

Review on Climate Smart Agriculture Practice: A Global Perspective

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Abstract: Climate change is having a detrimental effect on the environment's natural equilibrium. The population that depends on agriculture is suffering from rising temperatures, sporadic droughts and famines, unpredictable dry spells, and irregular rains. Deploying Climate Smart Agriculture (CSA) is a terrific strategy to cut greenhouse gas emissions and boost crop output for food security and climate change adaptation. The primary objective of this study is to provide an organized appraisal of current advancements in the field of climate-smart agriculture. For this study, the Scopus database was used to analyze 157 papers that were published between 2013 and 2022. However, the use of climate-smart agriculture technology that considers local knowledge is still quite low in developing countries. Therefore, raising the importance of indigenous knowledge in the context of climate change could aid smallholder agricultural groups in their adaptation. Improving adaptability, developing capacity, and fusing indigenous knowledge with climate-smart agricultural practices may all be necessary to increase a community's effective resilience to climate change.

Keywords: Climate change; Climate smart agriculture; Greenhouse gases; Bibliometric analysis.

Introduction

Climate Change is a matter of great concern worldwide. Environmental balance and Agriculture Production are drastically impacted by Climate Change. Agriculture is one of the industry's most vulnerable to impending climate change. Despite technological advances including the Green Revolution, weather and climate remain a primary determinant of agricultural productivity in the world (Barua and Barua, 2024). According to research on the economics of climate change, global warming will eventually have a negative effect over the longer term, even while it may somewhat boost crop production in the short term (before 2030) (Barua et al., 2023; Paul et al., 2021). There are various ways that climatic changes may affect agriculture. Because

agricultural productivity is mostly dependent on climatic stability and influenced by weather and climate, it poses problems for the prospective supply of food. Increased evapotranspiration, increased aridity, water shortages, desertification, and lower precipitation are caused by higher temperatures and less precipitation (Barua et al., 2022). These factors also result in decreased yield potential, declining yields, and expanding reductions in reproduction and milk production (Toungos and Bulus, 2019), degradation of cattle conditions (Gamage et al., 2023), and regions (Shrestha et al., 2022). Elevated temperatures and variations in precipitation can also impact biotic elements, leading to unintended consequences like accelerated weed growth, increased prevalence of pests and illnesses, the arrival of novel insects and diseases (Srivastava et al., 2021; Barua and

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Mitra, 2022), or abiotic elements like extensive nutrient depletion (Morel and Cartau, 2023). Coastal agricultural regions that experience sea intrusion lose agricultural land, contaminate freshwater supplies, and see a rise in salinity. Soil erosion and a reduction in fertility are further consequences (Mohasin and Barua, 2020; Barua and Eslamian, 2021): Economic losses and higher labour and equipment costs are examples of negative effects (Moayedi and Hayati, 2023).

Increased population, demand for high-yield crops, decreasing earth's producing capacity, and the need to exploit natural deposits more efficiently and effectively require "Climate Smart Agriculture". Climate Smart Agriculture (CSA) develops soil-land-water management techniques to promote efficient food production in this uncertain changing environment (Singh & Singh, 2017). CSA consolidates land and resource management to meet rising demands and plan for flexible resource use. The World Bank's 2016-2021 and 2021-2025 Climate Change Action Plans promote Climate Smart Agriculture. This research paper aims to find out the current trends in the field of Climate Smart Agriculture using science mapping review analysis.

Methodology

A 5-step structured procedure is used for conducting science mapping in bibliometric analysis. The first Step is Research Design where a researcher constructs the Research Questions and then finds out a suitable method for answering the research questions. The second step is the assortment of data in which the researcher must select the appropriate database and then export the bibliographic data. The third step is Analysis of data with the help of appropriate bibliometric software. Then, the fourth step is Visualisation of data and the final Step is the Interpretation of findings from the data.

For the present study, the Scopus database has been used to extract the data as "the most comprehensive overview of the world's research outputs" which is selected, organised, and presented by the subject experts. "TITLE-ABS-KEY" was used as a query string in the advanced search feature of Scopus. It helps us to find the documents that have keywords related to research in the Title and abstract. In this study "CLIMATE SMART AGRICULTURE" AND SUSTAINABLE DEVELOPMENT was used to extract the documents. A total of 157 documents were retrieved and then they were screened based on publication stage and language. Out of this, 153 documents were then identified, arranged, evaluated, and analyzed for

bibliometric analysis. The Bibliometric Analysis is the bundling of enormous quantities of bibliometric data to present the salient attributes and recent developments of the research study. The techniques of bibliometric analysis are exhibited around two main categories i.e., performance analysis and science mapping.

Results and Discussion

Climate Smart Agriculture Practice

Structural inequality and the disproportionate distribution of resources and entitlements across social axes affect a nation's and community's ability to adapt and reduce its vulnerability to climate change. In Vietnam, state-run initiatives encouraged farmers to grow irrigated rice, which reduced the ability of impoverished households to diversify their income and adjust over time. CSA projects in Uganda risk "elite capture" by favouring farmers with higher knowledge. Investigating how these organizations can better respond to shifting structural vulnerability—influenced by social, biophysical, economic, political, and technological context and processes—is crucial to preventing CSA interventions from reproducing social power relations that cause local injustices. The most vocal CSA opponents are NGOs and community-based actors, some of which have established social movements to prevent interest groups from joining the GACSA (Khatri-Chhetri et al., 2020; Barua and Barua, 2024). Local farmers often complain that seasonal climate projections (SCFs) are too imprecise for decision-making (Nyadzi et al. 2019).

Traditional and local knowledge is still being integrated into SCFs, but not enough (Nyadzi et al. 2021). Many organizations have combined local knowledge with forecast science to ensure resilience and adaptation (Nightingale et al., 2019). Indigenous tribes and the Kenyan Meteorological Agency formed strategic groupings to combine "rainmakers" knowledge with Western weather and climate forecasting. The two teams tested and altered their projections and the models' ability to respond to climate change's effects on agricultural output (Das and Ansari, 2021).

Several studies have examined how CSA technology and practice development and use affects local governments, communities, and peasants. Concerns range from carbon markets favouring privileged corporate sector actors to CSA greenwashing and the neglect of smallholders, women, equity, and justice (Barua & Barua, 2024). Zougmore et al. (2018) examined the CSA potential in Sub-Saharan Africa. They promoted resilient cultivars, water management,

agroforestry, insurance, and climate information. Abegunde et al. (2019) found that “conservation agriculture, agroforestry, integrated crop-livestock management, mulching, intercropping, crop rotation, an improvement on water management, and development on grazing” were the most common regional practices. Climate threats like droughts, bush fires, floods, and new diseases are the biggest issues in West African cattle (Zougmore et al., 2016) and they collected different adaptation possibilities. Additionally, climate information services are growing in importance. In Moldova, drought is the biggest constraint on smallholder output, although 82% of farms do not adopt CSA or crop rotation. (Setshedi and Modirwa, 2020).

Adhikari (2018) stressed the importance of adaptation for agriculture and non-agriculture. This encompasses funding, non-farm revenue, mainstreaming climate adaptation, CSA data access, governance and institutions, and migration. Farmers face social, normative, and institutional barriers; intellectual, technological, and financial constraints; and ecological and physical limits from unique environmental endowments when adopting the Community Supported Agriculture (CSA) model (Barua et al., 2022). McKune et al. (2018) found that small-scale farmers learn about CSA methods from family and extension agencies. Martinez-Baron et al. (2018) say social networks and key players are key to CSA uptake.

Computer Application in Agriculture

The authors examine 14 agricultural engineering works. Photosynthesis, agricultural machinery service systems, and agricultural goods drying and rehydrating are modeled in several papers. Golisz et al. (2022) explained leek drying using a probabilistic model of materials’ drying kinetics that included shrinkage. Seven empirical models, artificial neural networks, rehydration indices, and color variations (total colour difference) were used by Górnicki et al. (2022) to describe dried apple features following rehydration. Borowski et al. (2023) developed and successfully implemented a mathematical model to estimate agricultural machinery service system preventative replacements with little repair. García-Rodríguez et al. (2023) utilised mathematical modeling to estimate photosynthesis. Several publications in the research discuss optimisation.

AI was employed in several agriculture research articles. Górnicki et al. (2022) used artificial neural networks to characterise rehydration, while Trajer et al. (2021) evaluated fruit and vegetable processing water utilisation. Sun et al. (2021) used an adaptive

neuro-fuzzy inference system for manipulator trajectory tracking control, Xu et al. (2022) used deep learning to detect agricultural pests, Liu et al. (2022) used convolution neural networks to recognise buckwheat diseases, and Ma et al. (2022) used hyperspectral nitrogen content. Wei et al. (2022) simulated pregnant sow piggery airflow patterns numerically. Janaszek et al. (2022) designed a speckle-based sensor that might be used as a diagnostic tool in post-harvest fruit sorting. Zhang et al. (2022) employed computer simulation of a revolving tillage soil blade cutting soil.

Pests are a major factor in crop yields, regional agricultural economic stability, and food security (Ahmed et al., 2022). Pests and weeds harm 20–30% of worldwide agricultural production, costing USD 70 billion (Hu et al., 2019). Data on pests and illnesses in farm fields must be collected and analysed to prevent and control them (Yang et al., 2017). The diversity of pests on farmland and the complexity of available information types make manual observation and statistics unsuitable for pest control in modern large-scale agricultural production. Thus, deep-learning approaches for crop pest picture detection are a popular research topic (Sabanchi et al., 2022; Li et al., 2020). Recent deep-learning research has produced various pest-identification object-detection frameworks. Yang et al. (2017) used salient maps and a CNN to locate and identify 23 tea crop pest species. Cheng et al. (2017) discovered 35 insect species using sparse coding pyramids. Chen et al. (2020) used an AlexNet-based residual block to build a pest-identification network for ten natural pests.

Yearly Publication and Country Analysis

The final sample data included 153 documents. Published papers ranged from five in 2013 to thirty-two in 2021. Up until April 2022, 18 documents have been released. Thus, the final 2022 number should only rise. Global climate and sustainability awareness has increased, therefore Climate Smart Agriculture (CSA) research publishing is predicted to rise. Researchers have focused on smart agriculture, according to the findings. Table 1 shows that the top 10 climate-smart agriculture countries produced 153 documents. The average country publishes 16.5 documents, and just 5 publish more. The United States leads CSA with 28 publications, followed by the United Kingdom with 23. India ranks third with 22 publications. In developing nations, it contributes more to CSA research. The remaining 5 countries publish less than average. The tables demonstrate that developed countries USA, UK,

Netherlands, Italy, and Australia and emerging countries India, Kenya, Columbia, South Africa, and China are balanced.

Table 1: Complied country and publication data from Scopus database for 2013 to 30 April 2022

<i>Country</i>	<i>Average publication count (Percentage)</i>
United States	16.9
United Kingdom	13.9
India	13.33
Kenya	11.51
Netherlands	11.51
Italy	8.48
Columbia	6.66
South Africa	6.66
China	6.06
Australia	4.84
Total	100

Citation Analysis

Table 2 represents the Top 10 highest cited articles out of 153 documents, including Document title, Publication year, First author, source, and citation score. With 125 citations, the highest cited article from CSA was “Climate-Smart Agriculture Global Research Agenda: Scientific Basis for Action” by authors (Steenwerth et al., 2014) published in Agriculture and food security in 2014. This paper focussed on food and food systems, land management and regional issues, institutional and policy issues and identifying the barriers to CSA adoption, mitigation and adaptation of the livestock, climate risk management techniques and finding technologies for sustainable food production. (Thierfelder et al., 2017) published article “How Climate Smart is Conservation Agriculture (CA)- Its potential to deliver on adaptation, mitigation, and productivity of smallholder farms in southern Africa” in 2017 and

Table 2: Compiled citation data from Scopus database for 2013 to 30 April 2022

<i>Document title</i>	<i>Year</i>	<i>First author</i>	<i>Source</i>	<i>Citation score</i>
“Climate-Smart Agriculture global research agenda: 2014 scientific basis for action”	2014	Steenwerth, K.L.	Agriculture and food security	125
“How Climate smart is conservation agriculture 2017 (CA)- Its potential to deliver on adaptation, mitigation, and productivity of smallholder farms in Southern Africa”	2017	Thierfelder, C.	Food Security	97
“Agro-ecological options for fall armyworm 2019 (spodoptera frugiperda JE Smith) management: providing low cost, small holder farmers friendly solution to an invasive pest”	2019	Harrison, R.D.	Journal of environmental management	90
“Beyond Climate-Smart Agriculture: Toward safe 2013 operating spaces for global food system”	2013	Neufeldt, H.	Agriculture and food security	83
“Challenges and adaptations of farming to climate 2015 change in north China plain”	2015	Zhang, H.-L.	Climatic change	68
“Climate change adaptation and mitigation in 2016 smallholder crop- livestock systems in sub-Saharan Africa: a call for integrated impact assessment”	2016	Descheemaeker, K.	Regional environmental change	63
“Climate-smart soil water and nutrient management 2014 options in semiarid west Africa: a review evidence and analysis of stone bunds and zai techniques”	2014	Zougmore, R.	Agriculture and food security	61
“Developing Climate-smart agriculture to face 2018 climate variability in west Africa: challenges and lessons learnt”	2018	Partey, S.T.	Journal of cleaner production	57
“Evaluating manual conservation agriculture systems 2016 in southern Africa”	2016	Thierfelder, C.	Agriculture, ecosystem, and environment	55
“Climate Smart agriculture, farm households’ 2018 typologies and food security: an ex-ante assessment from Eastern India”	2018	Lopez-Ridaura, S.	Agriculture systems	52

has 97 citations. This article focused on Conservation Agriculture (CA), and it shows that CA has a direct and positive impact on production capacity and adaptability in extreme climate change environments as it conserves the moisture in the soil.

Co-occurrence of Keywords

The co-occurrence of keywords represents the focal point of research in the subject area of Climate Smart Agriculture. The co-occurrence of keywords is useful in exploring the methodology and themes of the research study. The analysis of the keywords table shows out of 1274 keywords only 39 meet the threshold of a minimum of 7 occurrences of keywords. Three Clusters were identified from the VOSviewer software (Table 3). The keyword “climate change” is the highest occurred keyword with 69 occurrences and total link strength of 299, followed by “sustainable development” with fifty-three occurrences and 233 total link strength. Cluster one represents 18 keywords, out of which Climate Smart Agriculture has the highest with 30 occurrences and 104 link strength.

Table 3 represents different Clusters and network analyses of the co-occurrence of keywords. Cluster 1 in Red has 18 items and out of which the keyword “Climate Smart Agriculture” has 30 occurrences and has a connection with 104 keywords. This cluster also suggests Alternate Agriculture, Sustainability, smallholder, and agriculture development as they have 19, 18, 12 and 11 keyword occurrences respectively. Cluster 2 in Green has a total of 11 items, a Climate-Smart Agriculture keyword with 48 occurrences and a connection with 207 keywords. This cluster suggests sustainable development, food security, agroforestry, greenhouse gas, mitigation, and adaptive management as they have 37, 12, 11, 9 and 9 keywords occurrences respectively. Cluster 3 in Blue has 10 items, climate change has the highest 69 occurrences out of all the occurrences and as connected with 299 keywords. This cluster also suggests smart agriculture, food supply and agricultural robots as it has 25, 17 and 15 occurrences.

Author Analysis

Table 4 represents the top ten most influential authors in the field of Climate Smart Agriculture. Campbell, B.M. from Centro Internacional de Agricultura Tropical has a score of five publications which is the highest amount of publications in the field of Climate Smart Agriculture. P. Bhattacharyya, S. Pal, and H. Pathak

from ICAR India have contributed equally with four publications in this field. Most authors mentioned in the table are constantly working in the field of agriculture production and sustainable development.

Affiliation Analysis

Table 5 elucidates the details of the documents published by the notable affiliation organisation in the subject area of CSA. The data from the top 10 affiliating organisation from 2013-2022 are being retrieved. A total of 65 documents were fetched from these top 10 affiliation organisations with an average of 6.5 documents per organisation. Out of all these 10 affiliation organisations only 2 organisations have more than the average documents and the rest 8 affiliations have less than average documents. Wageningen University & Research Affiliation is the most prominent organisation in the subject field with 16 published documents and the University of Vermont is the least constant organisation in the subject area with only 4 documents.

Among all the documents, the top 10 most influential authors are selected. Campbell is the leading author from Columbia with 5 publications in the subject area of Climate Smart Agriculture and 59 h-index. Bhattacharyya, P., Pal, S. and Pathak, H. are all from ICAR organisation from India with 4 publication counts. Stringer, L.C. and Whitfield, S. are from the United Kingdom with 4 publications. Among all the 153 documents, the top 10 documents having the highest number of citations are selected. Steenwerth et al. (2014) have the highest number of citations (125). Thierfelder et al. (2017) have 97 citations and Harrison et al. (2019) have 90 citations. Among all the countries, Table 1 shows top 10 most influencing countries in the field of Climate Smart Agriculture. United States of America has almost 16.9% of all the published documents in the field of CSA followed by the United Kingdom having 13.9% of all published documents and India the third highest publishing country with around 13.33% of total publications.

Top 10 affiliation organisations are portrayed which represent a total of 65 documents. Wageningen University & Research is at the top of the list with almost 24.62% of total publications in the subject area. The University of Leeds has around 12.33% of total publications followed by Centro Internacional de Agricultura Tropical. International Crops Research Institute for the Semi- Arid Tropics Mali, India is also a leading organization in the field of Smart Agriculture with 9.23% of total publications.

Table 3: Compiled cluster analysis data from Scopus database for 2013 to 30 April 2022

<i>Cluster</i>	<i>Keywords</i>	<i>Occurrences</i>	<i>Total link strength</i>
Cluster 1 (RED)	Agricultural development	11	66
	Agricultural technology	7	45
	Alternative agriculture	19	102
	Climate smart agriculture	30	104
	Crop yield	7	41
	Environmental protection	7	27
	Farming system	9	49
	Ghana	7	36
	Innovation	9	43
	Land management	8	44
	Maize	7	43
	Malawi	10	55
	Policy	7	35
	Smallholder	12	67
	Stakeholder	7	37
	Sustainability	18	81
	Sustainable intensification	8	47
	Zea mays	8	49
Cluster 2 (GREEN)	Adaptation	8	47
	Adaptive management	9	59
	Agricultural practice	7	42
	Agricultural production	9	57
	Agroforestry	12	59
	Climate-smart agriculture	48	207
	Food security	37	151
	Greenhouse gas	11	69
	Kenya	8	35
	Mitigation	9	52
Cluster 3 (BLUE)	Sustainable development	53	233
	Agricultural robots	15	69
	Agriculture	41	184
	Climate change	69	299
	Climate change adaptation	10	45
	Crops	10	43
	Cultivation	7	34
	Food supply	17	95
	Greenhouse gases	13	64
	Smart agricultures	25	124
	Sustainable agriculture	7	27

Table 4: Compiled author analysis data from Scopus database for 2013 to 30 April 2022

<i>Authors</i>	<i>Publications Count</i>	<i>h-index</i>	<i>Country</i>	<i>Affiliation</i>
Campbell, B.M.	5	59	Colombia	“Centro Internacional de Agricultura Tropical”
Bhattacharyya, P.	4	26	India	“ICAR – National Rice Research Institute”
Pal, S.	4	9	India	“ICAR – Indian Institute of Soil and Water Conservation”
Pathak, H.	4	54	India	“ICAR – National Institute of Abiotic Stress Management”
Stringer, L.C.	4	46	United Kingdom	“University of York, Department of Environment and Geography”
Whitfield, S.	4	14	United Kingdom	“University of Leeds, School of Earth and Environment, Leeds”
Zougmore, R.B.	4	28	Mali	“International Crops Research Institute for the Semi-Arid Tropics Mali”
Dougill, A.J.	3	47	United Kingdom	“University of Leeds, Sustainability Research Institute, Leeds”
Jat, M.L.	3	38	India	“International Maize and Wheat Improvement Center”
Thierfelder, C.	3	33	Zimbabwe	“International Maize and Wheat Improvement Center”

Table 5: Compiled sheet of the publication according to the leading educational institutes

<i>Affiliation</i>	<i>Documents</i>	<i>Percentage</i>
Wageningen University & Research	16	24.62
University of Leeds	8	12.30
“Centro Internacional de Agricultura Tropical”	6	9.23
“International Crops Research Institute for the Semi-Arid Tropics Mali”	6	9.23
“Food and Agriculture Organization of the United Nations”	5	7.69
“Centro Internacional de Mejoramiento de Maiz y Trigo”	5	7.69
University of the Witwatersrand, Johannesburg	5	7.69
World Agroforestry Centre	5	7.69
International Livestock Research Institute Nairobi	5	7.69
University of Vermont	4	6.17
TOTAL	65	100

Key Findings and Policy Implications

The study’s findings can help us understand how a holistic approach can help organisations appreciate, understand, and reflect on how food security, mitigation, and adaptation to climate change can be prioritised and achieved to go beyond simple managerial and technical fixes and enable triple wins for farmers and nation-states. The three main findings suggest that CSA-related training and research should give disadvantaged and disproportionately vulnerable groups local opportunities to engage and share their expertise

and perspectives. Agricultural experts and farmers need to share knowledge. CSA programs should involve farmers and incorporate their knowledge. Co-production can worsen power imbalances, thus it should be done carefully. An effective CSA solution must be based on science, utilise local expertise, and consider the social context. We encourage IGOs and INGOs to examine the social and political aspects of CSA to provide target audiences with information or services customised to their social advantages and disadvantages. Local actors, especially those disproportionately affected

by climate change, should share knowledge, tactics, and insights with international organisations. Farmers need supportive policies, institutional frameworks, and financial channels to embrace CSA techniques. CSA activities need a supportive environment, according to policy. This could include laws and regulations that promote effective water management, climate-resilient crop varieties, climate-smart livestock management, and sustainable soil management. Another policy issue is raising awareness and capacity to encourage farmers to employ CSA methods. Training and extension on CSA practices may help farmers make crop management decisions. Weather and climate information may be shared.

Conclusions

Climate-smart agriculture is practical, not theoretical. The implications of climate change on global food security are increasing. The CSA is a comprehensive framework that integrates resilience, environmental sustainability, and agricultural output to feed the world's growing population. CSA addresses climate change challenges and protects current and future generations by combining climate resilience, resource efficiency, and sustainable behaviours. CSA principles are about establishing a resilient and sustainable agricultural future, not just adapting to climate change.

In conclusion, resilience, sustainability, and innovation create climate-smart agriculture. It helps solve complex environmental issues and ensures that our farming systems thrive in difficult conditions. Hence, we encourage following the CSA principles to create a mindful, flexible, safe, resilient, and sustainable agriculture future. Due to climate change and economic sustainability, CSA research is growing rapidly worldwide. Climate-smart agriculture is maturing. Both developed and developing countries are developing CSA technologies like agriculture robots, conservation agriculture, climate information systems, and more to reduce greenhouse gases, and increase climate change adaptation, food security, and landscape management. Bibliometric analysis of significant authors, countries, and developing CSA clusters is presented in this work.

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