Climate-Smart Agriculture as a Mechanism for Climate Change Adaptation in Africa: The Cases of Rwanda and Kenya

CHEBLI Dounya [1], LABED BRINIS cherifa [2]

[1] University of Chadli Bendjedid-EL Tarf, (Algeria), d.chebli@univ-eltarf.dz

[2] University of Chadli Bendjedid-EL Tarf, (Algeria), Sustainable Local Development Laboratory: Agriculture, Rural Development and Ecotourism, labed-b-cherifa@univ-eltarf.dz

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Abstract:

The research study investigates climate-smart agriculture (CSA) as an essential adaptation method against climate change which produces severe impacts on agricultural systems and food production through heat increases and changing weather patterns and pest outbreaks and shifting crop growing locations and intensified extreme weather occurrences.

Through analysis of Kenyan and Rwandan experiences the study demonstrates that successful initiatives depend on both government policies which support the process and active involvement of community members. The research study suggests these methods should spread to other African nations for building sustainable food security and enhancing climate change defense systems.

Keywords: Agriculture; Climate Change; Climate-Smart Agriculture; Adaptation.

JEL classification codes: Q1 ;Q54 ;Q16 ;Q54

1. INTRODUCTION

Since the Industrial Revolution began the world entered into a major environmental crisis because of its heavy dependence on fossil fuels and the resulting increase in greenhouse gas pollution. The situation has made global warming worse which results in rising average temperatures across the planet. The effects have spread past climate impacts because extreme weather events have become more severe with longer droughts and sudden heavy rains and destructive cyclones and intense heatwaves. The changing climate presents a dual threat to natural environments and human settlements through glacial melting and rising ocean levels and species disappearance and farmland destruction.

Africa encounters severe climate change effects although the continent generates minimal greenhouse gas emissions which create this worldwide problem. The continent depends on agriculture as its main source of food and income and employment because millions of smallholder farmers need rainfall to water their crops. The agricultural output in multiple regions has dropped because of climate change which brings irregular rainfall patterns and worsening drought conditions and expanding desert areas. These conditions threaten food security and exacerbate poverty and social vulnerability.

In response to these challenges, climate-smart agriculture has emerged as a particularly important approach for Africa. It enables smallholder farmers to adopt modern practices and technologies such as improved water management, crop diversification, digital agriculture, and resource-conserving farming methods.

- **Study Problem**

How does climate-smart agriculture contribute to enhancing the adaptive capacity of Kenya and Rwanda in the face of climate change and to ensuring sustainable food security?

- **Study Hypothesis**

Climate-smart agriculture constitutes an effective mechanism for climate change adaptation and the promotion of sustainable food security in Kenya and Rwanda.

- **Study Significance**

The significance of this study lies in its focus on one of the most pressing global challenges of our time—climate change—and its direct impacts on agriculture and food security, particularly in Africa. Special emphasis is placed on the cases of Kenya and Rwanda as models for implementing climate-smart agriculture to foster adaptation and strengthen agricultural sustainability and food security. The study aims to identify essential success elements which will provide useful knowledge for farmers and researchers across Africa.

- **The Methodology and the Tools used**

This study employs a descriptive analytical method combined with the case study approach, focusing on Rwanda and Kenya. A SWOT analysis was used to highlight strengths, weaknesses, opportunities, and threats in the adoption of Climate Smart Agriculture (CSA). The analysis is based on official reports.

- **Study Objectives**

The objectives of the study are as follows:

- To highlight the role of climate-smart agriculture (CSA) as a strategic option for adapting to climate change.
- To identify the most prominent climate-smart agricultural techniques and practices implemented in Rwanda and Kenya.
- To extract the key success factors from the Kenyan and Rwandan CSA experiences and provide recommendations that can be utilized to strengthen the application of these practices in other African countries.

2. Climate-Smart Agriculture and Climate Change

Climate change functions as a persistent and intensifying crisis, which endangers agricultural stability because of changing weather patterns and mounting heat levels and uneven precipitation distribution. The modern solution of climate-smart agriculture depends on new methods and technological tools, which support farmers in adjusting to environmental changes while reducing greenhouse gas emissions and maintaining sustainable agricultural practices. The system proves vital because it enables food production expansion while protecting natural resources, which makes it a vital solution for food security and better living conditions in present and future times.

2.1 Climate-Smart Agriculture

Climate-smart agriculture (CSA) has become a major focus in climate change economic discussions because it provides methods to reduce agricultural greenhouse gas emissions. The Food and Agriculture Organization of the United Nations (FAO) together with academic institutions and international organizations developed a new framework which promotes climate-adaptive farming practices to reach three main objectives: food security improvement and climate change mitigation and enhanced adaptive capacity. CSA represents an evolution and integration of concepts such as agroecology, low-carbon agriculture, and circular and green farming systems (Rodino, Butu, & Ifrim, 2022, p. 248).

The World Bank describes CSA as a unified landscape management system which combines agricultural fields with animal husbandry and natural resources like forests and fisheries to solve food security and climate change problems (World Bank, 2024).

The research conducted by (Lou, 2024) shows that CSA functions as a productive method which unites farming operations with climate change strategies through carbon reduction initiatives and improved adaptation skills to create sustainable agriculture while keeping food security at its core. This method depends on four essential components:

- Reducing Greenhouse Gas Emissions: This includes mitigating emissions of methane, nitrous oxide, and other agricultural greenhouse gases.
- The method operates through soil and forest and marine ecosystem carbon storage systems which scientists call blue carbon.
- Analyzing the Impacts of Climate Change: The study examines how rising atmospheric CO_2 levels together with changing rainfall patterns and extreme weather events such as droughts and floods and wildfires affect the environment.
- The process of creating adaptation strategies involves developing methods which help agricultural systems while reducing negative effects according to Sustainable Development Goals (SDGs) (Lou, 2024, p. 03).

Smart Agriculture functions as a modern system which boosts farming operations through data-based digital technology applications and multiple information networks that include weather forecasts and market trends. The framework establishes Climate-Smart Agriculture (CSA) as a part of it but sets CSA apart through its emphasis on climate and environmental factors. The Sustainable Agriculture Initiative (SAI) works towards three main goals which include boosting production and income in a sustainable way and building climate change resilience and decreasing greenhouse gas emissions. The Sustainable Climate Agriculture (SCA) functions as a more advanced version of smart agriculture because it unites environmental protection with climate change adaptation strategies (Mizik, 2021, p. 02).

2.2 Objectives of Climate-Smart Agriculture

Climate-Smart Agriculture is centered on balancing the three dimensions of sustainable development—economic, social, and environmental—through simultaneously addressing the challenges of food security and climate change. Its core objectives are as follows (Bouzelha, 2020, p. 15):

- Sustainable Increases in Agricultural Productivity and Income (Economic Dimension): Meeting growing food security demands, particularly with the global population projected to reach nine billion by 2050, while countering the negative impacts of climate change on productivity. This is achieved through sustainable farming practices, innovation, modern technologies, and agroecological solutions.
- Adaptation and Resilience to Climate Change (Social Dimension): Implementing strategies for managing agricultural and economic risks, such as fluctuations in production, prices, and income, thereby reducing losses and facilitating the transition from disaster management to risk management.
- Reduction and/or Sequestration of Greenhouse Gas Emissions (Environmental Dimension): Lowering the use of industrial inputs and fossil fuels, while adopting practices that capture carbon—such as afforestation—and utilizing natural ecosystem-derived inputs. These measures contribute to both emissions reduction and productivity enhancement.

2.3 Climate-Smart Agriculture (CSA) Technologies

Climate-smart agriculture relies on the application of technology- and data-driven solutions to enhance agricultural productivity while minimizing the environmental impact of farming activities. This approach involves the use of remote sensing devices, drones, artificial intelligence, and other technologies to monitor climatic and agronomic conditions, optimize irrigation and crop management, and increase the efficiency of water, energy, and other natural resources. CSA also encompasses precision agriculture, which emphasizes the use of data to enhance efficiency and reduce environmental impact (Rodino, Butu, & Ifrim, 2022, p. 248).

Multiple practices exist to adapt to climate change, mitigate drought, heat stress, and flooding, as well as to reduce greenhouse gas emissions, sequester carbon, and enhance resilience. Other practices focus on increasing productivity and income. However, it is generally recommended to adopt a package of practices suited to local conditions in order to simultaneously achieve the three overarching goals of CSA, as implementing a single technology may address only one of these goals.

The following are examples of climate-smart agricultural practices (Intergovernmental Panel on Climate Change IPCC, 2019; Rosenstock, 2016, pp. 16-18):

- Soil and Fertility Management: This includes conservation agriculture, which combines three key practices: minimum soil tillage, crop rotation, and continuous soil cover. It also encompasses integrated soil fertility management by using a balanced mix of organic and inorganic inputs to improve soil health; microdosing, which involves applying small quantities of fertilizer at planting; subsurface fertilization, where fertilizer is applied directly in the root zone to improve uptake efficiency; composting, which consists of applying aerobically decomposed organic matter; the use of manure from livestock and green manure crops (typically legumes) incorporated into the soil; biochar application, where carbon derived from the pyrolysis of organic residues under high temperatures in the absence of oxygen is added to improve soil properties; and liming, which involves applying materials such as calcium carbonate to neutralize soil acidity.
- Precision Agriculture: The use of technologies such as GPS positioning systems and sensors to apply inputs—including water and fertilizers—at precisely the right location, in the correct amounts, and at the right time.
- Agroforestry: This includes boundary planting (growing trees or shrubs along field borders as hedgerows or windbreaks), sustainable forestry practices, assisted natural regeneration, intercropping with rows or alleys of leguminous or non-leguminous trees of single or multiple species, mixed cropping systems, silvopastoral systems, and multilayered agroforestry systems that integrate trees, shrubs, and crops.
- crop management and diversification: Several techniques play a crucial role in climate-smart crop management. These include increasing the number of crop varieties, diversifying crop species, adopting multiple cropping systems, cultivating heat-stress-resistant varieties, growing drought-tolerant crops, and planting varieties resilient to soil salinity.
- Water management: In response to water scarcity and recurring droughts, a range of techniques has been developed:

- Drip Irrigation: Delivers water directly to the root zone in the form of droplets through a network of pipes, significantly reducing water loss.
- Deficit Irrigation: Applies less water than the crop's full requirements in a strategic manner to optimize water use efficiency.
- Rainwater Harvesting: Employs methods for collecting and storing rainwater for later use in irrigation.
- Alternate Partial Root-Zone Irrigation: Involves irrigating one portion of the root zone while leaving the other portion dry, alternating between them to enhance water-use efficiency.
- Smart Irrigation: Utilizes sensor-based systems that monitor soil moisture, temperature, and weather data to automatically supply water only when crops need it.

- Climate-smart livestock and aquaculture:
  - Feed Management: Use of unconventional feed resources, improvement of feed quality and digestibility, and inclusion of nutritional supplements.

- Pasture Improvement: Planting fodder shrubs, introducing new forage species, and enhancing palatability.
- Pasture Management: Optimizing carrying capacity, rotational grazing, cutting-and-carry systems, and transport of feed.
- Manure Management: Collection, storage, and treatment to reduce greenhouse gas emissions.
- Genetic Improvement and Crossbreeding: Developing resilient breeds with higher productivity.
- Integrated Multi-Trophic Aquaculture (IMTA): Combining different aquatic species in a complementary manner to improve resource efficiency.
- Disease Management: Use of disease-resistant breeds and biological control measures.

- Post-harvest innovations include alternative harvesting techniques to minimize breakage and spoilage, adjusting harvest timing to reduce mold incidence and improve quality, and applying advanced storage technologies to reduce post-harvest losses.

2.4 Challenges to the Adoption of Climate-Smart Agriculture

Several key factors hinder the widespread adoption of climate-smart agriculture (Dibbern, Romani, & Silveira Massruha, 2024, p. 08):

- Economic and Financial Constraints: High initial and maintenance costs, the need for skilled labor, and a tendency to prioritize short-term profit goals.
- Infrastructure and Technology: Limited internet connectivity and digital devices, interoperability challenges, and difficulty integrating new systems with existing ones; additionally, data efficiency remains weak in rural settings.
- Knowledge and Skills: Need for digital training and capacity building, educational background of farmers, and limited perceived need for new information.
- Social and Demographic Factors: Generational differences in willingness to adopt new practices, conflicts with entrenched agricultural traditions, and lack of organization or collective action.
- Trust and Acceptance: Low trust in technology, fear of risks, and concern about disruption to routine agricultural activities.
- Policies and Institutional Support: Regulatory barriers, insufficient government support (funding and facilitation), and the need for clear implementation plans and field trials.
- Risks and Environmental Factors: The technology performance encounters threats from disease outbreaks and natural elements which affect its operation and farmers face difficulties when adopting new technology because their farm sizes vary and there are worries about data protection and privacy breaches.

2.5 Climate Change, Agriculture, and Sustainable Food Security

The agricultural sector faces a major worldwide threat because climate change affects crop yields through shifting soil water content and temperature patterns while causing water shortages and more frequent crop diseases and pest outbreaks. The combination of these elements damages crop development and quality which creates risks for worldwide food stability and major financial damages for agricultural producers.

These problems get worse because food prices change often while the population grows quickly and people eat differently and governments face health problems and political instability. The COVID-19 pandemic revealed the weak points of worldwide supply networks which made the existing food shortage worse.

Conversely, modern agricultural technologies and infrastructure development offer promising opportunities to strengthen food system sustainability by enhancing productivity and minimizing losses. Nevertheless, doubts remain about agriculture's capacity to meet the growing global demand for food, especially in low-income developing countries that lack the technological capacity and expertise required for self-sufficiency. This underscores the urgent need for investment in agricultural research, extension services, and innovation to ensure medium- and long-term food security (Pawlak & Kołodziejczak, 2020, p. 02).

Food security refers to a condition in which all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and preferences, allowing them to lead healthy and active lives. Beyond agricultural production and food processing methods, food safety is a critical component of food security, as it protects public health and fosters trust in food supply systems (Toupictionnaire, 2025).

Achieving sustainable food security in the face of climate change, environmental challenges, and other stressors requires the development of advanced agricultural technologies—particularly climate-smart agriculture—that increase productivity without further depleting the earth's ecological capacity or accelerating biodiversity loss, thereby safeguarding natural resources for future generations. To this end, it is essential to apply technological innovations throughout all stages of production, improve energy efficiency in the agricultural sector to mitigate the impact of oil price volatility, rationalize water use, and adopt sustainable agricultural policies that take long-term climate change into account. Moreover, strengthening international cooperation is necessary to achieve price stability (Frona, 2020, pp. 44-45).

In this context, the World Resources Institute, in collaboration with the World Bank, the United Nations Environment Programme, the United Nations Development Programme, and the French agricultural research institutions CIRAD and INRA, has published a report offering a set of solutions for reforming global food production and consumption systems, with the goal of achieving a sustainable food system by 2050. The key proposed solutions include: (World Bank, 2019):

- Reducing Growth in Food Demand: Achieved through lowering food loss and waste, encouraging healthy and sustainable dietary patterns, and promoting rational consumption.
- Increasing Productivity Without Expanding Agricultural Land: Focusing on improving crop yields and livestock productivity.
- Protecting and Restoring Natural Ecosystems: Halting deforestation, rehabilitating degraded land, and linking increased production with biodiversity conservation.
- Developing Fishery Resources: Advancing aquaculture techniques and improving the management of natural fisheries.
- Reducing Greenhouse Gas Emissions from Agriculture: Utilizing technological innovations and climate-friendly agricultural practices.

In addition, scaling up climate-smart agriculture financing is a strategic imperative to ensure that available financial resources align with the critical role of this sector in sustainable development. Although agri-food systems contribute nearly one-third of global greenhouse gas emissions, they receive only about 4% of total climate finance. Moreover, just one-fifth of this funding reaches smallholder farmers—who constitute the backbone of agricultural production. This imbalance highlights the urgent need to restructure financial flows and redirect them more equitably and effectively, thereby supporting the transition toward sustainable agri-food systems capable of withstanding climate challenges and achieving global food security (World Bank, 2024).

3. Rwanda's Experience

Rwanda's agricultural sector is highly vulnerable to climate- and weather-related risks, including prolonged droughts (particularly in the eastern and southeastern regions), irregular rainfall, floods, hailstorms, and landslides (especially in the northern and western regions). Recent events have vividly illustrated the devastating impacts of extreme climatic phenomena on agricultural production.

Studies show that rainfall patterns now display growing unpredictability which results in shorter wet seasons that damage agricultural operations throughout Rwanda. The land area which supports crop production and animal husbandry will decrease according to forecasts while the growing period will shorten and crop production potential will decrease. The World Bank predicts Rwanda will experience a temperature increase of 1.5°C and higher annual rainfall by 2030 according to RCP 4.5 climate model projections and delta method adjustments (World Bank, 2019).

3.1 Climate-Smart Agriculture Project in Rwanda

The government of Rwanda has implemented climate-smart agriculture (CSA) throughout the nation by introducing various programs which include better climate information systems and agricultural support services and investment planning and digital value chain development and modern technologies like agroforestry and smart irrigation systems. The initiatives show the nation backs sustainable farming practices which protect food security and environmental health.

3.1.1 Climate Services for Agriculture Project

The project started in 2016 through financial support from USAID while the Rwanda Meteorology Agency (Meteo Rwanda) and the Ministry of Agriculture and Animal Resources (MINAGRI) and the International Center for Tropical Agriculture (CIAT) executed it under the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). The project aims to achieve these goals:

- Enhancing farmers' capacity to adapt to climate change;
- Providing accurate, locally tailored climate services to support agricultural decision-making;
- Integrating climate information into national plans and policies.

The project has achieved the following results:

- Training more than 75,000 farmers in climate planning tools, such as the Participatory Integrated Climate Services for Agriculture (PICSA) approach;
- Building the capacity of over 1,000 agricultural extension agents and local government officials to effectively use climate information;
- Developing systems for collecting and analyzing climate and historical data to improve both short- and long-term forecasting;
- Introducing SMS services and community radio programs to disseminate weather forecasts and agricultural advice to farmers;
- Receiving the award for "Best Climate-Smart Agriculture Project in Africa" at the 2018 AIDF Summit in Nairobi, in recognition of its innovative approach and multi-stakeholder partnerships.

The project has created multiple benefits for smallholder farmers through enhanced agricultural production and climate adaptability and it has developed national climate-based agricultural planning systems and established a regional East African model for agricultural climate services expansion (CCAFS, 2018)

3.1.2 Land, Soil, and Crop Information Services (LSC-IS)

The Rwanda Agriculture and Animal Resources Development Board (RAB) started the DeSIRA Land, Soil and Crop Information Services (LSC-IS) project between November 10 and 18 of 2022. The program receives funding from the European Union through DeSIRA and Dutch Ministry of Foreign Affairs and various other donors who work with agricultural research institutions based in Rwanda and Kenya and Uganda. The project establishes national hubs for land and soil and crop information to support climate-smart agriculture (CSA) which enhances Agricultural Knowledge and Innovation Systems (AKIS) and connects scientific research with field implementation.

The project holds value because agricultural planning faces challenges from disorganized soil and crop data which exists in small amounts and lacks proper organization. The project works to help small farmers and national and local decision-makers access reliable quality data which enables them to make sustainable agricultural choices that resist climate change. The project works to create improved AKIS development roadmaps through partnership building and information accessibility and national data management system development for policy guidance.

The project will create the RwaSIS Center as its main output which functions as a national platform to deliver land and soil and crop information services for sustainable food and agricultural system development and Sustainable Development Goals (SDGs) achievement.

The project launch began with multiple workshops which started in Kigali for national participants before moving to Musanze and Rwamagana for district-based attendees. The workshops concentrated on creating a soil and crop information system for decision support and tracking soil fertility management effects on productivity and forecasting future landscape requirements and assessing agricultural data governance policies (Rwanda Agriculture and Animal Resources Development Board, 2022).

3.1.3 Rwanda Accelerated Adaptation Program (RAAP)

The Rwanda Accelerated Adaptation Program (RAAP) started in 2024 through the CGIAR Hub for Sustainable Finance (ImpactSF) which teamed up with Rwanda Green Fund (RGF) and Bill & Melinda Gates Foundation to support the initiative. The program works to help small and medium-sized businesses in the agri-food industry tackle climate change obstacles through training programs and financial support and creative solutions.

Between August and October 2024, thirty-one SMEs participated in training sessions focusing on:

- Climate finance and impact management;
- Integration of climate-smart solutions into business operations;
- Seasonal agricultural planning based on climate information.

The program enabled participants to anticipate climate risks, improve agricultural practices, adopt sustainable strategies, and prepare robust investment proposals to attract climate finance.

Furthermore, RAAP strengthened the capacity of these enterprises to design impact monitoring frameworks and measure social, economic, and environmental outcomes. This, in turn, empowered them to support and guide smallholder farmers toward more resilient practices.

The partnership among CGIAR, RGF, the Gates Foundation, and ImpactSF exemplifies a commitment to transforming climate challenges into opportunities for sustainable development by expanding access to climate finance and enhancing the resilience of Rwanda's agricultural sector in the service of food security and economic development (CGIAR, 2024).

3.1.4 Rwanda Climate-Smart Agriculture Investment Plan 2025

On July 18, 2025, Rwanda, with the support of the International Finance Corporation (IFC), launched its Climate-Smart Agriculture Investment Plan, with a total value of 449.7 billion Rwandan francs (approximately USD 335.4 million). The plan focuses in the short term on awareness-raising, building an investment base, and providing technical assistance, while its long-term objective is to scale up investments by mobilizing financing and implementing structural reforms.

Approximately two-thirds of the planned investments are allocated to water and irrigation projects, along with initiatives to develop climate-resilient crops, reduce post-harvest losses, strengthen resilient livestock systems, and improve soil health.

The plan targets 83,250 hectares of agricultural land, 170,200 farmers, and 375 agribusinesses, providing them with access to green financing opportunities.

This initiative is aligned with Rwanda's Strategic Plan for Agriculture Transformation (PSTA5) and the National Strategy for Transformation (NST2), with the aim of increasing private sector investment in agriculture from 15.9% of GDP (USD 2.2 billion) to 21.5% (USD 4.6 billion). These measures are expected to enhance food security, drive economic growth, and improve rural livelihoods (International Finance Corporation, 2025).

3.2 Field Experiences

3.2.1 Climate-Smart Agriculture Project in Rusizi District

The Climate-Smart Agriculture (CSA) project was launched in Rusizi District in 2022, funded by the United Evangelical Mission (UEM) and implemented by the RDIS organization in collaboration with the dioceses of the Anglican Church of Rwanda. The project aims to address

the impacts of climate change—such as land degradation, deforestation, declining agricultural productivity, and unemployment—while supporting the achievement of the Sustainable Development Goals (SDGs) in Rwanda.

Key activities of the project include:

- Environmental Training and Awareness: Training 20 farmers, along with local leaders and RDIS staff, on climate change adaptation and environmental protection.
- Farm Management and Practical Experimentation: Appointing a specialized farm manager for 18 months to oversee Murangi Farm, which serves as a training center where horticultural crops are cultivated regularly to generate income and transfer knowledge.
- Introduction of Modern Technologies: Installing solar-powered water pumps to reduce water and fuel consumption as well as carbon emissions, alongside the construction of greenhouses and drip irrigation systems in collaboration with Holland Green Tech Ltd.
- Knowledge Dissemination: Sharing project results through brochures, banners, radio and television programs, and social media platforms.
- Livestock Training: Providing programs composed of 20% theoretical instruction and 80% hands-on practice focusing on livestock husbandry and its effects on crops and the environment.

The organization conducted an evaluation meeting with church leaders during February 2023 to verify the complete success of solar-powered irrigation systems and greenhouses and water tanks and practical training for nearby farmers who now receive direct benefits from the project. The project shows positive outcomes through its combination of modern farming methods and hands-on education and public awareness campaigns which serve as a model for climate resilience and sustainable agriculture in Rwanda (Rural Development Inter-Diocesan Service RDIS, 2023).

3.2.2 Strengthening Climate-Smart Agriculture in Eastern Rwanda

The project which runs from February 2022 to March 2026 focuses on building climate-smart agriculture in Rwanda to help farmers in the eastern province because this area experiences severe climate change effects. The project focuses on sustainable farming methods which include agroforestry for better production and climate resistance and irrigation systems to defend crops against dry conditions. These interventions contribute to enhanced carbon sequestration and higher agricultural productivity.

The program targets arid regions which include Nyagatare and Gatsibo and Kayonza and Kirehe and Akagera National Park buffer areas. The program works to build community strength and boost food security and better living conditions for vulnerable farmers according to (CIFOR-ICRAF), n.d.).

3.2.3 Developing Climate-Smart Agriculture Knowledge

The project “Stimulating Market Opportunities for Smallholder Horticulture Farmers and Small and Medium Enterprises in Rwanda” received funding from the European Union to support AEE Rwanda and AGRIRESEARCH UNGUKA Ltd. which conducted an advanced training program from January 9 to 10 in 2024. The training program focused on enhancing the

agricultural project staff members' competencies regarding climate-smart agriculture (CSA) methods.

The project works to boost the competitive power and market entry of around 30,000 smallholder farmers and small and medium enterprises in the horticulture industry through better marketing methods and product value addition. The training program taught participants about Climate Smart Agriculture (CSA) principles and vermicomposting methods and Integrated Pest Management (IPM) practices for tomatoes and bell peppers and French beans and pineapples and eggplants and cucumbers and chili peppers and onions. The program included a field visit to UNGUKA Ltd.'s model farm where participants watched the practical application of these methods (AGRIRESEARCH UNGUKA Ltd, 2024).

3.2.4 Climate-Smart Agriculture Program for Refugee Communities (DUHAMIC-ADRI–UNHCR)

The program operates to boost economic stability for refugees who live in Rwanda together with the native population. DUHAMIC-ADRI began working with the United Nations High Commissioner for Refugees (UNHCR) through a partnership agreement in July 2024 to run the second phase of "Climate-Smart Agriculture and Market Development to Strengthen the Livelihoods of Refugees and Host Communities in Rwanda."

The project works to improve food security and self-reliance for 2,036 beneficiary households who include 732 refugee families and 1,304 host-community families with 1,091 women and 945 men. The project will reach 7,851 people by 2026 through its implementation of CSA practices and market development programs that promote environmentally friendly livelihoods (DUHAMIC-ADRI, 2024).

Rwanda uses climate-smart agriculture as evidence to show how investment and digitization function as essential tools for creating a resilient agricultural sector. The analysis leads to an evaluation of this method's positive and negative aspects as well as its potential and obstacles.

Strengths	Weaknesses
National plan for investment in climate-smart agriculture (CSA) by 2025.	Limited natural resources, including small land area and mountainous terrain.
Government support and integration of CSA into agricultural policies.	High dependence on external financing.
Successful initiatives such as PICSA and agroforestry projects.	Institutional capacity disparities across rural regions.
Adoption of digital systems, for example, the Smart Nkunganire System.	Uneven adoption of technologies among smallholder farmers.
Opportunities	**Threats**
Plan to attract USD 335 million in private investment.	High sensitivity to rainfall variability and drought.
Integration of digital technology to support smallholder farmers.	High population density and pressure on land resources.

Development of sustainable irrigation projects and solar energy initiatives.	Environmental degradation, including soil erosion.
Potential for Rwanda to become a leading African model in CSA.	Economic risks in the event of delays in private investment.

The SWOT analysis indicates that climate-smart agriculture (CSA) in Rwanda presents significant opportunities for improving agricultural productivity and enhancing food security. However, the long-term sustainability of these efforts remains contingent upon addressing resource-related and infrastructural challenges.

4. The Kenyan Experience

Kenya's total land area is composed of 97.8% landmass and 2.2% water bodies. However, only 16% of the country receives moderate to high rainfall. This relatively small portion of land sustains approximately 75% of the population and serves as the primary source of food production and livestock rearing. Areas with high rainfall (above 1,000 mm annually) account for less than 20% of productive agricultural land but support nearly 50% of the population. Meanwhile, areas with medium rainfall (750–1,000 mm annually) make up about 30–35% of productive land and host around 30% of the population. In contrast, arid and semi-arid lands (ASALs) constitute roughly 84% of Kenya's total land area, housing 80% of the nation's livestock and 65% of its wildlife.

Nevertheless, Kenyan agriculture faces considerable challenges due to climate change, including recurrent droughts, floods, and shifting rainfall patterns. These changes contribute to land degradation, declining agricultural productivity, increased prevalence of pests and diseases, and a reduction in agricultural investment. Additionally, mounting pressure on natural resources has given rise to conflicts that negatively affect livelihoods and economic development (Ministry of Agriculture, Livestock and Fisheries of Kenya, 2017, p. 22).

4.1 Kenya's Climate-Smart Agriculture Project

Kenya's Climate-Smart Agriculture Investment Plan (CSAIP) plays a pivotal role in supporting major national policies and plans, particularly the Nationally Determined Contributions (NDCs) and the National Adaptation Plan (NAP). Kenya is an active participant in global efforts to address climate change, especially through the Paris Agreement (PA), which aims to limit global temperature rise to below 2°C. The country's NDCs outline the national actions to meet the goals of the Paris Agreement, including both mitigation and adaptation measures.

At the domestic level, Kenya has adopted a comprehensive set of legal, policy, planning, and institutional frameworks at both national and county levels to address climate change. Notable examples include:

- Climate Change Act (2016): The primary legislation for mainstreaming climate considerations into all sectors.
- National Climate Change Response Strategy (2010)
- National Climate Change Action Plan (2013–2017)
- National Adaptation Plan (2015–2030)

- Climate-Smart Agriculture Strategy (2017–2026)
- Climate Risk Management Framework (2017)
- National Climate Change Policy (2018)
- National Climate Finance Policy (2018) and other complementary frameworks (Republic of Kenya, 2023).

4.1.1 Climate-Smart Agriculture Strategy (2018–2027)

The Kenya Climate-Smart Agriculture Implementation Framework (KCSAIF) aligns investment priorities with the country's sectoral needs, levels of climate vulnerability, and areas of strategic importance. The total baseline budget required for implementing the program is estimated at KES 167.31 billion through 2027. These resources are to be mobilized through national funding sources, bilateral and multilateral development partners in climate finance, the Adaptation Fund, the Green Climate Fund, as well as contributions from the private sector. All funds are subject to auditing in accordance with the applicable financial management agreements, with particular reference to the Government of Kenya's Climate Finance Policy 2017 (Ministry of Agriculture Livestock and Fisheries of Kenya, 2018, p38).

The framework was developed to promote sustainable, climate-resilient, and low-carbon agricultural growth that ensures food security and contributes to the achievement of Kenya's national development objectives as articulated in Kenya Vision 2030. The development of this framework began in 2015 with the participation of the Ministries of Agriculture and Environment, along with relevant government agencies responsible for crop and livestock development, fisheries, aquaculture, and the blue economy, as well as the agricultural research and irrigation sectors. County governments, the private sector, civil society, researchers, and academic institutions also contributed through consultative workshops, shaping the framework's overall direction and strategic priorities (Kenya, Kenya Climate Smart Implementation Framework 2018–2027, 2018, p. 07).

4.1.2 AgriFI Kenya Climate-Smart Agricultural Productivity Project (AgriFI Kenya CS APP), 2019–2023

The AgriFI Kenya Climate-Smart Agricultural Productivity Project (CS APP) is a five-year initiative launched by the Government of Kenya with co-financing provided through a grant from the European Union. The project's total budget is approximately €6.5 million, of which €5 million was provided as a grant by the European Union and €1.5 million as co-financing by the Government of Kenya. The project was officially launched on January 4, 2019, under the supervision of the Kenya Agricultural and Livestock Research Organization (KALRO), in collaboration with its partners.

This project forms an integral part of the EU–Kenya AgriFI Program, under the theme "Support for smallholder agriculture that is productive, climate-adapted, and market-integrated, including contributing to the Africa Investment Facility." KALRO bears primary responsibility for achieving the first outcome of the program, namely: the development and adoption of

innovative, climate-adapted agricultural technologies with the potential for market integration (Kenya Agricultural and Livestock Research Organization, 2024).

4.2 Field Experiences of Climate-Smart Agriculture in Kenya

4.2.1 The Nyando Basin Case

In Kenya's Nyando Basin, farmers have faced severe impacts from recurring storms and highly variable climate patterns, alternating between floods and droughts, which have complicated harvest planning. To address these challenges, the International Center for Agricultural Research (CGIAR) adopted the Climate-Smart Village (CSV) approach, which emphasizes participatory engagement with local communities in selecting context-specific solutions.

This approach has facilitated the introduction of practical innovations such as the breeding of a more productive goat variety, the adoption of agroforestry practices, solar-powered irrigation systems, greenhouse construction, and efficient water management systems, all of which have enhanced the sustainability of agricultural land. Additionally, a community-based collective action fund was established to support savings and finance further innovations, thereby ensuring the continuity of adaptation efforts.

As a result of this initiative, the Climate-Smart Village model has become a successful prototype that has been scaled to thousands of communities worldwide, empowering farmers to build resilience and secure a more stable future (CGIAR, n.d.).

4.2.2 Climate-Smart Agriculture in Kericho County

Given the combined pressures of global population growth and shifting dietary patterns that drive increased food demand, the Kenya Climate-Smart Agriculture Project (KCSAP) has intensified its efforts to address food security challenges. The project seeks to empower smallholder farmers in Kericho County through an integrated approach to managing agricultural, livestock, forestry, and water resources, thereby enhancing productivity and strengthening resilience to climate-related risks such as drought, pests, and diseases.

4.3 Case Study: Finger Millet Cultivation in Kipture Village

In Kipture, located in the Soin-Sigowet sub-county, a women's group of 17 members received KES 15 million in funding to support a finger millet cultivation project. The group, which began as an informal association before registering as a community-based organization, gained access to improved seed varieties (KAKS3 and KAKS1) as well as training in climate-smart agricultural practices. The intervention also provided mechanization support through plowing and leveling equipment.

This initiative led to a significant increase in productivity: three acres are cultivated twice per year, yielding approximately 20 bags of finger millet in three months. The total income amounts to roughly KES 320,000, which is distributed equally among the members. The production not only meets household food needs but also enables market sales at KES 400 per 2 kg (Kenya News Agency, 2025).

4.4 Case Study: Poultry Farming in Sigongo Village

In Sigongo, the Matunda Indigenous Hatchery Project was established with KES 26 million in funding from KCSAP. The project is equipped with four large incubators, each with a capacity of 5,000 eggs, enabling the weekly production of approximately 20,000 chicks and

generating nearly KES 1.8 million in weekly revenue. The project currently consists of 58 poultry farmers and serves as a primary source of income and livelihood for the members. There are ongoing plans to expand membership to 100 participants. Additionally, the group has been provided with a specialized refrigerator capable of storing more than 50 types of vaccines for the chicks.

4.5 Banana Seedling Nursery Project in Cheplanget

The Kenya Climate-Smart Agriculture Project (KCSAP) established banana seedling hardening nurseries through its funding program which operates in Cheplanget. The initiative will deliver financial advantages to farmers through seedling sales while providing enhanced food security for the participating families.

The programs demonstrate KCSAP helps small farmers through monetary aid and new crop seeds and by backing farming equipment and poultry production and agricultural nursery development. The project achieves its objectives through these programs which boost agricultural production and raise family earnings and improve local community abilities to handle climate-related difficulties (Kenya News Agency, 2025).

4.6 Kenya Sustainable Potato Initiative (KSPI)

The Kenya Sustainable Potato Initiative (KSPI) operates as a three-year program which receives funding from the Alliance for a Green Revolution in Africa (AGRA) to support its activities between July 2024 and June 2027. The program operates through a three-way collaboration between the National Potato Council of Kenya (NPCK) and the Kenya Agricultural and Livestock Research Organization – Tigoni Center (KALRO-Tigoni) and Egerton University. The project operates in the counties of Laikipia, Meru, Nyandarua, and Nandi.

The KSPI organization works to reduce the potato seed shortage by 50% through building a strong seed distribution network and promoting environmentally friendly farming techniques. The project works to diversify crops while backing agricultural programs which focus on nutrition and climate resilience and it creates policies to involve private businesses in food security and livelihood development. The program works to solve legal and regulatory problems which impact potato production and marketing and distribution through better seed quality access and sustainable commercial potato production and market organization and sector coordination support (National Potato Council of Kenya, 2024).

Kenya shows us that innovation together with community partnerships serves as the foundation for climate-smart agriculture SWOT analysis development. The table below shows the analysis results which include the positive elements and the challenges and opportunities and threats that could affect the path to climate-smart agriculture.

Strengths	Weaknesses
National Strategy for Climate-Smart Agriculture (2017–2026).	Variability in technology adoption across regions.
Strong support from the government and the World Bank (KCSAP).	High dependence on external financing.
Practical implementation through Climate-Smart Villages (CSV).	Weak rural infrastructure.

Ecological diversity allowing for the testing of different techniques.	Lack of training and awareness among some farmers.
Opportunities	**Threats**
Potential to expand the CSV model to new areas.	Intensifying impacts of climate change (droughts/floods).
Attraction of additional international investments.	Continued dependence on external donors.
Advancement of digital agriculture and reliance on climate data.	Population growth and pressure on resources.
Growing need for food security solutions.	Market volatility and fluctuations in agricultural input prices.

The study shows that climate-smart agriculture (CSA) functions as a viable solution in Kenya to boost food security and build resilience against climate change impacts. The method will reach success by solving internal problems while defending against external threats to sustain its continuous operations.

5. CONCLUSION

The experiences of Rwanda and Kenya demonstrate that CSA functions as a vital solution to build climate resilience and achieve food security across Africa. The programs have helped farmers boost their productivity while creating new income streams and building communities which can better withstand droughts and floods and rising temperatures. The authors demonstrate that local community participation together with agricultural research and institutional cooperation creates the foundation for sustainable agricultural sector transformation.

Study Findings

- The KCSAP and AgriFI Kenya CS APP programs in Kenya have boosted smallholder farmer and pastoralist productivity while diversifying agricultural value chains and promoting climate-smart agriculture through solar-powered irrigation and conservation agriculture and cooperative community farming ;
- The National CSA strategies in Rwanda have improved sustainable farming practices through agricultural innovation and digital agriculture expansion which helps farmers achieve food security and climate fluctuation mitigation;
- Both Cases: The integration of climate adaptation into national agricultural policies has strengthened sustainability and food security while encouraging private sector engagement and scientific research in developing solutions.

Test Hypotheses

The hypothesis is partially accepted: Climate-smart agriculture proves to be an effective mechanism for climate change adaptation and for promoting sustainable food security in Kenya and Rwanda.

However, its full potential is still constrained by challenges related to financial resources, institutional capacity, and implementation practices.

Study Recommendations

- Expand the use of CSA practices by integrating them into other African nations which face climate vulnerability;
- Governments must create policies which back climate-smart agricultural strategies through their political institutions;
- Scientific research funding together with domestic innovation development should focus on creating technology adaptation solutions which match the unique needs of each country;
- Flexible sustainable financing systems need to be improved because they help farmers get resources and new technologies;
- Training programs together with capacity development initiatives must receive support because they help communities get long-lasting benefits from these projects.

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