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Climate-Smart Agriculture and Food Security: A Bibliometric Analysis

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ABSTRACT

Climate change poses significant challenges to agricultural productivity and global food security, particularly in regions highly dependent on climate-sensitive farming systems. Climate-Smart Agriculture (CSA) has emerged as an integrated approach aimed at enhancing agricultural productivity, strengthening resilience to climate variability, and reducing greenhouse gas emissions. Despite the rapid growth of CSA-related studies, a comprehensive understanding of the global research landscape, thematic evolution, and collaboration patterns remains limited. This study aims to map and analyze the scientific development of CSA and food security research through a bibliometric approach. Using publication data indexed in the Scopus database, this study applies network and visualization analysis with VOSviewer to examine keyword co-occurrence, citation structures, co-authorship networks, and geographical research distribution. The findings reveal that research on CSA and food security has expanded significantly, with dominant themes focusing on climate change adaptation and mitigation, smallholder farming systems, crop resilience, sustainable land management, and technology adoption. The results also highlight strong international collaboration networks, particularly among countries in Asia, Europe, and Africa, reflecting the global relevance of CSA in addressing food security challenges. This study contributes to the literature by providing a systematic overview of research trends, influential works, and emerging themes, offering valuable insights for researchers, policymakers, and practitioners in designing evidence-based strategies for sustainable agriculture and food security under climate change.

Keywords: *Climate-Smart Agriculture, Food Security, Bibliometric Analysis, Climate Change, Vosviewer*

1. INTRODUCTION

Agriculture has been the backbone of human civilization, providing the essential resources for survival and economic development. However, the sector is increasingly threatened by the impacts of climate change, which include rising temperatures, unpredictable rainfall patterns, soil degradation, and increased frequency of extreme weather events [1], [2]. These changes not only compromise agricultural productivity but also undermine global food security. Food security, defined as the availability, accessibility, utilization, and stability of food, remains a critical challenge, particularly in developing countries where agriculture is predominantly rain-fed and highly vulnerable to climate variability [3]. As such, innovative approaches are required to ensure that agricultural practices can adapt to environmental changes while maintaining or improving productivity.

Climate-Smart Agriculture (CSA) has emerged as a holistic approach to address the twin challenges of climate change and food insecurity. CSA encompasses practices, technologies, and policies designed to increase agricultural productivity sustainably, enhance resilience to climate variability, and reduce greenhouse gas emissions. By integrating climate risk management into agricultural decision-making, CSA provides pathways for farmers to adapt to changing environmental conditions while contributing to broader climate mitigation goals [4], [5]. The approach emphasizes the interconnection between agricultural practices, environmental sustainability, and socio-economic well-being, making it an essential strategy in achieving global sustainable development targets.

Despite the growing attention on CSA, its adoption and implementation vary significantly across regions and farming systems. Socio-economic factors, including access to knowledge, credit, and markets, play a critical role in determining whether smallholder farmers can adopt CSA interventions effectively. Moreover, the diversity of agro-ecological zones requires context-specific solutions to optimize the benefits of CSA practices [6], [7]. Understanding the patterns of research, technological innovations, and policy interventions in CSA is therefore essential for promoting evidence-based strategies that can improve food security outcomes at local, national, and global levels.

Bibliometric analysis has become an increasingly valuable tool in mapping scientific knowledge, identifying research trends, and evaluating the evolution of scholarly work in specific domains. By systematically examining publications, citations, and authorship patterns, bibliometric studies provide insights into the growth and focus areas of a research field. In the context of CSA and food security, bibliometric analysis can help identify the most influential studies, emerging research themes, and potential knowledge gaps. Such insights are critical for guiding future research, informing policy decisions, and fostering collaborations among scientists, practitioners, and policymakers [8].

Furthermore, the intersection of CSA and food security aligns closely with global agendas, including the United Nations Sustainable Development Goals (SDGs), particularly SDG 2, which aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture. By promoting resilient agricultural systems and enhancing adaptive capacities, CSA contributes to long-term sustainability, equitable food distribution, and climate mitigation. Consequently, understanding the landscape of CSA research and its implications for food security is pivotal in designing effective strategies that address both environmental and socio-economic dimensions of agricultural development [9].

Despite the recognized importance of CSA, there remains a fragmented understanding of its global research trends, key thematic areas, and the extent to which it contributes to food security. Previous studies often focus on localized case studies or sector-specific interventions, leaving a knowledge gap in comprehensively evaluating the evolution of CSA research. Without a systematic overview, it is challenging to identify the most impactful studies, emerging innovations, and areas that require further investigation. Additionally, policymakers and practitioners may lack clear guidance on prioritizing interventions that are both effective and scalable, limiting the potential benefits of CSA in addressing food security challenges. This study aims to conduct a bibliometric analysis of research on climate-smart agriculture and food security, providing a systematic overview of the scientific literature.

2. METHODS

This study employs a bibliometric analysis to systematically evaluate research trends, authorship patterns, and thematic developments in the field of Climate-Smart Agriculture (CSA) and food security. Bibliometric analysis is a quantitative approach that uses publication data to map scientific knowledge, measure research impact, and identify emerging areas of study. The data for this analysis were retrieved from Scopus, which are recognized for their extensive coverage of peer-reviewed journals in agriculture, environmental sciences, and related disciplines. The search strategy involved using a combination of keywords such as "climate-smart agriculture," "food security," "adaptation," and "sustainable agriculture," ensuring that publications relevant to both the CSA framework and food security were included. Inclusion criteria focused on peer-reviewed articles, reviews, and conference proceedings published in English, while duplicate records, editorials, and non-scientific publications were excluded. Data cleaning and validation were conducted to ensure accuracy and reliability of the extracted records for subsequent bibliometric analysis. Data analysis was performed using VOSviewer, to visualize co-authorship networks, keyword co-occurrence, citation patterns, and research clusters.

3. RESULTS AND DISCUSSION

3.1 Network Visualization

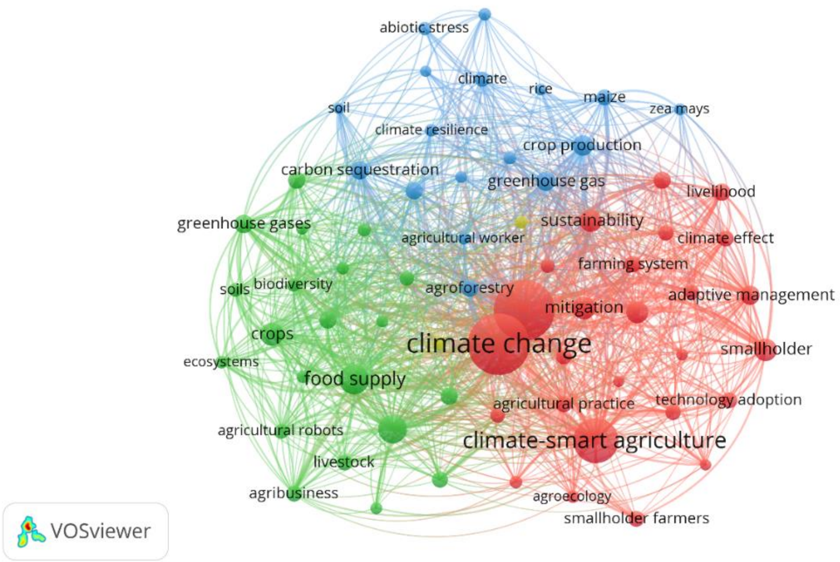

Figure 1. Network Visualization
Source: Data Analysis Result, 2025

This figure visualizes the relationships between various keywords related to climate-smart agriculture (CSA) and food security using VOSviewer, a bibliometric analysis tool. The visualization is structured as a network map where the keywords are represented as nodes, and the strength of their relationships is shown through the thickness of the connecting lines. The keywords are grouped into distinct clusters, each indicating a thematic area within CSA and food security research. The size of the nodes represents the frequency of the keywords, with larger nodes reflecting higher occurrence rates in the literature. The red cluster in the central part of the diagram represents core concepts related to climate change and climate-smart agriculture. This cluster contains high-frequency terms like "climate change," "mitigation," "adaptive management," "smallholder," "agricultural practice," and "technology adoption." These keywords highlight the importance of addressing climate change through innovative agricultural practices and technologies, particularly for smallholder farmers. The focus on adaptation and mitigation strategies aligns with global efforts to reduce agricultural greenhouse gas emissions and build climate resilience in agricultural systems.

The blue cluster is focused on terms related to climate resilience and crop production. Keywords like "abiotic stress," "rice," "maize," "crop production," "soil," and "greenhouse gases" are central to this cluster. These terms indicate the growing emphasis on improving the resilience of crops to climate-induced stresses such as droughts, floods, and temperature extremes. The presence of "soil" and "greenhouse gas" suggests the ongoing research on soil health and sustainable agricultural practices, which are integral to ensuring long-term food security in the face of climate change. The green cluster is centered around themes of food security and sustainability. This cluster includes keywords like "food supply," "ecosystems," "crops," "agroforestry," and "biodiversity."

These terms reflect the link between sustainable agricultural practices and the availability of food. The inclusion of "agroforestry" and "biodiversity" highlights the growing interest in multifunctional agricultural systems that enhance biodiversity while ensuring food production and ecosystem services. The emphasis on food supply underscores the need for resilient agricultural systems to secure access to food for growing populations.

The relationships between these clusters demonstrate the interconnected nature of CSA and food security. While the red cluster focuses on the adaptation and mitigation aspects of climate change, the blue cluster deals with technical solutions for crop resilience, and the green cluster emphasizes the broader environmental context of food production. The interactions between these clusters are facilitated by common keywords like "sustainability," "livelihood," "agriculture," and "climate effect," suggesting an interdisciplinary approach to tackling food security under climate change.

3.2 Overlay Visualization

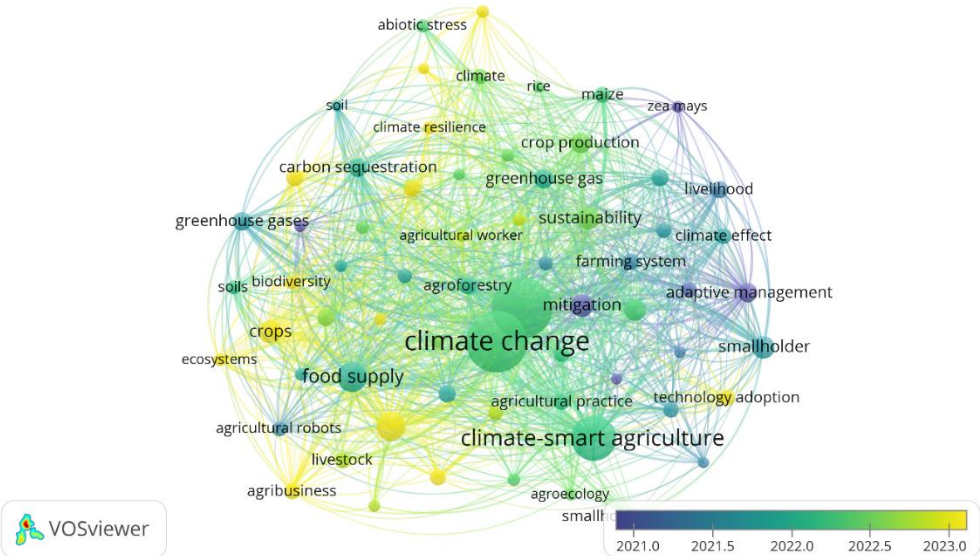

Figure 2. Overlay Visualization
Source: Data Analysis Result, 2025

This figure represents the evolution of research trends in climate-smart agriculture and food security, visualized using a bibliometric analysis in VOSviewer. The map shows how the connections between key terms have developed over time, with the colors indicating publication years. The gradient color scale, ranging from blue to yellow, highlights the temporal distribution of research, with blue representing earlier publications (2021) and yellow signifying more recent studies (2023). The nodes, or keywords, are clustered into groups based on their thematic relationships, and the size of the nodes represents the frequency of occurrences of each term. The central green cluster illustrates the core themes of climate change and climate-smart agriculture. This cluster includes terms like "climate change," "mitigation," "sustainability," and "food supply." These terms dominate recent research (2022 and 2023), reflecting a growing emphasis on mitigating climate change impacts through agricultural practices. The presence of smaller nodes like "smallholder" and "agricultural practice" further indicates a focus on addressing the needs of smallholder farmers, who are often the most vulnerable to climate impacts. The evolution of these keywords over time shows a shift toward understanding how climate-smart agriculture practices can contribute to sustainable food security.

The blue and yellow clusters represent secondary themes that have become more prominent in recent years. The blue cluster at the top emphasizes the relationship between crop production and climate resilience, with terms like "abiotic stress," "rice," and "maize" appearing more frequently.

These keywords highlight the increasing attention to crop-specific challenges under climate change. The yellow cluster, which includes terms such as "technology adoption," "agricultural robots," and "agroforestry," reflects the rise of innovative agricultural technologies and practices in response to climate impacts. These terms also emphasize the growing importance of technological and ecological solutions for ensuring food security in the face of environmental challenges.

3.3 Citation Analysis

Table 1. The Most Impactful Literatures

Citations	Authors and year	Title
1701	[10]	Climate-smart soils
1484	[11]	Climate-smart agriculture for food security
1401	[12]	Impact of climate change on crops adaptation and strategies to tackle its outcome: A review
1050	[13]	Impact of climate change on agriculture and its mitigation strategies: A review
551	[14]	Soil salinity under climate change: Challenges for sustainable agriculture and food security
457	[15]	Sustainable intensification: What is its role in climate smart agriculture?
325	[16]	Nexus on climate change: agriculture and possible solution to cope future climate change stresses
306	[17]	Novel approaches and practices to sustainable agriculture
293	[18]	Climate-Smart Landscapes: Opportunities and Challenges for Integrating Adaptation and Mitigation in Tropical Agriculture
281	[19]	From climate-smart agriculture to climate-smart landscapes

Source: Scopus, 2025

3.4 Density Visualization

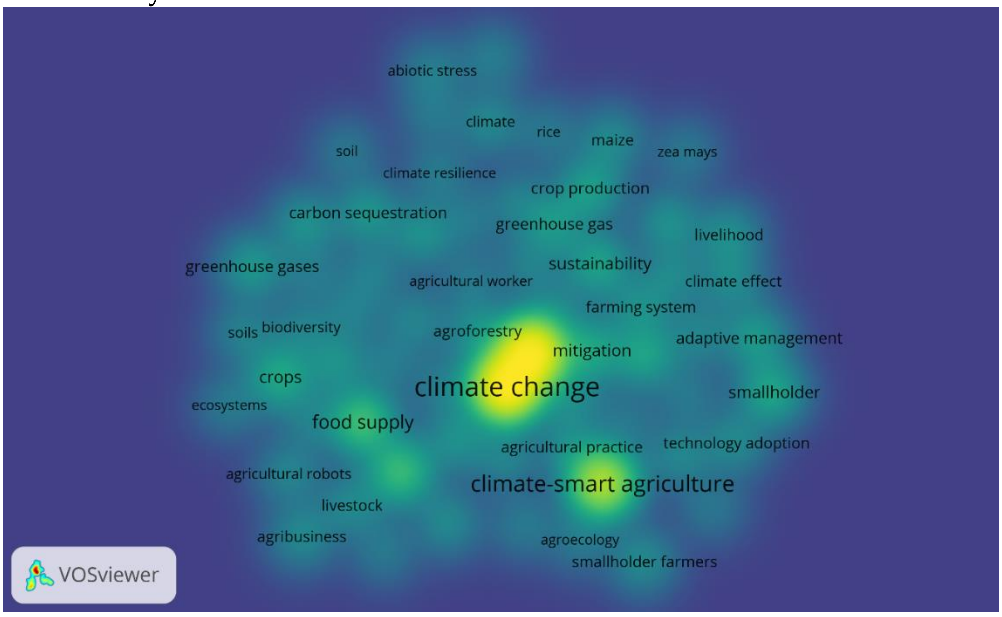

Figure 3. Density Visualization

Source: Data Analysis Result, 2025

This figure is a heatmap visualization generated from bibliometric data related to climate-smart agriculture (CSA) and food security. The colors on the map represent the density of keyword occurrences in the literature, with the yellow area indicating a high concentration of research and the blue areas signifying lower frequency. The central region of the map, dominated by the keywords "climate change" and "climate-smart agriculture," is the most densely concentrated, showing that these topics are the focal points of recent research. The keywords surrounding this central focus, such as "mitigation," "adaptation," "smallholder," and "food supply," reflect the increasing attention on strategies to enhance climate resilience in agriculture and ensure food security. The keywords surrounding the central cluster are spread out across various clusters related to specific aspects of CSA and food security. For instance, terms like "soil," "agroforestry," "sustainability," and "carbon sequestration" appear in close proximity, indicating the focus on sustainable farming practices and environmental benefits. Similarly, terms like "technology adoption," "agricultural robots," and "smallholder farmers" reflect a growing interest in technological innovations and their role in improving agricultural systems. Overall, this heatmap provides a clear visual representation of the key themes in current CSA research, highlighting both environmental and socio-economic factors as crucial areas of study.

3.5 Co-Authorship Network

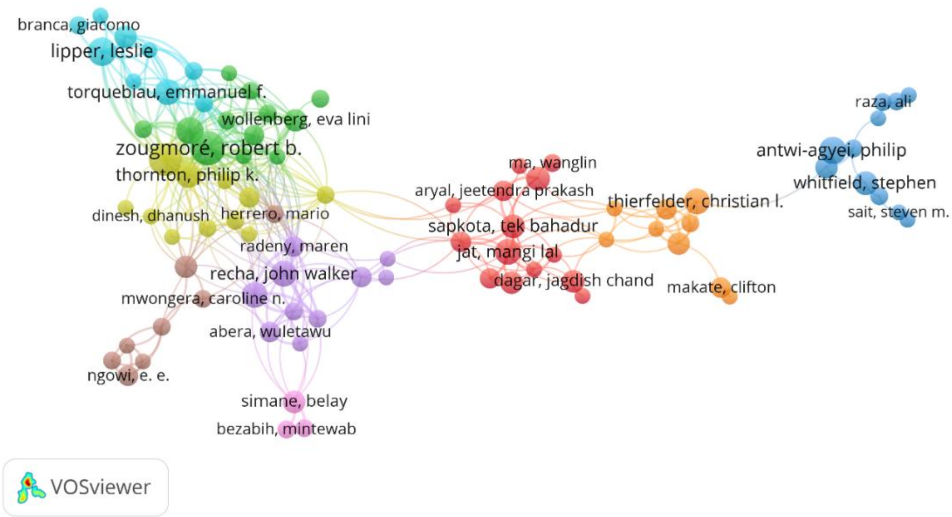

Figure 4. Author Visualization
Source: Data Analysis Result, 2025

This figure presents a co-authorship network of researchers, visualized using VOSviewer. The nodes represent individual authors, and the connections between them indicate co-authorship relationships in the literature. The colors of the nodes correspond to different clusters of authors who frequently collaborate with each other, with each cluster representing a distinct research network or community within the field. The central cluster, including authors like Zougmoré, Robert B., Thornton, Philip K., and Wollenberg, Eva Lini, appears to be the largest, indicating a highly interconnected group. Other smaller clusters, such as the blue group with Raza Ali and the red group with Ma, Wanglin, represent different research teams, each contributing to various aspects of the broader field of climate-smart agriculture or related topics. This map offers insights into the key players and collaborative patterns within the field.

Figure 5. Affiliation Visualization
Source: Data Analysis Result, 2025

This figure represents a network of academic institutions, visualized through their co-authorship relationships in the field of climate-smart agriculture or related research. The nodes represent different institutions, with the size of the nodes indicating their level of involvement or frequency of collaboration. The connections between the institutions are represented by the lines, highlighting co-authorship and collaborative efforts in research. The institutions are clustered into groups, with some, like "Centro Internacional de Agricultura" and "University of Agriculture, Farm," showing tighter relationships with multiple other institutions. This indicates that these institutions play a central role in research networks and are involved in extensive collaborations across the field. The varied colors of the clusters represent different research teams or thematic areas, providing insight into the global collaborative landscape.

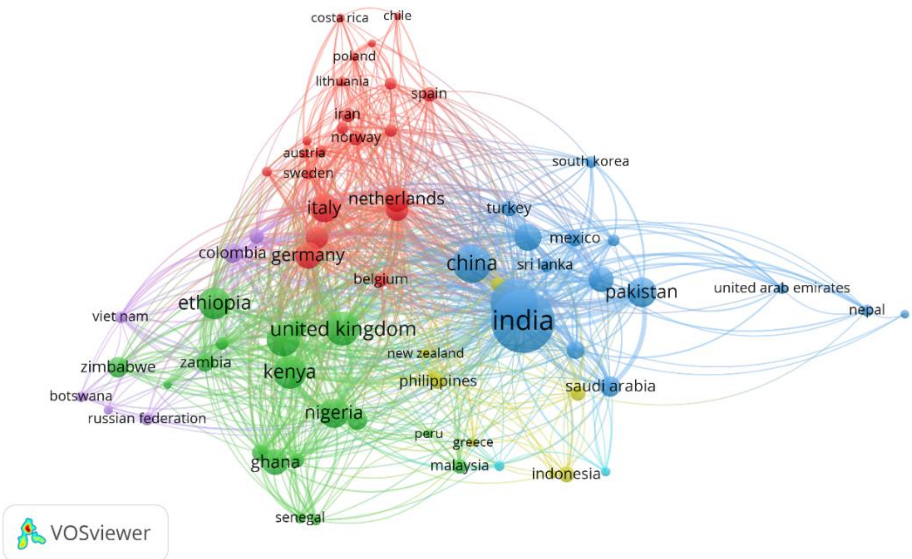

Figure 6. Country Visualization
Source: Data Analysis Result, 2025

This figure presents a global network of countries involved in research related to climate-smart agriculture or a similar field, as visualized through a co-authorship network. The nodes represent countries, with their size indicating their level of involvement or frequency of collaboration in research. The countries are clustered into different groups based on their co-authorship connections. The blue cluster, which includes India and China, represents prominent research hubs in Asia, showing extensive collaboration with surrounding regions like Pakistan, Sri Lanka, and Nepal. The red cluster, centered around Italy and the Netherlands, highlights a strong European network of countries involved in this research area. The green cluster includes African nations like Ethiopia, Nigeria, and Kenya, indicating a focus on agricultural research within these regions. Additionally, smaller nodes represent countries from Latin America and the Middle East, illustrating global engagement in this area. The lines connecting these countries represent their collaborative research efforts, with denser connections suggesting stronger collaboration. This map illustrates the broad international scope and interconnectedness of climate-smart agriculture research.

Discussion

Practical Implications

The findings of this bibliometric analysis offer several important insights for practitioners working in the field of climate-smart agriculture (CSA) and food security. First, the geographic distribution of research highlights key regions that are actively engaging in CSA-related research, with a notable concentration in countries like India, China, Italy, and the Netherlands. This suggests that policymakers, agricultural professionals, and development organizations can benefit from learning from these regions' best practices, technological innovations, and policy frameworks. The emphasis on smallholder farmers and their adaptation to climate change in these countries underscores the importance of targeting climate-smart agricultural practices to the most vulnerable populations, particularly in developing regions. Additionally, the growing focus on technological innovations such as agricultural robots and precision farming offers potential avenues for improving agricultural productivity while mitigating environmental impacts, which could be leveraged to strengthen food security in both developed and developing countries.

Theoretical Contributions

This study contributes to the academic literature on CSA and food security by providing a comprehensive bibliometric overview of the field's evolution, key trends, and research hotspots. The network analysis of co-authorships and keyword co-occurrence offers a clearer understanding of how the field has evolved over time and the major research areas that have emerged. By identifying clusters of research on climate change mitigation, crop resilience, and smallholder adaptation, this study contributes to the theoretical framework of CSA by emphasizing the interconnectedness of climate change, agricultural sustainability, and food security. Moreover, the identification of key themes such as technology adoption and agroecology reflects the interdisciplinary nature of the field, bridging ecological, technological, and socio-economic perspectives. The findings further highlight the importance of collaborative research networks, reinforcing the idea that addressing global challenges like climate change and food security requires cross-sectoral and international cooperation.

Limitations

While this study provides valuable insights into the global research landscape of CSA and food security, several limitations should be considered. First, the bibliometric approach focuses on published articles and may not capture the full range of gray literature, such as reports, policy documents, or local-level research that may be crucial for understanding region-specific challenges and solutions. Second, the study relies on databases like Scopus and Web of Science, which may have coverage biases, especially for countries or regions with less access to these databases. Third, the use of co-authorship and keyword co-occurrence as the primary metrics does not fully account for the depth and quality of the research, potentially overlooking significant contributions from individual researchers or institutions with fewer publications. Finally, while the study captures the broad trends in CSA and food security, it does not delve into the specific impacts of the identified research on policy or practice, which could be an area for future qualitative exploration

CONCLUSION

In conclusion, this bibliometric analysis provides a comprehensive overview of the research landscape in climate-smart agriculture and food security, highlighting key trends, regional hotspots, and emerging themes in the field. The study reveals a growing emphasis on mitigating climate change impacts through innovative agricultural practices, with a strong focus on smallholder farmers, technological adoption, and sustainable food production systems. The findings underscore the importance of international collaboration and knowledge exchange, particularly between countries leading research in both developed and developing regions. While the study provides valuable insights, it also highlights the need for further research that incorporates diverse types of literature, regional case studies, and qualitative analyses to better understand the practical applications and policy implications of the identified research trends. Overall, this study contributes to the understanding of how climate-smart agriculture can address global food security challenges and calls for continued interdisciplinary and cross-sectoral cooperation to achieve long-term sustainability in agriculture.

REFERENCES

[1] D. Bazzana, J. Foltz, and Y. Zhang, "Impact of climate smart agriculture on food security: An agent-based analysis," *Food Policy*, vol. 111, p. 102304, 2022.

[2] M. Paul Jr, G. B. D. Aihounton, and J. C. Lokossou, "Climate-smart agriculture and food security: cross-country evidence from West Africa," *Glob. Environ. Chang.*, vol. 81, p. 102697, 2023.

[3] C. S. Mutengwa, P. Mnkeni, and A. Kondwakwenda, "Climate-smart agriculture and food security in Southern Africa: A review of the vulnerability of smallholder agriculture and food security to climate change," *Sustainability*, vol. 15, no. 4, p. 2882, 2023.

[4] W. Kabato, G. T. Getnet, T. Sinore, A. Nemeth, and Z. Molnár, "Towards climate-smart agriculture: Strategies for sustainable agricultural production, food security, and greenhouse gas reduction," *Agronomy*, vol. 15, no. 3, p. 565, 2025.

[5] R. B. Wakweya, "Challenges and prospects of adopting climate-smart agricultural practices and technologies: Implications for food security," *J. Agric. Food Res.*, vol. 14, p. 100698, 2023.

[6] M. Ghosh, "Climate-smart agriculture, productivity and food security in India," *J. Dev. Policy Pract.*, vol. 4, no. 2, pp. 166–187, 2019.

[7] G. Owuso Essegbey, D. K. Nutsukpo, N. Karbo, and R. B. Zougmoré, "National climate-smart agriculture and food security action plan of Ghana (2016-2020)," 2015.

[8] M. Aria and C. Cuccurullo, "A brief introduction to bibliometrix," *J. Informetr.*, vol. 11, no. 4, pp. 959–975, 2017.

[9] S. Jamil *et al.*, "Climate-smart agriculture: a way to ensure food security," *Pakistan J Bot*, vol. 55, pp. 1157–1167, 2023.

[10] K. Paustian, J. Lehmann, S. Ogle, D. Reay, G. P. Robertson, and P. Smith, "Climate-smart soils," *Nature*, vol. 532, no. 7597, pp. 49–57, 2016.

[11] L. Lipper *et al.*, "Climate-smart agriculture for food security," *Nat. Clim. Chang.*, vol. 4, no. 12, pp. 1068–1072, 2014.

[12] A. Raza *et al.*, "Impact of climate change on crops adaptation and strategies to tackle its outcome: A review," *Plants*, vol. 8, no. 2, p. 34, 2019.

[13] G. S. Malhi, M. Kaur, and P. Kaushik, "Impact of climate change on agriculture and its mitigation strategies: A review," *Sustainability*, vol. 13, no. 3, p. 1318, 2021.

[14] R. Mukhopadhyay, B. Sarkar, H. S. Jat, P. C. Sharma, and N. S. Bolan, "Soil salinity under climate change: Challenges for sustainable agriculture and food security," *J. Environ. Manage.*, vol. 280, p. 111736, 2021.

[15] B. M. Campbell, P. Thornton, R. Zougmoré, P. Van Asten, and L. Lipper, "Sustainable intensification: What is its role in climate smart agriculture?," *Curr. Opin. Environ. Sustain.*, vol. 8, pp. 39–43, 2014.

[16] A. Shahzad *et al.*, "Nexus on climate change: Agriculture and possible solution to cope future climate change stresses," *Environ. Sci. Pollut. Res.*, vol. 28, no. 12, pp. 14211–14232, 2021.

[17] S. H. Muhie, "Novel approaches and practices to sustainable agriculture," *J. Agric. Food Res.*, vol. 10, p. 100446, 2022.

[18] C. A. Harvey *et al.*, "Climate-smart landscapes: opportunities and challenges for integrating adaptation and mitigation in tropical agriculture," *Conserv. Lett.*, vol. 7, no. 2, pp. 77–90, 2014.

[19] S. J. Scherr, S. Shames, and R. Friedman, "From climate-smart agriculture to climate-smart landscapes," *Agric. Food*

Secur., vol. 1, pp. 1–15, 2012.