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Overview of the Implementation and Lessons Learnt of Climate Smart Village Approach in Sub-Saharan Africa from 2010 to 2025: A Systematic Review

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Abstract

Sub-Saharan Africa is a vulnerable region facing climate crises, leading to severe food insecurity due to its rainfed agriculture sector. The Climate Smart Village (CSV) approach, developed in 2010, aims to scale promising climate-smart agricultural technologies and innovations among rural communities and small-scale farmers who significantly contribute to the production of the food we consume worldwide. The Climate Smart Village approach has been piloted and implemented in Latin America, Southeast Asia, South Asia, East and West Africa. A comprehensive literature review using the PRISMA methodology was conducted from 2010 to 2025, focusing on the current mapping, implementation, challenges, and lessons learned in Sub-Saharan Africa. The resources included a mix of journal articles and grey literature from: 1) Scopus, 2) the Directory of Open Access Journals, 3) Google Scholar, and 4) the Consultative group data base called CG Space of the Consultative Group of International Agricultural Research Institutes databases, supplemented with a key informant's interview with relevant institutions of the AICCRA and CGIAR climate action programs and other stakeholders in Sub-Saharan Africa. Results show that 20 Climate Smart Villages have been established in Sub-Saharan Africa from 2010 to 2025. Despite low adoption rates, several climate-smart agriculture technologies and practices have improved the lives of farming communities. Climate-smart technologies, practices, and innovations should be considered in climate-related projects and innovative extension services to facilitate their wider dissemination, especially in the Central Africa Region, where these technologies are lacking. The CSV approach should be upgraded by integrating digital innovations as a 7th and last component. The concept should be renamed "DIGIT CSV". The Climate Smart Village approach is recommended for scaling up and out of climate-smart agriculture everywhere in Sub-Saharan Africa.

Keywords

Climate Smart Village, Climate Smart Agriculture, Implementation, Challenges, Lessons Learnt, DIGIT CSV, Sub-Saharan Africa

1. Introduction

Climate change is having severe consequences on the lives and livelihoods of millions of people around the world. Africa is considered one of the most vulnerable regions, given both high exposure to climate change and relatively low community resilience and governance capabilities (Busby et al., 2014). Increasing weather risks due to climate change threaten agricultural production systems and food security across the world, especially in developing countries. Since agriculture in the developing world is predominantly rain-fed, such weather-related threats are particularly important (Aggarwal et al., 2018). Due to the disparities and anomalies present within and among countries, the rise in poverty, especially in developing nations, the depletion of the ozone layer and consequent global warming, the exhaustion of natural resources threatening certain flora and fauna, air and water pollution, and other issues, sustainable development seems to be an effort to change perceptions of the world. Thus, these unfortunate consequences of global environmental change, including those of climate change, have pushed public authorities and scientists worldwide to develop solutions that support the sustainability of production systems, including agri-food systems. This led to the development of the idea of sustainable development in 1987 with the publication of "Our Common Future", which firmly established sustainable development as a critical component of international development and has been taken into account in the report of the United Nations World Commission on Environment and Development during the 21 Agenda of the Rio de Janeiro Earth Summit in 1992 and mainstreamed in the eight (08) Millennium Development Goals (Redclift, 2005; Fehling et al., 2013; Hajian and Kashani, 2021).

Despite all these efforts, global environmental problems persist, and some are even exacerbated by climate change. These issues will be addressed in detail in a new agenda, the 17 Sustainable Development Goals (SDGs) by 2030, set by the United Nations (UN), of which Goal 13 is particularly dedicated to climate action. The Food and Agriculture Organization of the United Nations (FAO) has developed the concept of Climate-Smart Agriculture (CSA), which consists of three pillars (FAO, 2018; Taylor, 2018):

1) sustainably increasing agricultural productivity and incomes (food security);

2) adapting and building resilience to climate change (adaptation); and

3) reducing and/or removing greenhouse gas emissions (mitigation), where possible.

To operationalize this concept, the Consortium of International Agricultural Research Institutions for Development (CGIAR) and other partners, through multilateral donors, received funding to design the necessary tools needed to deploy the CSA approach in the field in 2011 all over the world. Thus, the Climate Change Agriculture and Food Security (CCAFS) program of the CGIAR initiated, with funding from the World Bank, a pilot phase of implementation and operationalization of the Climate Smart Village (CSV) concept in high-risk areas, which likely suffer most from a changing climate, in West Africa, East Africa, South Asia, Southeast Asia, and Latin America (Njogu et al., 2024).

The CSV approach has been implemented by CCAFS during two phases from 2012 to 2022 across the world (CCAFS, 2018a), where several options of climate smart agriculture practices, technologies, and innovations have been tested, and have been scaled up and out thanks to multiples partnerships with National Agricultural Research Institutes, Agricultural and Rural Extension Services, National Meteorological Institutes, Non-Governmental Organizations (NGOs), Private Sector, Producer Organizations, and other partners (Makate et al., 2019; Bayala et al., 2021; Zougmoré et al., 2021; Damba et al., 2024). Several interventions, including the CSV approach, over the period from 2012 to 2022, have been documented and have made it possible to readjust and improve some practical implementation tools on the ground, thanks to some lessons learned around the world.

However, the documentation on the evolution of the concept and lessons learned from its implementation in SSA, still remains unclear to numerous users, including policymakers and actors in charge of formulating climate resilient related projects and programs in some Sub-Saharan African (SSA) countries, particularly in Central, and Southern Africa regions, where the problem of climate change on the agricultural sector is as burning as in other regions of the developing countries.

Furthermore, the mainstreaming of the CSV approach in SSA in research and development projects is gaining momentum at the moment. In West and Central Africa, for example, the CSV approach has been recently extended to six countries, namely Benin, Burkina Faso, Mali, Niger, and Chad through technical assistance of Alliance of Bioversity and International Centre for Tropical Agriculture (CIAT) to West and Central Africa Council for Agricultural Research and Development (CORAF)'s regional climate resilient projects in West and Central Africa Region, namely, "Agricultural Technologies and Innovations for Increasing the Resilience of Production Systems and Family Farms in West and Central Africa" (TARSPro), and to "Climate Resilience Agriculture and Productivity Enhancement Project" (ProPAD) in Chad (Ogou et al., 2022; Ogou and Ouédraogo, 2023; Ogou et al., 2024a).

This study provides a comprehensive literature review of current knowledge about the implementation of the CSV approach in SSA. Topics covered in this paper include where CSVs have been set up in SSA from the year 2010 to date. How is this approach implemented, and how have implementation tools evolved to date? Who are the beneficiaries, what are the lessons learned, and what are the main challenges? To suggest future directions for improving the operationalization of the CSV approach in rural settings in SSA.

Specifically, this review aims to:

- synthesize the key components and implementation strategies of the Climate Smart Village (CSV) approach across Sub-Saharan Africa between 2010 and 2025, including technologies, practices, and institutional arrangements.
- evaluate the impacts of the CSV approach on agricultural productivity, climate resilience, and mitigation outcomes among farming communities in Sub-Saharan Africa.
- identify the major challenges and enabling factors influencing the successful implementation and scalability of Climate Smart Villages in the region.
- extract and analyse lessons learned and best practices from CSV initiatives to inform future climate-smart agriculture policies and programs in Sub-Saharan Africa, and to suggest future directions for the improvement of the climate smart village approach.

2. Review Methodology

To carry out our review on the CSV approach, we used the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) methodology (Page et al., 2021). This methodology is applied to search for appropriate and suitable documents, articles, and case studies in two languages, both French and English, during the period from 2010 to 2025, on the CSV approach in SSA, using selection and rejection criteria. This allowed us to retain the most relevant documents for our study. The resources included a mix of journal articles and grey literature for selecting publications for the review. We conduct our research from January to June 2025 through the following databases: i) Scopus, ii) the Directory of Open Access Journals (DOAJ), iii) Google Scholar, and iv) the CG Space of the Consultative Group of International Agricultural Research Institutes (CGIAR) database, supplemented with a key informant's interview with relevant institutions of the AICCRA and CGIAR climate action programs and other stakeholders in SSA. The Consultative Group data base (CG Space) is particularly important because it is the global repository of all the research outputs related to the Climate Change, Agriculture and Food Security (CCAFS) program of the CGIAR, which is the parent of the development and management of the CSV concept in the world from 2011 onwards. This has led us to limit our literature review to the period from 2010 to 2025, as the concept of CSA was developed in 2010 by the Food and Agriculture Organization of the United Nations (FAO). The search keys used in this study are: "Climate Smart Village (CSV) approach", "CSV and lessons learnt", "CSV conceptual framework", "CSV implementation", "Climate Smart Agriculture (CSA) technologies" AND "CSV" OR "Climate Smart Agriculture (CSA)" AND "practices", "Agricultural Innovations" AND "CSV", "CSV" AND "policies", "CSV" AND "Scaling out" OR "CSV" AND "Scaling up" OR "CSV" AND "climate information dissemination", "CSV" AND "Information and Communication Technologies (ICT)"; "Climate Insurance" AND "CSV", "Seed Smart" AND "CSV", "Breed smart" AND "CSV", "Weather Smart" AND "CSV," "Water Smart" AND "CSV", "Carbone Smart" AND "CSV", "Nutrient Smart" AND "CSV", "Institution Smart" AND "CSV", "Market Smart" AND "CSV", "CSV" AND "Challenges", "Knowledge Smart" AND "CSV", "Finance Smart" AND "CSV", "New thinking of CSV" OR "Artificial Intelligence (AI)" AND "CSV", "Parcs of agricultural technologies" AND "CSV". Only these keywords are considered in titles or abstracts of articles, case studies, technical reports, working papers, Policy briefs, Posters, and Info Notes Consulted. Initially, about 1077 documents were found. The inclusion and rejection criteria (documents out of SSA, documents published before the year 2010, Documents that do not contain at least "CSV OR Climate Smart Village" in the abstract or in the keywords), according to the PRISMA method, allowed us to retain 70 documents, which were finally used to conduct our review.

3. Results and Discussion

3.1. Conceptual Framework of Climate Smart Village

3.1.1. Climate Smart Village (CSV) Approach

The concept of the CSV was developed by the Climate Change, Agriculture and Food Security (CCAFS) research program initiated by the CGIAR in 2011, with effective implementation in 2012. The CSV is both a tool and an approach to scaling and disseminating the concept of CSA developed by the FAO in 2010, which aims to meet the triple-win objectives in the face of the climate change challenges that the world is facing. These objectives constitute the CSA pillars, which consist of: 1) improving the adaptation and therefore the resilience of agri-food systems and communities to climate change, 2) improving agricultural productivity and food and nutrition security, and 3), where possible, mitigating greenhouse gases (Lipper et al., 2014; FAO, 2018). The CSV approach employs Participatory Action Research to engage stakeholders in developing CSA strategies. It represents a bottom-up, participatory development opportunity that ensures smallholder farmers have the best interventions and the relevant partners to prepare themselves and their communities for a climate-secure future (Bayala et al., 2021). Key success factors include building strong partnerships, capacity strengthening, and using climate information for livelihood planning. The CSV approach is therefore a bottom-up approach to scaling up climate-smart technologies, practices, and innovations within agricultural and rural communities. It integrates technological and social factors to address the impacts of climate change on rural communities

(Sarkar et al., 2022).

The concept of CSV is a participatory and integrated scientific approach to action-research with beneficiary communities that includes six components and seven implementation steps for its operationalization. These components and steps are presented below.

3.1.2. Key Components and Principles, and Implementation Steps of a Climate Smart Village (CSV)

Bayala et al. (2021) have proposed a conceptual framework for Climate Smart Village development compromising six (06) components (**Figure 1**). These components range from: 1) Capacity building on the CSV approach as well as CSA, 2) community management of resources, 3) designing crops, varieties, livestock systems, and biodiversity, 4) providing climate services to targeted beneficiaries, 5) weather insurance development, and 6) mitigation or carbon sequestration.

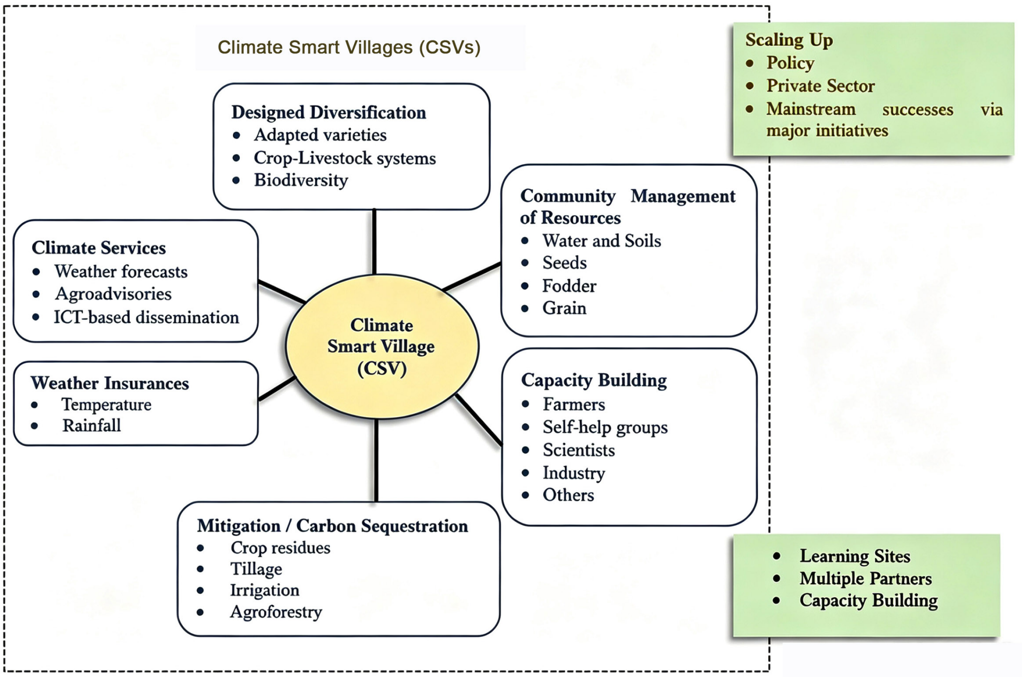

Figure 1. Conceptual framework for the Climate Smart Village (Bayala et al., 2021).

However, this initial CSV conceptual framework used during the period from 2012-2016 has been improved by the CCAFS teams and their implementation partners, learning from the lessons on the ground. The improved version of the conceptual framework of the CSV approach incorporates six key components or dimensions as previously suggested by Bayala et al. (2021), but is now well-structured. It has therefore taken, into account many relevant aspects, including weather, water, crops, nutrients, carbon/energy, and institution/knowledge smart practices (Bhattacharyya et al., 2020). **Figure 2** below illustrates the major components of a typical CSV. Climate-smart agriculture interventions are broadly to include practices, technologies, climate information services, index-based insurance, institutions, policies, and finance (Aggarwal et al., 2018; Defe & Matsa, 2024). There is no fixed package of interventions or a one-size-fits-all approach (Aggarwal et al., 2018; Ouédraogo et al., 2018; Gwagwa et al., 2020; Rosenstock et al., 2020; Zougmoré et al., 2021; Ghimire et al., 2022; Ogunyiola et al., 2022; Joshi et al., 2024). Options differ based on the CSV site, its agro-ecological characteristics, level of development, and the capacity and interest of farmers and of local government. The results of the CSV approach are usually a portfolio of CSA options, along with institutional and financial mechanisms that enable their successful adoption. Promising innovations are then available for scaling out by national/subnational governments, NGOs, and private-sector actors in regions with similar agro-ecological conditions (Ouédraogo et al., 2018; Bashiru et al., 2024).

There are 7 stages in implementing the CSV approach. Key implementation steps include building strong partnerships, strengthening stakeholders' capacity and using climate information for livelihood planning (Bayala et al., 2021).

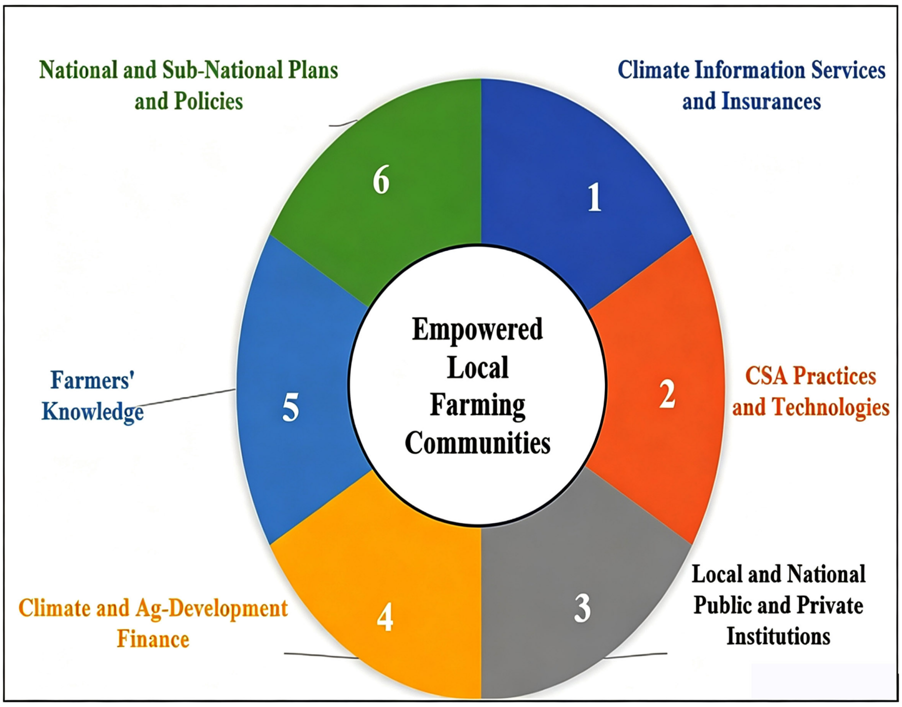

Figure 2. Key components of a CSV approach (Adesipo et al., 2020).

The approach involves participatory vulnerability analysis, adaptation capacity planning, and communication for development, focusing on local knowledge, climate information services, climate-smart technologies, and local development plans (Sanogo et al., 2020). CSV models are context-specific, with incremental implementation in five (05) steps, initially developed through technical expertise (Simelton et al., 2018; Feliciano et al., 2022) as shown in **Figure 3**. To these initial five (05) steps, two (02) additional steps have been recently added, including the selection of the CSV site in regard to climate risk profile, willingness of local community to participate, accessibility of the site, and the socio-political environment in the given area/site/country. This step precedes the baseline assessment (Bayala et al., 2021; Ogou & Ouédraogo, 2023). The second step added for the improvement of the implementation steps is the capitalization of the CSV approach (CCAFS, 2018a).

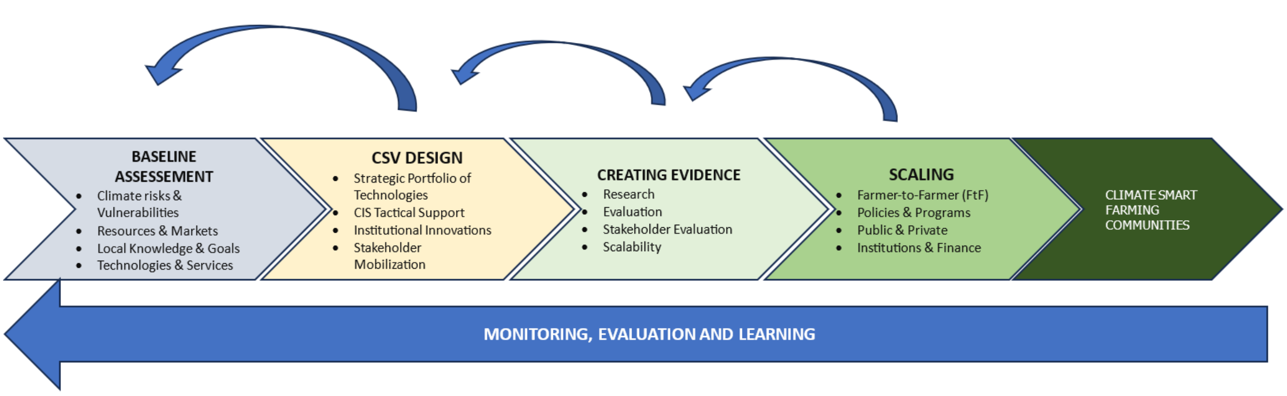

Figure 3. CSV implementation steps (Aggarwal et al., 2018).

3.2. Implementation of the Climate Smart Village (CSV) Approach in Sub-Saharan Africa

3.2.1. Mapping of Climate Smart Village (CSV) in Sub-Saharan Africa (SSA)

Climate Smart Villages (CSVs) have been established in developing countries in many regions of the world, such as Latin America, Southeast Asia, South Asia, including SSA such as East Africa, West Africa, and Central Africa, in order to test, promote, and put at scale climate-smart agriculture (CSA) innovations, practices, and technologies (Njogu et al., 2024). The goal is to improve agri-food production, increase resilience, and mitigate climate change. These CSVs were set up as part of the implementation of research and development projects financed by multilateral and bilateral donors, including the World Bank and the Suisse Development Cooperation Agency (SDC). This work was carried out in particular by the CGIAR CCAFS program. The main International Agricultural Research Institutions during the period from 2012 to 2022 were the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in West Africa and the International Livestock Research Institute (ILRI) in Central Africa. The number of CSVs set up and operationalized is twelve (12), and those set up particularly from the Alliance of Bioversity International and CIAT from the year 2022 to 2024, in collaboration with the National Agricultural Research and Extension Systems (NARES) in the West and Central Africa Region, are eight (08). The CSVs recently set up within the framework of the TARSPro and ProPAD projects are eight (08), bringing the total number of CSVs set up and operationalized in SSA to twenty

(20), including nine (09) in West Africa, seven (07) in East Africa, and four (04) in Central Africa, particularly in Chad (Table 1).

Table 1. Current mapping of Climate Smart Villages across Sub-Saharan Africa from 2010-2025.

SSA Regions	Country	CSV Sites	In-country Region	Program/Project	Period	Longitude	Latitude	References
West Africa	Benin	Worogui-Goura	Centre	TARSPro, SDC Suisse Confederation funded project/CORAF	2022-2025	2˚35'51"E	8˚53'11"N	Ogou et al. (2024b)
	Burkina Faso	Ouda	Centre-Sud	TARSPro, SDC Suisse Confederation funded project/CORAF	2022-2025	1˚9'50.04"W	12˚0'20.88"N	Ogou et al. (2024b)
		Tougou	Yatenga	CCAFS/CGIAR	2012-2022	2˚15'10"W	13˚40'47"N	CCAFS (2018a)
	Ghana	Lawra	Lawra Jirapa	CCAFS/CGIAR	2012-2022	2˚52'57.552"W	10˚38'45.232"N	CCAFS (2018a)
	Mali	Cinzana	Ségou	CCAFS/CGIAR	2012-2022	−5˚57'59.99"W	13˚14'60.00"N	CCAFS (2018a)
		Sabenebougou	Sikasso	TARSPro, SDC Suisse Confederation funded project/CORAF	2022-2025	5˚35'20"W	11˚27'9"N	Ogou et al. (2024b)
	Niger	Fakara	Kollo	CCAFS/CGIAR	2012-2022	2˚31'27"E	13˚09'49"N	CCAFS (2018a)
		Kieche	Dosso	TARSPro, SDC Suisse Confederation funded project/CORAF	2022-2025	4˚0'46"E	13˚28'51"N	Ogou et al. (2024b)
	Senegal	Daga Birame	Kaffrine	CCAFS/CGIAR	2012-2022	−15˚32'44.34"W	14˚06'19.01"N	CCAFS (2018a)
East Africa	Ethiopia	Doyogena	Southern Nations, Nationalities, and Peoples, Region/Kembata Tembaro Zone	CCAFS/CGIAR	2012-2022	39˚9'15.72"E	14˚56'52.33"N	CCAFS (2018a)
		Borona	Oromia Region	CCAFS/CGIAR	2012-2022	38˚15'0"E	5˚0'0"N	CCAFS (2018a)
	Kenya	Nyando	Nyanza Province	CCAFS/CGIAR	2012-2022	35˚06'60.00"E	0˚16'60.00"N	CCAFS (2018a)
		Wote	Makueni	CCAFS/CGIAR	2012-2022	37˚37'43.75"E	−1˚46'50.84"S	CCAFS (2018a)
	Tanzania	Lushoto	Tanga Region	CCAFS/CGIAR	2012-2022	38˚16'60"E	4˚46'60"S	CCAFS (2018a)
	Uganda	Hoima	Western Region	CCAFS/CGIAR	2012-2022	31˚21'8.68"E	1˚25'59.30"N	CCAFS (2018a)
		Rakai	Central Region	CCAFS/CGIAR	2012-2022	31˚24'59.99"E	0˚39'59.99"N	CCAFS (2018a)
Central Africa	Chad	Tambling	Wadi Fira	TARSPro, SDC Suisse Confederation funded project/CORAF	2022-2025	21˚31'85"E	14˚25'58"N	Ogou et al. (2024b)
		Amsinéné	Province du Salamat	ProPAD, a World Bank funded Project/CORAF	2023-2025	20˚28'33.33"E	11˚03'33.33"N	Allhabo et al. (2023)
		Bédogo 2	Province de Mandoul	ProPAD, a World Bank funded Project/CORAF	2023-2025	17˚28'04'4.02"E	8˚37'55.29"N	Mahamat et al. (2023)
		Maïbéssé	Province de Moyen-Chari	ProPAD, a World Bank funded Project/CORAF	2023-2025	18˚14'04'23.99"E	9˚9'36"N	Non-ndé et al. (2023)

3.2.2. Conceptualization of CSV Models

Climate Smart Villages (CSVs) have shown promising results in Sub-Saharan Africa since 2012. Its conceptualization requires collaborative work and the deployment of climate-sensitive technologies. It requires making judicious choices at the level of each of the six components across the six (06) climate smartness, which are:

1) Seeds and breeds smart technologies implemented in the CSVs across SSA.

2) Water Smart Technologies and Innovations implemented in the CSVs across SSA.

3) Nutrient and carbon-smart Technologies and Innovations implemented in the CSVs across SSA.

4) Institutions, Markets, and Finance-Smart Innovations implemented in CSVs across SSA.

5) Weather-Smart technologies and innovations implemented in CSVs across SSA.

6) Knowledge-Smart implemented in the CSVs across SSA.

An ideal CSV model should incorporate all six components during operationalization (Beal et al., 2021; CCAFS, 2018b). However, the specific realities did not allow this ideal to be met, given the results of the pilot sites in West- and East Africa and even elsewhere (Ouédraogo et al., 2018). It would be wise to focus during the very first years on the real needs and aspirations of the communities at the grassroots level to identify "the gateway" to a successful operationalization of a CSV.

Beal et al. (2021) suggest that at least three components of the six must be met to speak of a good Climate Smart Village model. These components are: 1) Weather and Climate Information Services (WCIS), 2) Climate-smart technologies, practices, and innovations, and 3) policies and plans.

In the SSA, various CSV models were implemented, each using at least three of the six components of the approach. The results for the six (06) climate smartness are presented below.

1) Seeds and breeds smart technologies implemented in the CSVs across SSA

Various CSA technologies, such as improved crop varieties, including both local and exotic drought-tolerant, and Extra-early or Short-cycle variety seeds, such as maize, sorghum, pearl millet, beans, and groundnut, have been introduced and tested in West African CSVs in Senegal, Mali, Niger, Ghana, and Burkina Faso (Ouédraogo et al., 2018; Zougmoré et al., 2018). While knowledge of seed-smart technologies among smallholder farmers is increasing, adoption rates remain low due to socioeconomic, institutional, and biophysical constraints (Ouédraogo et al., 2018; Kombat et al., 2021). Despite challenges, CSVs have shown positive impacts on crop productivity, farmers' welfare, improving food access, and income (Ogada et al., 2020a).

Breed-smart technologies, such as climate-resilient breeds, efficient milking breeds, and pests and diseases-resilient breeds, are being promoted and adopted across sub-Saharan Africa in some countries, such as Burkina Faso, Ghana, Mali, Niger, Tanzania, Ethiopia, Uganda, and Kenya, to address climate change challenges and enhance food security in the rural communities (Tran et al., 2017; Bashiru et al., 2024; Mbuvha et al., 2024; Nakalembe & Kerner, 2024). These climate-smart breeds include cattle, sheep, goats, and poultry (Ouédraogo et al., 2018; Ogada et al., 2020b; Ogisi and Begho, 2023).

To accelerate the adoption of seed or breed technologies, experts recommend building on conventional CSA practices, strengthening linkages between farmers, researchers, and extension practitioners, investors, financing institutions/micro-credits, as well as the government's subsidies, by implementing bottom-up approaches (Kombat et al., 2021; Bashiru et al., 2024).

2) Water Smart technologies and innovations implemented in the CSVs across SSA

Promising CSAs include water harvesting and small-scale irrigation techniques (Zougmoré et al., 2018). Soil and water conservation techniques such as Zaï, half-moon, and tie ridging in the CSVs in Burkina Faso, Mali, and Niger have been pointed out by Ouédraogo et al. (2018). These technologies are low-cost, affordable, and technically feasible. They are widely adopted by farmers in the Sahel region, especially Burkina Faso, Mali, and Niger (Ouédraogo et al., 2018; Zougmoré et al., 2018; Ouedraogo et al., 2022).

3) Nutrient and carbon-smart technologies and innovations implemented in the CSVs across SSA

Climate-smart agriculture (CSA) practices have shown promising results in improving soil fertility and crop productivity across sub-Saharan Africa. In East African Climate Smart Villages, CSA interventions increased soil macro- and micronutrient levels over a six-year period (Recha et al., 2022). Similarly, in West Africa, techniques such as zaï, half-moons, and stone bounds, combined with organic and inorganic nutrient sources, have proven effective in maintaining food production and securing livelihoods (Zougmoré et al., 2014; Ouédraogo et al., 2018). Other technologies such as tree planting (agroforestry), farmer-managed natural regeneration (FMNR), integrated soil fertility management techniques (micro-dosing), use of organic manure/compost, and crop association have had positive effects on soil organic, mitigation, thus the greenhouse gas emissions, improving soil fertility, and enhancing crop productivity, especially in West African CSVs (Ouédraogo et al., 2018). These practices are being promoted by various institutions, including research organizations and local entities (Bashiru et al., 2024). However, the adoption of modern smart farming technologies by smallholders remains low, with efforts primarily focused on conventional CSA practices (Bashiru et al., 2024). To scale up CSA adoption, it is crucial to understand the determinants influencing farmers' uptake of these technologies (Ouédraogo et al., 2018). Incentive measures and capacity building are needed to empower rural farmers to adopt these climate-smart techniques (Zougmoré et al., 2014).

In East Africa, CSVs have demonstrated significant soil carbon sequestration potential, with increases of 20% - 110% compared to control sites (other villages), contributing to emissions reductions through the implementation of Mulching techniques, agroforestry, alley cropping systems, and conservation agriculture (Ambaw et al., 2020). The CSVs contributed to a reduction in greenhouse gas emissions by 87 - 420 Mg CO_2 eq ha^{-1}. The annual increase in soil carbon sequestration under CSVs ranged from 1.6 to 6.2 Mg C $ha^{-1}\cdot yr^{-1}$, with forests sequestering the most carbon in Lushoto (Tanzania), Hoima (Uganda), Wote and Nyando (Kenya), leading to an improvement of soil quality and health (Ambaw et al., 2020; Recha et al., 2022).

In West Africa's CSVs, Zougmoré et al. (2018) highlighted the potential of carbon sequestration due to the adoption of carbon-smart technologies such as Agroforestry, Mulching techniques, cover crops and crops residues in Burkina Faso, Mali, Niger, and Senegal, even though there are very few studies done to assess the impact of the climate smart technologies on soil carbon stocks in the CSVs in West Africa intervention sites.

4) Institutions, Markets and Finance-Smart innovations implemented in CSVs across SSA

The development of regional, sub-regional, and national climate change policies aims to mainstream CSA into agricultural development plans and policies (Zougmoré et al., 2016). It includes capacity building of actors at all levels, including regional, national, and local levels, taking into consideration gender issues while integrating women and men in a balanced manner (Totin et al., 2018; Marty et al., 2024; Segnon et al., 2024). The establishment of national science-policy dialogue platforms at the national level, as well as sub-national or local platforms in the areas of intervention of the CSVs, enables national actors to all issues related to the climate and food insecurity crises. It allows for both mainstreaming and scaling of climate-smart technologies adapted to each geographical area, taking into account the real needs and aspirations of grassroots communities (Dinesh et al., 2018; Marty et al., 2024).

However, challenges remain in raising awareness and implementing CSA practices. A study in South Africa found that many stakeholders lacked knowledge of CSA policies and practices, highlighting the need for targeted education and awareness initiatives (Kubanza and Oladele, 2024). To scale up CSA adoption, it is crucial to understand the determinants of adoption and address obstacles through enabling policies, institutional commitments by local authorities, and improved information dissemination (Ouédraogo et al., 2018; Zougmoré et al., 2018; Kubanza & Oladele, 2024). By taking into consideration all these enabling environments as well as socio-political issues in sub-Saharan Africa, it would be possible in the future to leverage the Climate-Smart Village (CSV) approach to implement the Integrated Land Management (ILM) and therefore assure a climate-smart landscape instead of limiting the scope to climate-smart agriculture only (Ganyo et al., 2024).

Financial commitments from governments and development agencies are crucial for improving large-scale adoption of CSA technologies in Sub-Saharan Africa through the CSVs set up by CCAFS (Wattel et al., 2018; Zougmoré et al., 2018). The adoption of CSA practices is influenced by resource mobilization and capacity-building in financial services and products to communities, especially farmers (Makate et al., 2019). Various CSA technologies, including improved crop varieties, soil and water conservation techniques, and agroforestry, have been tested thanks to the microfinance financing mechanisms for the farmers in the CSVs in Burkina Faso and Mali (Ouédraogo et al., 2018). Also, some insurance schemes have been tested and shown promising results, indicating that climatic and weather-based index insurance schemes can scale up in the future (Müller et al., 2020; Ouedraogo et al., 2023). However, the adoption of modern smart farming technologies remains low among smallholders in SSA, with efforts primarily focused on sustaining conventional CSA practices (Bashiru et al., 2024). To improve the adoption and scaling of CSA innovations, it is essential to engage local communities and their indigenous institutions with innovative financing mechanisms (Makate et al., 2019).

Farmers in the CSV are encouraged to join local savings and credit groups that can facilitate the adoption of CSA practices. Improved livestock breeders in Uganda have, for instance, formed a savings group to support the development of climate-smart livestock value chains, through the CSV. The availability of credit helped make the diffusion of improved livestock more equitable within CSV than in non-CSV areas (Ogada et al., 2020b). It also increased the membership in savings and credit groups, which in turn increased the adoption of improved livestock breeds. These findings point to the importance of community-based savings and loan initiatives in mobilising finance among farmers, enabling them to invest in CSA practices. Ogada et al. (2020b) have shown in Lushoto CSV in Tanzania (Est Africa) that the introduction of improved breeds in CSVs, thanks to the Village Savings and Loan Association (VSLA), has benefited especially the larger livestock owners by reducing the poverty levels with a reduced Gini index of 0.04. However, the availability of microcredits is found to have mitigated the concentration of improved livestock ownership since the diffusion of improved livestock in CSVs in Uganda, Ethiopia, Kenya, and Tanzania was somewhat more equitable than the (spontaneous) spill-over diffusion in the non-CSVs (Ogada et al., 2020b; Ogisi and Begho, 2023).

5) Weather-Smart technologies and innovations implemented in CSVs across SSA

A participatory action research (PAR) approach was used to develop and test CSA options in SSA, with the use of climate information services (CIS) becoming a key component in guiding farmers' decisions, and capacity building of various stakeholders being a key component to improve understanding and use of climate data and evidence-based decision-making (Ouedraogo et al., 2022). Information and Communication Technologies (ICTs) play a crucial role in adapting to climate change risks in agriculture. ICTs offer potential for recording, transforming, and disseminating information, strengthening adaptability through remote sensing tools, data visualization, machine learning analysis, and seasonal climate forecasting (Zella et al., 2023). These innovations are essential for sustainable agriculture and food security in the face of climate change.

Climate information dissemination channels in Climate Smart Villages across sub-Saharan Africa have been implemented to reach farmers and rural communities. Mobile phones, particularly SMS and voice services, are widely used to communicate weather information to smallholder farmers (Yegbemey and Egah, 2021). Other channels include radio, newsletters, and interactive voice response systems (Oladele et al., 2025), and the Participatory Integrated Climate Services for Agriculture (PICSA) approach for CIS dissemination to targeted farmers (Dayamba et al., 2018), as well as Digital AgroClimatic Advisory applications (DACA) (Kagabo et al., 2024a; Kagabo et al., 2024b).

However, the effectiveness of these channels depends on factors such as language, reliability, farmers' literacy, and trust in information providers (Yegbemey and Egah, 2021; Ouedraogo et al., 2022). Multi-actor partnerships involving research institutions, meteorological services, and NGOs have been crucial in co-designing and implementing climate-smart agriculture strategies (Ouédraogo et al., 2018; Bayala et al., 2021; Djido et al., 2021; Ky-Dembele et al., 2021; Damba et al., 2024; Nyoni et al., 2024; Appiah et al., 2025).

Despite these efforts, access to agro-weather information remains low among small-scale farmers, with limited outreach and utilization reported in some areas (Wamalwa et al., 2016). Improving timely access through effective channels like vernacular rural radios and enhanced extension services is recommended to increase adoption of climate-smart practices (Wamalwa et al., 2016; Agyekum et al., 2022; Twahirwa, 2023).

6) Knowledge-Smart innovations implemented in the CSVs across SSA

The success of CSA adoption relies on incorporating indigenous knowledge and local institutions, which improve information dissemination, resource mobilization, and stakeholder networking (Makate et al., 2019; Sarkar et al., 2022). To scale up CSA technologies, it is crucial to understand adoption determinants and address barriers. Farmers use endogenous knowledge based on their experiences to predict the start of seasons, likely periods of the first rains, and the crops to be planted (Ouédraogo et al., 2018). This endogenous knowledge sometimes includes cultural and religious aspects often attributed to black deities in West Africa (Ouedraogo et al., 2022). Some communities often resort to endogenous relative knowledge based on the certain elements of nature or the environment. Some farmers use the species of plants and animals as indicators, the moon, the sun, the wind, etc. Traditional endogenous forms of organization are involved, for example, in disseminating climate information to the village community. In the CSV of Ouda in Burkina Faso, for example, Sodré et al. (2024) relied on churches, mosques, women's and men's groups, as well as the town crier of the traditional chiefdom, to convey agro-climatic advisory services to the farmers of Ouda in the south-central part of Burkina Faso.

3.3. Challenges Faced and Lessons Learnt from the CSV Approach in SSA

Climate-smart agriculture (CSA) is seen as a potential solution to address food insecurity and climate change challenges in sub-Saharan Africa (Kaptymer et al., 2019; Wakweya, 2023). However, its implementation faces numerous obstacles. These include lack of practical understanding, inadequate policies, limited financial resources, and insufficient knowledge among smallholder farmers (Kaptymer et al., 2019; Wakweya, 2023). The adoption of CSA practices is influenced by factors such as age, farm size, and access to extension services (Dey and Mishra, 2022). Many climate adaptation projects have failed due to a focus on technology transfer without considering local farming circumstances (Abegunde et al., 2019). Upscaling CSA requires addressing social, institutional, environmental, and economic barriers (Suleman, 2017). To overcome these challenges, there is a need for improved policy coordination, strengthened institutions, and better linkages between farmers, researchers, and extension practitioners (Kaptymer et al., 2019; Wakweya, 2023).

Key success factors include building strong partnerships, strengthening capacity, and utilizing climate information for livelihood planning (Bayala et al., 2021). CSA can drive rapid food system transformation through implementing climate-resilient technologies, developing weather and climate information services, minimizing resource waste, and realigning policies and finance (Zougmoré et al., 2021). In West Africa, various CSA practices have been tested in CSVs, including improved crop varieties, soil and water conservation techniques, agroforestry, and integrated soil fertility management (Ouédraogo et al., 2018). However, adoption of these innovations and technologies is influenced by socioeconomic, institutional, infrastructural, biophysical, and political factors, highlighting the need to understand determinants of adoption for effective scaling (Ouédraogo et al., 2018).

From our review, we can highlight some lessons that can help decision makers, policymakers, researchers, the private sector, and farmer organizations to advocate for taking the CSV approach into the development of climate-smart agriculture-related projects in SSA countries:

- The CSV approach has high potential for scaling out promising climate-smart agricultural technologies, practices, and services.
- Three major principles of the CSV Vision have been defined and include: 1) participatory action research (PAR) and tailoring the intervention to site-specific and context-specific enabling conditions; 2) focusing on generating greater evidence with the rural communities on CSA effectiveness; and iii) facilitating the co-development of scaling mechanisms at national and subnational levels.

- The CSVs theory of change integrates complementary bottom-up and top-down approaches, guided by science (CCAFS, 2018b).
- The implementation of the CSV approach can contribute to transforming food systems in SSA by implementing climate-smart technologies and practices to reroute farming and livelihoods to climate-resilient and low-emission trajectories among small-scale farmers and rural communities in SSA (CCAFS, 2018b). CSA can support the de-risking of livelihoods, farms, and climate-smart value chains through the development and application of weather and climate information services. CSA can minimize waste and mitigate the carbon footprint of food systems by using climate-smart options for growing, processing, packaging, transporting, and marketing food, realigning policies and finance to facilitate action in SSA countries.
- Various climate-smart agriculture (CSA) technologies and practices tested in the Climate Smart Villages (CSVs) across SSA have shown a positive impact on life and livelihoods of rural communities, even though the adoption rate is very low due to some socioeconomic, institutional, infrastructural, biophysical, and political factors in SSA (CCAFS, 2018b; Cramer et al., 2018).

Ogou et al. (2024b) recommended that a CSV can be set up in a period of two (02) to three (03) years at least and could be funded by each local African state budget line. But to do so, it needs a real, actionable commitment and willingness of national and local governments and stakeholders.

3.4. Study Limitations, Gaps and Future Directions

The in-depth analysis of the concept of the Climate-Smart Village that emerged in our systematic review here has made it possible to identify several limitations both of the conceptual framework and of its operationalization on the ground in SSA. Certainly, the operationalization of the field approach in the 20 CSVs in SSA has been successful with tangible results. However, several aspects did not make it possible to identify the numerical results in each of the 20 CSVs in SSA given the fact that no monitoring and evaluation system specific to the concept of CSV has been developed and is still not available to date. Although Ogou et al. (2024b) suggested during the workshops with the national implementation teams of the CSV approach in the context of the implementation of the TARSPro project between 2022 and 2024, in Benin, Burkina Faso, Niger, Mali and Chad the design of a monitoring and evaluation system specific to the CSV concept at the strategic level and a monitoring and evaluation plan with predefined operational indicators, nothing has yet been done about it, to date. At the level of CSVs, several aspects related to digitalization are poorly operationalized. This finding has been reported by Kagabo et al. (2024b). Although the ESSOKO business model in Ghana, for example, has been successful in terms of providing climate information to agrosylvopastoral and fisheries producers in CSVs in Ghana, it has not been successful at all for all CSVs in SSAs. Knowing the reasons behind this low uptake of business models on climate information services and agricultural producers' willingness to pay has been the subject of research in West Africa by Ouedraogo et al. (2025) who noted the persistence of a number of producers' reluctance to agree to pay for climate information services. In fact, bundled climate information services in the form of input packages at the beginning of the agricultural season and facilitating access to micro-credits for small producers could facilitate the adoption of technologies in CSVs and their scaling out in other neighbouring villages. In the future, therefore, it would be appropriate to:

1) Design and implement a monitoring and evaluation system specific to the CSV concept. This will have to be done in a participatory manner between the scientists and specialized researchers of the CGIAR International Center for Tropical Agriculture (CIAT), which is the designer of the approach in collaboration with the national agricultural research and extension institutes.

2) Test the CSV monitoring and evaluation system in the field in the coming years while integrating the post-project impact assessment.

3) Test research on the different business models of bundled climate information services in the field in the CSVs to come up with the most technically feasible and socially justified models taking into account the specific realities of each CSV. This would allow for good post-project scaling of business models.

4) Fully integrate digitalization tools and new climate-smart information and communication technologies and digital farming tools as new and last component (7th component) of the CSV approach. This could significantly improve the concept of CSV and transition to what we refer to here as the "Digital Climate Smart Village" or "DIGIT CSV". This new concept could be an attractive channel for young people of this new generation to get involved in agriculture. This approach, which we call "DIGIT CSV", should therefore be tested in the future at pilot sites in certain countries.

4. Conclusion

This paper analyses and provides insights into the Climate Smart Village approach in Sub-Saharan Africa during the period 2010 to 2025. Results show that twenty (20) CSVs have been successfully implemented in SSA, of which nine (09) are in West Africa, seven (07) are in East Africa, and four (04) are in the Central Africa Region (Only in Chad). This illustrates different examples of the CSV approach in diverse agro-ecological settings in SSA. Key barriers and opportunities for further work are also discussed. The challenges faced and lessons learned at the CSV sites during the implementation period from 2010 to 2025 would be relevant to adaptation planning in a large number of countries, particularly in the Central Africa Region, where the concept is very new. The CSV approach has shown positive impacts on farmers' welfare, enhancing adaptive capacity and improving food access, asset holding, and income. However, evidence for CSA effectiveness remains geographically and topically clustered, highlighting the need for more comprehensive research to support CSV projects and programs that scale CSA in

SSA. Overall, the CSV concept shows promise for promoting CSA adoption and addressing climate change challenges among small-scale farming systems in SSA. The scaling up and scaling out of context-specific and site-specific climate-smart technologies, practices, and innovations, as well as tailored weather and climate information services throughout the CSVs approach, enhanced the adaptive capacity and resilience of smallholder farmers and rural communities. It improves the welfare of farmers by increasing their access to food varieties, improving their asset holdings, and increasing their income. Minimising climate-related risks and shocks through the CSV approach is crucial to building resilient food production systems and achieving the sustainable development goals (SDGs) in vulnerable SSA countries. It ensures that the CSV approach is aligned with local knowledge and can therefore be mainstreamed into climate-sensitive national policies, plans, programs, and projects in each SSA country in the coming decade, 2025-2035.

Authors' Contributions

Anani Ogou: Designed the study, performed the methodology, conducted the review, wrote the original draft of the manuscript, reviewed and finalized the manuscript. Christopher Mubeteneh Tankou: Supervised the study, performed the methodology, conducted the review, and edited the manuscript. Honoré Beyegue-Djonko: Performed the methodology, and edited the manuscript. Asafor Henry Chotangui: edited the manuscript. Eric Bertrand Kouam: edited the manuscript. Komi Agboka: Performed the methodology, and edited the manuscript. Komi Kouma Mokpokpo Fiaboe: Supervised, and edited the manuscript. Peter Läderach: Supervised, performed the methodology, and edited the manuscript. All the authors checked and approved the final manuscript for the final publication.

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Conflicts of Interest

The authors affirm that they have no known financial or interpersonal conflicts that would have impacted the research presented in this study.

References

Abegunde, V. O., Sibanda, M., & Obi, A. (2019). The Dynamics of Climate Change Adaptation in Sub-Saharan Africa: A Review of Climate-Smart Agriculture among Small-Scale Farmers. *Climate, 7,* Article 132. https://doi.org/10.3390/cli7110132

Adesipo, A., Fadeyi, O., Kuca, K., Krejcar, O., Maresova, P., Selamat, A. et al. (2020). Smart and Climate-Smart Agricultural Trends as Core Aspects of Smart Village Functions. *Sen-*

sors, 20, Article 5977. https://doi.org/10.3390/s20215977

Aggarwal, P. K., Jarvis, A., Campbell, B. M., Zougmoré, R. B., Khatri-Chhetri, A., Vermeulen, S. J. et al. (2018). The Climate-Smart Village Approach: Framework of an Integrative Strategy for Scaling up Adaptation Options in Agriculture. *Ecology and Society, 23,* Article 14. https://doi.org/10.5751/es-09844-230114

Agyekum, T. P., Antwi-Agyei, P., & Dougill, A. J. (2022). The Contribution of Weather Forecast Information to Agriculture, Water, and Energy Sectors in East and West Africa: A Systematic Review. *Frontiers in Environmental Science, 10,* Article 935696. https://doi.org/10.3389/fenvs.2022.935696

Allhabo, A., Mahamat, N. Z., Hachim, Y., Mahamat, A., Wadi, E., Ogou, A., Ouédraogo, M., & Laderach, P. (2023). *Etude de base communautaire pour la mise en place de village intelligent face au climat à Amsinéné, Province de Salamat au TCHAD* (p. 32). Rapport De Site. https://cgspace.cgiar.org/server/api/core/bitstreams/f0163c77-f8d2-4961-ae32-85b1d0c14dca/content

Ambaw, G., Recha, J. W., Nigussie, A., Solomon, D., & Radeny, M. (2020). Soil Carbon Sequestration Potential of Climate-Smart Villages in East African Countries. *Climate, 8,* Article 124. https://doi.org/10.3390/cli8110124

Appiah, C. E., Quarmine, W., Osei-Amponsah, C., Okem, A. E., & Sarpong, D. B. (2025). Improving Smallholder Farmers' Access to and Utilization of Climate Information Services in Sub-Saharan Africa through Social Networks: A Systematic Review. *Climate Services, 37,* Article ID: 100528. https://doi.org/10.1016/j.cliser.2024.100528

Bashiru, M., Ouedraogo, M., Ouedraogo, A., & Läderach, P. (2024). Smart Farming Technologies for Sustainable Agriculture: A Review of the Promotion and Adoption Strategies by Smallholders in Sub-Saharan Africa. *Sustainability, 16,* Article 4817. https://doi.org/10.3390/su16114817

Bayala, J., Ky-Dembele, C., Dayamba, S. D., Somda, J., Ouédraogo, M., Diakite, A. et al. (2021). Multi-Actors' Co-Implementation of Climate-Smart Village Approach in West Africa: Achievements and Lessons Learnt. *Frontiers in Sustainable Food Systems, 5,* Article 637007. https://doi.org/10.3389/fsufs.2021.637007

Beal, C., Bernardo, E., Castellanos, A. E., Martinez, J. D., Ouedraogo, M., Recha, J. W., & Bonilla-Findji, O. (2021). *CCAFS Outcome Synthesis Report: Outcomes Achieved Within the Context of Climate-Smart Village Approach.* https://cgspace.cgiar.org/items/3aff23c6-a4de-4c2c-92a2-3a6c88f5da33

Bhattacharyya, P., Pathak, H., & Pal, S. (2020). Mainstreaming of Climate-Smart Agriculture. In P. Bhattacharyya, H. Pathak, & S. Pal (Eds.), *Climate Smart Agriculture* (pp. 169-188). Springer. https://doi.org/10.1007/978-981-15-9132-7_11

Busby, J. W., Smith, T. G., & Krishnan, N. (2014). Climate Security Vulnerability in Africa Mapping 3.0. *Political Geography, 43,* 51-67. https://doi.org/10.1016/j.polgeo.2014.10.005

CCAFS (2018a). *Climate-Smart Villages.* https://ccafs.cgiar.org/climate-smart-villages

CCAFS (2018b). *Climate-Smart Village AR4D Approach: Synthesis of Lessons Learned.* CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). https://ccafs.cgiar.org/es/node/113789

Cramer, L., Thornton, P. K., Dinesh, D., Jat, M. L., Khatri-Chhetri, A., Läderach, P., & Veeger, M. (2018). *Lessons on Bridging the Science-Policy Divide for Climate Change Action in Developing Countries.* Consultative Group on International Agricultural Research. https://cgspace.cgiar.org/items/d3ef221b-e1df-4540-8a98-bcf0fce3f87a

Damba, O. T., Ageyo, C. O., Kizito, F., Mponela, P., Yeboah, S., Clottey, V. A. et al. (2024). Constructing A Climate-Smart Readiness Index for Smallholder Farmers: The Case of Prioritized Bundles of Climate Information Services and Climate Smart Agriculture in Ghana. *Climate Services, 34,* Article ID: 100453. https://doi.org/10.1016/j.cliser.2024.100453

Dayamba, D. S., Ky-Dembele, C., Bayala, J., Dorward, P., Clarkson, G., Sanogo, D. et al. (2018). Assessment of the Use of Participatory Integrated Climate Services for Agriculture (PICSA) Approach by Farmers to Manage Climate Risk in Mali and Senegal. *Climate Services, 12,* 27-35. https://doi.org/10.1016/j.cliser.2018.07.003

Defe, R., & Matsa, M. M. (2024). Building Community Resilience to Enhance the Development of Climate Smart Villages in Developing Countries of Southern Africa. *SSRN Electronic Journal.* https://doi.org/10.2139/ssrn.4983860

Dey, K., & Mishra, P. K. (2022). Mainstreaming Blended Finance in Climate-Smart Agriculture: Complementarity, Modality, and Proximity. *Journal of Rural Studies, 92,* 342-353. https://doi.org/10.1016/j.jrurstud.2022.04.011

Dinesh, D., Zougmore, R., Vervoort, J., Totin, E., Thornton, P., Solomon, D. et al. (2018). Facilitating Change for Climate-Smart Agriculture through Science-Policy Engagement. *Sustainability, 10,* Article 2616. https://doi.org/10.3390/su10082616

Djido, A., Zougmoré, R. B., Houessionon, P., Ouédraogo, M., Ouédraogo, I., & Diouf, N. S. (2021). To What Extent Do Weather and Climate Information Services Drive the Adoption of Climate-Smart Agriculture Practices in Ghana? *Climate Risk Management, 32,* Article ID: 100309. https://doi.org/10.1016/j.crm.2021.100309

FAO (2018). *Upscaling Climate Smart Agriculture. Lessons for Extension and Advisory Services. Occasional Papers on Innovation in Family Farming.* Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/handle/20.500.14283/i9209en https://openknowledge.fao.org/items/07ca0c8e-1e05-44f0-8c2c-cd4861a1072a

Fehling, M., Nelson, B. D., & Venkatapuram, S. (2013). Limitations of the Millennium Development Goals: A Literature Review. *Global Public Health, 8,* 1109-1122. https://doi.org/10.1080/17441692.2013.845676

Feliciano, D., Recha, J., Ambaw, G., MacSween, K., Solomon, D., & Wollenberg, E. (2022). Assessment of Agricultural Emissions, Climate Change Mitigation and Adaptation Practices in Ethiopia. *Climate Policy, 22,* 427-444. https://doi.org/10.1080/14693062.2022.2028597

Ganyo, K. K., Kpadonou, G. E., Segnon, A. C., Ouédraogo, H., Tall, B., Lamien, N., & Zougmore, R. B. (2024). *Leveraging the Climate-Smart Village (CSV) Approach to Implement the Integrated Land Management (ILM) Concept in FSRP Countries.* https://cgspace.cgiar.org/items/24670c72-f57b-42ce-bcc8-4697280e034a

Ghimire, R., Khatri-Chhetri, A., & Chhetri, N. (2022). Institutional Innovations for Climate Smart Agriculture: Assessment of Climate-Smart Village Approach in Nepal. *Frontiers in Sustainable Food Systems, 6,* Article 734319. https://doi.org/10.3389/fsufs.2022.734319

Gwagwa, A., Kraemer-Mbula, E., Rizk, N., Rutenberg, I., & De Beer, J. (2020). Artificial Intelligence (AI) Deployments in Africa: Benefits, Challenges and Policy Dimensions. *The African Journal of Information and Communication (AJIC), No. 26,* 1-28. https://doi.org/10.23962/10539/30361

Hajian, M., & Kashani, S. J. (2021). Evolution of the Concept of Sustainability. from Brundtland Report to Sustainable Development Goals. In C. M. Hussain, & J. F. Velasco-Muñoz (Eds.), *Sustainable Resource Management* (pp. 1-24). Elsevier. https://doi.org/10.1016/b978-0-12-824342-8.00018-3

Joshi, S., Sharma, M., Luthra, S., Garza-Reyes, J. A., & Anbanandam, R. (2024). An Assessment Framework to Evaluate the Critical Success Factors to Quality 4.0 Transition in Developing Countries: A Case Experience of Sustainable Performance of Indian Manufacturers. *The TQM Journal, 36,* 1756-1793. https://doi.org/10.1108/tqm-10-2023-0311

Kagabo, D. M., Mvuyibwami, P., Byandaga, L., Nasson, N., & Manjari, S (2024a). *Innovative Digital AgroClimate Solutions for Effective Agricultural Risk Management.* https://cgspace.cgiar.org/server/api/core/bitstreams/6afdf219-71d7-4bf4-962b-ceee9d4988ce/content

Kagabo, D. M., Byandaga, L., Gatsinzi, P., Mvuyibwami, P., Munyangeri, Y. U., Ntwari, N. et al. (2024b). Scaling Climate Information Services and Climate Smart Agriculture through Bundled Business Models. *Climate Services, 37,* Article ID: 100526. https://doi.org/10.1016/j.cliser.2024.100526

Kaptymer, B. L., Abdulkerim Ute, J., & Negeso Hule, M. (2019). Climate Smart Agriculture and Its Implementation Challenges in Africa. *Current Journal of Applied Science and Technology, 38,* 1-13. https://doi.org/10.9734/cjast/2019/v38i430371

Kombat, R., Sarfatti, P., & Fatunbi, O. A. (2021). A Review of Climate-Smart Agriculture Technology Adoption by Farming Households in Sub-Saharan Africa. *Sustainability, 13,* Article 12130. https://doi.org/10.3390/su132112130

Kubanza, N. S., & Oladele, O. J. (2024). Climate Smart Agricultural Policy in Sub-Saharan Africa: A Case Study of Ngaka Modiri Molema District Municipality of North West Province, South Africa. *Local Environment, 29,* 1579-1593. https://doi.org/10.1080/13549839.2024.2390467

Ky-Dembele, C., Dorward, P., Clarkson, G., & Bayala, J. (2021). *Manuel de formation pour une utilisation efficace des informations et services climatiques au Sahel.* https://www.cifor-icraf.org/publications/pdf/manuals/REELS-Manual-04.pdf

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M. et al. (2014). Climate-Smart Agriculture for Food Security. *Nature Climate Change, 4,* 1068-1072. https://doi.org/10.1038/nclimate2437

Mahamat, A. Y., Mahamat, N. Z., Ache Billah, K. A., Ngue'ndoyoum, G., Baimi, T., Ogou, A., Ouédraogo, M., & Laderach, P. (2023). *Etude de base communautaire pour la mise en place de village intelligent face au climat à Bédogo 2, Province de Mandoul au TCHAD* (p. 35). https://cgspace.cgiar.org/server/api/core/bitstreams/2c6ec5e8-a41c-4f62-a949-055abe1f36c0/content

Makate, C., Makate, M., Mutenje, M., Mango, N., & Siziba, S. (2019). Synergistic Impacts of Agricultural Credit and Extension on Adoption of Climate-Smart Agricultural Technologies in Southern Africa. *Environmental Development, 32,* Article ID: 100458. https://doi.org/10.1016/j.envdev.2019.100458

Marty, E., Segnon, A. C., Tui, S. H., Trautman, S., Huyer, S., Cramer, L. et al. (2024). Enabling Gender and Social Inclusion in Climate and Agriculture Policy and Planning through Foresight Processes: Assessing Challenges and Leverage Points. *Climate Policy, 24,* 1034-1049. https://doi.org/10.1080/14693062.2023.2268042

Mbuvha, R., Yaakoubi, Y., Bagiliko, J., Hincapie Potes, S., Nammouchi, A., & Sabrina Amrouche, S. (2024). Leveraging AI for Climate Resilience in Africa: Challenges, Opportunities, and the Need for Collaboration. *SSRN Electronic Journal.*

https://doi.org/10.2139/ssrn.4815919

Müller, M., Dembélé, S., Zougmoré, R., Gaiser, T., & Partey, S. (2020). Performance of Three Sorghum Cultivars under Excessive Rainfall and Waterlogged Conditions in the Sudano-Sahelian Zone of West Africa: A Case Study at the Climate-Smart Village of Cinzana in Mali. *Water, 12,* Article 2655. https://doi.org/10.3390/w12102655

Nakalembe, C. L., & Kerner, H. R. (2024). Applications and Considerations for AI-EO for Agriculture in Sub-Saharan Africa. In *AIJR Proceedings* (pp. 3-14). AIJR Publisher. https://doi.org/10.21467/proceedings.157.1

Njogu, J. W., Karuku, G., Busienei, J., & Gathiaka, J. K. (2024). Assessing Determinants of Scaling up Pathways for Adopted CSA Climate Smart Agricultural Practices: Evidence from Climate Smart Villages in Nyando Basin, Kenya. *Cogent Food & Agriculture, 10,* Article ID: 2316362. https://doi.org/10.1080/23311932.2024.2316362

Non-ndé, D. I., Mahamat, N. Z., Abdelaziz, B., Ndjelassem, N., Mbaigolem, J. C., Moyan, F., Allahtaroum, S., Djogo, B. S., Ogou, A., Ouédraogo, M., & Laderach, P. (2023). *Etude de base communautaire pour la mise en place de village intelligent face au climat à Maïbéssé, Province de Moyen-Chari au TCHAD. Rapport De Site* (p. 37). https://cgspace.cgiar.org/server/api/core/bitstreams/c5615776-7a08-448b-9b2a-fc4880fcecf6/content

Nyoni, R. S., Bruelle, G., Chikowo, R., & Andrieu, N. (2024). Targeting Smallholder Farmers for Climate Information Services Adoption in Africa: A Systematic Literature Review. *Climate Services, 34,* Article ID: 100450. https://doi.org/10.1016/j.cliser.2024.100450

Ogada, M. J., Radeny, M., Recha, J., & Solomon, D. (2020a). *Adoption of Climate-Smart Agricultural Technologies in Lushoto Climate-Smart Villages in North-Eastern Tanzania.* CCAFS Work Paper. https://cgspace.cgiar.org/items/dbdfb814-c642-4268-8b90-5b7d3eb228a8

Ogada, M. J., Rao, E. J. O., Radeny, M., Recha, J. W., & Solomon, D. (2020b). Climate-Smart Agriculture, Household Income and Asset Accumulation among Smallholder Farmers in the Nyando Basin of Kenya. *World Development Perspectives, 18,* Article ID: 100203. https://doi.org/10.1016/j.wdp.2020.100203

Ogisi, O. D., & Begho, T. (2023). Adoption of Climate-Smart Agricultural Practices in Sub-Saharan Africa: A Review of the Progress, Barriers, Gender Differences and Recommendations. *Farming System, 1,* Article ID: 100019. https://doi.org/10.1016/j.farsys.2023.100019

Ogou, A., & Ouédraogo, M. (2023). *Atelier de formation de la coordination du projet ProPAD et ses partenaires au Tchad sur la mise en place de villages intelligents face au Climat (VIC).* https://cgspace.cgiar.org/server/api/core/bitstreams/6b0b4af9-e051-45e6-898f-d4151886a606/content

Ogou, A., Siagbe, G., & Ouédraogo, M. (2022). *Atelier de lancement du projet AT-TARSPro et formation des équipes pays sur l'Agriculture Intelligente face au Climat (AIC).* https://cgspace.cgiar.org/items/6a38a64b-5050-4a36-ba85-a18d266df6ba

Ogou, A., Kagabo, D., Ouédraogo, M., Sogbui, C. M., & Laderach, P. (2024a). *Technical Assistance of the Alliance of Bioversity International and International Centre for Tropical Agriculture (CIAT) to Agricultural Productivity & Climate Resilience Enhancement Project in Tchad (TA-ProPAD): Achievements and Lessons Learnt.* https://cgspace.cgiar.org/items/f283f4e9-a6c4-42c9-901a-e69b5aa3f1e8

Ogou, A., Singh, M., Kagabo, D. M., Ouédraogo, M., & Laderach, P. (2024b). *Modelling*

Climate Analogues of Climate Smart Village Sites in West and Central Africa: Case Study from Benin, Burkina Faso, Mali, Niger, and Tchad (p. 1). https://cgspace.cgiar.org/items/f617231e-ccce-4590-8f00-b624db5af6f8

Ogunyiola, A., Gardezi, M., & Vij, S. (2022). Smallholder Farmers' Engagement with Climate Smart Agriculture in Africa: Role of Local Knowledge and Upscaling. *Climate Policy, 22,* 411-426. https://doi.org/10.1080/14693062.2021.2023451

Oladele, O., Yakubu, D., & Oladele, O. (2025). Determinants of the Joint Adoption of Climate-Smart Agriculture Practices by Agro-Pastoralists in Sokoto State, Nigeria. *Zeszyty Naukowe SGGW w Warszawie—Problemy Rolnictwa Światowego, 25,* 21-38. https://doi.org/10.22630/prs.2025.25.1.2

Ouedraogo, A., Egyir, I. S., Ouedraogo, M., & Jatoe, J. B. D. (2022). Farmers' Demand for Climate Information Services: A Systematic Review. *Sustainability, 14,* Article 9025. https://doi.org/10.3390/su14159025

Ouedraogo, I., Sarr, Y., Omar, S., & Chilambe, P. (2023). *Scaling Access to Index-Based Insurance for More Productive Agriculture: Experiences, Lessons Learned and Perspectives.* https://cgspace.cgiar.org/items/ff761b57-2d87-4768-ab71-97663a804528

Ouedraogo, A., Ouedraogo, M., Egyir, I. S., Läderach, P., Mensah-Bonsu, A., & Jatoe, J. B. D. (2025). Climate Services Bundles Preferences of Smallholder Farmers in West Africa: A Stated Choice Modelling. *Frontiers in Climate, 7,* Article 1581001. https://doi.org/10.3389/fclim.2025.1581001

Ouédraogo, M., Barry, S., Zougmoré, R., Partey, S., Somé, L., & Baki, G. (2018). Farmers' Willingness to Pay for Climate Information Services: Evidence from Cowpea and Sesame Producers in Northern Burkina Faso. *Sustainability, 10,* Article 611. https://doi.org/10.3390/su10030611

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D. et al. (2021). Updating Guidance for Reporting Systematic Reviews: Development of the PRISMA 2020 Statement. *Journal of Clinical Epidemiology, 134,* 103-112. https://doi.org/10.1016/j.jclinepi.2021.02.003

Recha, J. W., Olale, K. O., Sila, A. M., Ambaw, G., Radeny, M., & Solomon, D. (2022). Measuring Soil Quality Indicators under Different Climate-Smart Land Uses across East African Climate-Smart Villages. *Agronomy, 12,* Article 530. https://doi.org/10.3390/agronomy12020530

Redclift, M. (2005). Sustainable Development (1987-2005): An Oxymoron Comes of Age. *Sustainable Development, 13,* 212-227. https://doi.org/10.1002/sd.281

Rosenstock, T. S., Lubberink, R., Gondwe, S., Manyise, T., & Dentoni, D. (2020). Inclusive and Adaptive Business Models for Climate-Smart Value Creation. *Current Opinion in Environmental Sustainability, 42,* 76-81. https://doi.org/10.1016/j.cosust.2019.12.005

Sanogo, D., Sall, M., Camara, B. A., Diop, M., Badji, M., & Ba, H. S. (2020). *The Climate Smart Village Approach: Putting Communities at the Heart of Restoration.* https://cgspace.cgiar.org/items/3cc66cbc-5dc5-4bca-a040-6739cd27bf18

Sarkar, S., Padaria, R. N., Das, S., Das, B., Biswas, G., Roy, D. et al. (2022). Conceptualizing and Validating a Framework of Climate Smart Village in Flood Affected Ecosystem of West Bengal. *Indian Journal of Extension Education, 58,* 1-7. https://doi.org/10.48165/ijee.2022.58201

Segnon, A. C., Magassa, M., Obossou, E. A. R., Partey, S. T., Houessionon, P., & Zougmoré, R. B. (2024). Gender Vulnerability Assessment to Inform Gender-Sensitive Adaptation Action: A Case Study in Semi-Arid Areas of Mali. *Frontiers in Climate, 6,* Article

1418015. https://doi.org/10.3389/fclim.2024.1418015

Simelton, E., Le, T., Coulier, M., Duong, M., & Le, D. (2018). *Developing Participatory Agro-Climate Advisories for Integrated and Agroforestry Systems. Towards Low-Emissions Landscapes in Viet Nam* (pp. 129-144). https://www.researchgate.net/profile/Rachmat-Mulia/publication/333088696_Towards_low-emission_landscapes_in_Viet_Nam/links/5cdac3b092851c4eab9dd47c/Towards-low-emission-landscapes-in-Viet-Nam.pdf#page=129

Sodré, E., Tarpaga, W. V., Bandaogo, A. A., Tassembedo, B., Saba, F., Sawadogo, F. V., Ogou A., & Ouedraogo, M. (2024). *Co-conception d'un modèle de village intelligent face au climat ou climate smart village à Ouda, dans le Centre-Sud du Burkina Faso.* https://cgspace.cgiar.org/items/c44eb1a3-d87e-43c1-bbf3-579bf12bedfa

Suleman, K. K. (2017). *Balancing Coal Mining and Conservation in South-West Ethiopia* (p. 40). Policy Insights. https://www.jstor.org/stable/resrep29515

Taylor, M. (2018). Climate-Smart Agriculture: What Is It Good For? *The Journal of Peasant Studies, 45,* 89-107. https://doi.org/10.1080/03066150.2017.1312355

Totin, E., Segnon, A. C., Schut, M., Affognon, H., Zougmoré, R. B., Rosenstock, T. et al. (2018). Institutional Perspectives of Climate-Smart Agriculture: A Systematic Literature Review. *Sustainability, 10,* Article 1990. https://doi.org/10.3390/su10061990

Tran, H., Simelton, E., & Quinn, C. (2017). *Roles of Social Learning for the Adoption of Climate-Smart Agriculture Innovations: Case Study from My Loi Climate Smart Village, Vietnam.* https://cgspace.cgiar.org/items/7d6d488d-f3f6-44e9-8c33-9b064f8070f1

Twahirwa, A. (2023). Determine Communication Channels Used by Smallholder Farmers to Access Climate Services in Musanze District. *East African Journal of Science, Technology and Innovation, 4.* https://doi.org/10.37425/eajsti.v4i2.525

Wakweya, R. B. (2023). Challenges and Prospects of Adopting Climate-Smart Agricultural Practices and Technologies: Implications for Food Security. *Journal of Agriculture and Food Research, 14,* Article ID: 100698. https://doi.org/10.1016/j.jafr.2023.100698

Wamalwa, I. W., Mburu, B. K., & Mang'uriu, D. G. (2016). Agro Climate and Weather Information Dissemination and Its Influence on Adoption of Climate Smart Practices among Small-Scale Farmers of Kisii Country, Kenya. *Journal of Biology, Agriculture and Healthcare, 6,* 14-23.

Wattel, C., Asseldonk, M. V., Wesenbeeck, L. V., Oostendorp, R., Recha, J. W., Radeny, M. A., & Mulwa, R. (2018). *Financial Landscape Mapping for Climate-Smart Agriculture in the Nyando Basin, Western Kenya.* https://cgspace.cgiar.org/items/28b9ed9f-2f09-47fb-8613-48d3d8fc1167

Yegbemey, R. N., & Egah, J. (2021). Reaching Out to Smallholder Farmers in Developing Countries with Climate Services: A Literature Review of Current Information Delivery Channels. *Climate Services, 23,* Article ID: 100253. https://doi.org/10.1016/j.cliser.2021.100253

Zella, A. Y., Kitali, L. J., Lusiru, S. N., Malekela, A. A., Msambichaka, S., Nassor, Z. et al. (2023). Adapting Innovation of Information and Communication Technologies to Climate Change Risks for Agriculture Sustainability in Central Tanzania. *World Journal of Advanced Science and Technology, 3,* 052-066. https://doi.org/10.53346/wjast.2023.3.1.0057

Zougmoré, R. B., Läderach, P., & Campbell, B. M. (2021). Transforming Food Systems in Africa under Climate Change Pressure: Role of Climate-Smart Agriculture. *Sustainability, 13,* Article 4305. https://doi.org/10.3390/su13084305

Zougmoré, R. B., Partey, S. T., Ouédraogo, M., Torquebiau, E., & Campbell, B. M. (2018). Facing Climate Variability in Sub-Saharan Africa: Analysis of Climate-Smart Agriculture Opportunities to Manage Climate-Related Risks. *Cahiers Agricultures, 27,* Article ID: 34001. https://doi.org/10.1051/cagri/2018019

Zougmoré, R., Jalloh, A., & Tioro, A. (2014). Climate-Smart Soil Water and Nutrient Management Options in Semiarid West Africa: A Review of Evidence and Analysis of Stone Bunds and Zaï Techniques. *Agriculture & Food Security, 3,* Article No. 16. https://doi.org/10.1186/2048-7010-3-16

Zougmoré, R., Partey, S., Ouédraogo, M., Omitoyin, B., Thomas, T., Ayantunde, A. et al. (2016). Toward Climate-Smart Agriculture in West Africa: A Review of Climate Change Impacts, Adaptation Strategies and Policy Developments for the Livestock, Fishery and Crop Production Sectors. *Agriculture & Food Security, 5,* Article No. 26. https://doi.org/10.1186/s40066-016-0075-3