field, bringing together agricultural science, climate policy, and social sciences. This shift signifies a move toward systems thinking in extension research, emphasising technological, behavioural, and institutional change (Dangles et al., 2016; Dougill et al., 2021). This systems-based approach is promising, but it also reveals ongoing challenges in coordination across sectors and governance levels, which extension research has not yet fully addressed.

Changes in key research themes further confirm a clear shift away from traditional, top-down extension models. Earlier emphasis on awareness and technology transfer has given way to stronger attention on farmer empowerment, sustainability, and innovation systems (Waters-Bayer et al., 2015; Tambo & Wünscher, 2017; Arowosegbe et al., 2024; Prajapati et al., 2025; Barman et al., 2026). Alignment with Agricultural Innovation Systems and pluralistic extension approaches (Klerkx et al., 2012; Paschen et al., 2017; Panja et al., 2022) suggests that extension policies now need to rethink mandates, skills, and incentives to support collaboration and learning. Despite this progress, important gaps remain. Evidence is still heavily concentrated in sub-Saharan Africa, with far fewer studies from Southeast Asia and Latin America. This underscores the need for more comparative, long-term, and mixed-methods research to better understand how extension systems perform under sustained climate stress (Autio et al., 2021; Prajapati et al., 2025).

In summary, the results of this bibliometric synthesis suggest that EAS is no longer viewed simply as a channel for advice, but as a key institutional driver of climate adaptation and innovation. To fully realise its role in improving productivity, adaptation, and mitigation, policies must focus on strengthening extension capacities, ensuring inclusiveness, and supporting the scaling of climate-smart practices based on strong evidence.

CONCLUSION

The study affirms that extension advisory services are a fundamental driver of climate-smart agricultural transformation, serving as the vital link between scientific knowledge, policy frameworks, and on-ground practices. The analysis reveals a global transition from traditional dissemination models to participatory, adaptive, and farmer-centred systems that enhance innovation, behavioural change, and resilience. Strengthening institutional capacity, investing in inclusive digital tools, and fostering multi-stakeholder collaboration emerge as key priorities for scaling sustainable adaptation and productivity. The findings highlight that well-integrated advisory systems enable effective adoption of climate-resilient practices and improve farmers' ability to manage risks and uncertainties. Future research can explore region-specific models, digital integration strategies, and impact assessments of advisory innovations. Expanding cross-regional comparative studies will further enrich our understanding and guide policy frameworks that ensure agricultural sustainability and resilience in the face of changing climatic conditions.

DECLARATIONS

Ethics approval and informed consent: As the research was carried out with bibliometric analysis, the Scopus database from KAU, Thrissur, was used for the study, with inclusion and exclusion criteria.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author declares that they have thoroughly reviewed, revised, and edited the content as needed. The authors take full responsibility for the final content of this publication.

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