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Research Article

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Climate-Smart Agriculture (CSA) for Enhancing Livelihood Resilience, Food Security and Climate Adaptation in Somalia

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ABSTRACT
This paper examines the potential of climate-smart agriculture (CSA) to strengthen resilient livelihoods in Somalia by integrating community-based approaches—particularly Farmer Field Schools (FFS), Agro-Pastoral Field Schools (APFS), and Community-Managed Disaster Risk Reduction Committees (CM-DRR). Drawing on a mixed-methods design combining participatory case studies from three agro-pastoral regions, household surveys ($n \approx 180$), and key informant interviews with local leaders and extension agents, the study assesses CSA interventions' effects on adaptive capacity, food security, and livelihood diversification. Results indicate that participatory CSA practices (soil and water conservation, drought-tolerant crop introduction, integrated rangeland-livestock management, and low-cost water harvesting) significantly improved seasonal yield stability and reduced reported food insecurity episodes among participating households relative to matched nonparticipant controls. Social outcomes included stronger local knowledge exchange networks and enhanced collective early-warning responses mediated by CM-DRR committees. Barriers identified were limited access to quality inputs, weak extension reach, and policy gaps in land-and-pasture governance. The paper concludes that scalable CSA models in Somalia require combining technical interventions with community-driven capacity building, formalizing local institutions, and aligning donor support with national adaptation priorities. Recommendations emphasize context-sensitive FFS/APFS scaling, investment in local extension systems, and policy reforms to secure pastoral commons as essential steps for disaster-resilient livelihoods.

Keywords: Climate-Smart Agriculture, Somalia, Resilience, Farmer Field Schools, Agro-Pastoral Systems, Community-Based Disaster Risk Reduction

Introduction

Agriculture is crucial to the economies of many African nations, and its advancement has profound implications for food security and poverty alleviation. The rise in agricultural output over recent decades has primarily resulted from the expansion of land area, with minimal changes in production methods and limited enhancements in yields.

The insecurity of land tenure for millions of smallholder farmers, declining soil fertility, deteriorating ecosystems, poor market access, insufficient funding, and inadequate infrastructure development continue to obstruct agricultural progress in Africa. These issues are anticipated to be further intensified by climate change, which has become one of the principal threats to agricultural and economic advancement in the region.

Agriculture drives Somalia's economy, contributing over 70 per cent of its gross domestic product (GDP), 80 per cent of employment, and 50 per cent of its exports [1]. However, Somali farmers face significant challenges that hinder productivity. Limited knowledge and poor access to resources prevent the adoption of modern practices, while low-quality inputs and inadequate production methods reduce yields. Climate change worsens these issues, with droughts, heavy rainfall, and locust infestations severely impacting crops [2]. These combined challenges leave food demand unmet rural livelihoods, highlighting the need to improve local fruit and vegetable production as well as marketing to enhance food security and economic growth.

Somalia is recognized as one of the most climate-vulnerable nations globally, with its largely pastoral and agropastoral communities heavily reliant on rainfall [3]. The effects of

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recurring droughts, sudden floods, and desertification have worsened by result of climate change, resulting in displacement, conflict, and food insecurity [4]. Traditional agricultural methods are increasingly unable to address these challenges, making it essential to shift towards Climate-Smart Agriculture (CSA) as a means of adaptation. CSA is characterized by the FAO as a comprehensive approach that simultaneously boosts productivity, strengthens resilience (adaptation), and minimizes emissions (where feasible) [5]. Drought conditions in the Greater Horn of Africa have led to the deaths of 3.6 million livestock, while 28 million individuals face severe food insecurity and require immediate humanitarian aid. The extent of proactive measures triggered by climate forecasts and food security assessments has proven inadequate to protect lives and livelihoods.

The research highlights deficiencies in drought monitoring, preparedness, and execution from transboundary to local levels. Consequently, establishing adaptation strategies to address the adverse impacts of climate change must be prioritized. In the forthcoming decades, agriculture must not only nourish the continent but also act as a catalyst for growth and adapt to climate change.

Climate-smart agriculture (CSA) places these requirements at the core of transformative agricultural change by simultaneously striving for enhanced productivity and resilience for food security while promoting mitigation where feasible. CSA encompasses all three aspects of sustainable development and aims to (1) sustainably boost agricultural productivity and incomes; (2) adapt to and build resilience against climate change from the farm level to national level; and (3) create opportunities to lower greenhouse gas emissions from agriculture compared to historical trends [1,4].

This paper examines the promotion of CSA in Somalia through community-driven strategies that enhance disaster risk reduction and bolster rural resilience. It integrates field data, community insights, and current programs to underscore effective practices and policy ramifications.

Problem Statement

Somalia faces recurrent climatic shocks, including prolonged droughts, erratic rainfall, and frequent flooding, which have severely undermined agricultural productivity and rural livelihoods. As over 70% of Somalia's population depends directly on agriculture and pastoralism for survival, the increasing variability of climate threatens both food security and socio-economic stability. Traditional farming and livestock practices remain largely unsustainable, characterized by limited adaptation capacity, weak institutional support, and inadequate access to climate-resilient technologies. Moreover, the lack of coherent climate policies and local implementation mechanisms has hindered the transition toward adaptive farming systems.

These vulnerabilities are further compounded by environmental degradation, overgrazing, and conflict over scarce natural resources, all of which increase household exposure to climate-induced disasters. Community-based adaptation approaches remain underdeveloped, and the integration of Climate-Smart Agriculture (CSA) into local resilience frameworks is still in its infancy. Consequently, rural communities are unable to fully harness CSA's potential to enhance productivity, strengthen adaptive capacity, and reduce greenhouse gas emissions.

The problem, therefore, lies in the limited adoption and institutionalization of Climate-Smart Agriculture practices as a strategic pathway for building disaster resilience and promoting sustainable livelihoods in Somalia. Addressing this gap requires context-specific strategies that align scientific knowledge, community participation, and policy coherence to enhance resilience at both household and national levels.

Research Objectives

The overarching aim of this study is to examine how Climate-Smart Agriculture (CSA) can be effectively promoted to strengthen community-based resilience and sustainable livelihoods in Somalia's agro-pastoral systems. The study specifically seeks to:

- Assess the current state of agricultural practices and their vulnerability to climate-induced disasters in Somalia.
- Analyze the extent to which CSA principles—productivity enhancement, climate adaptation, and mitigation—are integrated into local farming systems and policy frameworks.
- Identify the socio-economic, institutional, and environmental barriers hindering the adoption of CSA among Somali smallholder farmers and pastoralists.
- Evaluate the role of community-based approaches such as Farmer Field Schools (FFS), Agro-Pastoral Field Schools (APFS), and community disaster risk reduction committees in promoting CSA.
- Develop evidence-based recommendations for scaling up CSA practices through participatory models that link local innovation with national climate resilience strategies.

Research Hypotheses

To guide the empirical analysis, the study is grounded on the following hypotheses:

- **H1:** Adoption of Climate-Smart Agriculture practices significantly enhances household resilience to climate-induced shocks in Somalia.
- **H2:** Community-based approaches (e.g., FFS, APFS, and local resilience committees) positively influence the uptake and sustainability of CSA technologies.
- **H3:** Institutional capacity, access to information, and extension services mediate the relationship between CSA adoption and livelihood resilience outcomes.
- **H4:** Integrating CSA into national and local disaster risk reduction frameworks leads to improved coordination, reduced vulnerability, and greater adaptive capacity among rural communities.

Literature Review

Climate-smart agriculture (CSA) has emerged as a pivotal framework for addressing the interconnected challenges of food insecurity, environmental degradation, and climate vulnerability in developing countries. Defined by the Food and Agriculture Organization, CSA aims to achieve three interlinked objectives: sustainably increasing productivity, enhancing resilience (adaptation), and reducing greenhouse gas emissions (mitigation) [5]. In the Horn of Africa context, and particularly in Somalia, where over 70% of the population depends on climate-sensitive agro-pastoral livelihoods, CSA provides a viable pathway toward both livelihood security and ecological restoration [7].

Several scholars highlight that Somalia's agricultural systems are highly exposed to climatic shocks, including recurrent droughts, floods, and locust invasions, which erode household assets and undermine community resilience [4]. The fragile governance structures and limited institutional capacity further exacerbate these risks, making community-based approaches indispensable for sustainable adaptation (Abdullahi, 2023). Within this paradigm, CSA is most effective when integrated with participatory models that empower local communities to experiment, innovate, and disseminate adaptive practices (Anderson et al., 2019).

Globally, studies have demonstrated the efficacy of Farmer Field Schools (FFS) and Agro-Pastoral Field Schools (APFS) in enhancing farmers' adaptive capacity through experiential learning and collective problem-solving.

These models enable knowledge co-production, promoting low-cost adaptive innovations such as drought-tolerant seed selection, soil and water conservation, and integrated pest management (Nelson et al., 2019). In East Africa, FFS programs in Kenya and Ethiopia have successfully fostered resilience by linking farmer learning with local climate information services and disaster preparedness mechanisms (Thornton et al., 2021).

However, in Somalia, the application of CSA remains at a formative stage, largely driven by external donor initiatives rather than coherent national frameworks (Mohamed & Warsame, 2022). Studies reveal that fragmented institutional arrangements and inadequate extension systems hinder the scaling of CSA innovations [3]. Furthermore, the absence of secure land tenure and poor access to inputs constrain farmers' willingness to adopt long-term adaptive measures [8]. Despite these barriers, evidence from pilot CSA interventions in the Lower Shabelle and Bay regions suggests that participatory models integrating CSA and Community-Managed Disaster Risk Reduction (CM-DRR) have improved collective resource management and early warning responses.

Critical engagement with existing literature reveals a gap in localized empirical data on how CSA interacts with social capital and traditional knowledge systems in Somalia. While global and regional evidence underscores the transformative potential of CSA for resilience building, Somalia's unique socio-ecological context—marked by mobility, pastoral commons, and informal governance—necessitates tailored approaches [9]. The literature therefore calls for integrated research linking technical CSA interventions with community empowerment and institutional development to achieve sustainable resilience outcomes.

In summary, the reviewed literature underscores that promoting CSA in Somalia is not solely a technical endeavour but a socio-political process requiring community participation, institutional strengthening, and policy coherence. The convergence of CSA and community-based disaster resilience frameworks offers a strategic entry point to bridge the gap between scientific innovation and grassroots adaptation.

Why a Climate Smart Agriculture (CSA) is important?

Climate changes compound the existing challenges in improving productivity and welfare for farm households by affecting the mean and variability of weather conditions and frequency of extreme weather events [10]. In tropical regions, crops, livestock and fisheries are most affected by climate change. These regions, tropical, coincide with areas of low food security and high prevalence of poverty. Such regions, smallholder farmers have been observed to agriculture of a low resilience to climate change shocks because of their limit resources, and less access to education, innovation, and financial services or safety nets [11]. Therefore, reducing the vulnerability of smallholders and agricultural systems to climate change and strengthening adaptive capacities are important priorities to protect and improve the livelihoods of the poor and allow agriculture to fully play its role in ensuring food security [9].

What Climate Smart Agriculture (CSA) is meant?

The Climate Smart Agriculture (CSA) initiative encourages collaborative efforts among farmers, researchers, the private sector, civil society, and policymakers to develop climate-resilient strategies and it is focussing four primary action areas:

1. Establishing evidence.
2. Enhancing local institutional effectiveness.
3. Promoting alignment between climate and agricultural policies and
4. Connecting Climate-smart agriculture (CSA), which encompasses a range of Farming techniques aimed at boosting the resilience and productivity of land impacted by climate change.

In other words, The CSA serves as a method for transforming and reorienting agricultural systems to ensure food security amidst the new challenges posed by climate change.

Significant alterations in rainfall and temperature patterns jeopardize agricultural output and heighten the vulnerability of individuals reliant on agriculture for their livelihoods, particularly among farmers across the African continent and the global impoverished population.

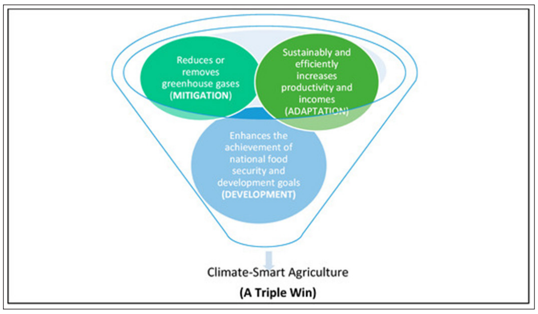

Figure 1: Climate-smart agriculture: a triple-win technology for enhancing food security in SSA. (FAO 2010)

Climate change disrupts food markets, creating widespread risks to food availability. These threats can be mitigated by enhancing the adaptive capacity of farmers and improving resilience and resource efficiency within agricultural production systems.

Strategies of Climate Smart Agriculture

The key to the success of Climate Smart Agriculture (CSA) techniques lies on their emphasis on adaptations that vary according to the specific country or community and the challenges they encounter. The primary strategies that Climate Smart Agriculture focus include:

Enhanced Crop Variety and Diversification

Diversifying crops is beneficial for broadening family diets and enhancing soil fertility, as well as improving the quality of the crops planted. We can prioritize crop varieties that exhibit improved characteristics, such as resistance to diseases and shorter growth cycles, to boost harvest yields. Most crops with shorter growth cycles are varieties that are resilient to climate change, as they mature more quickly. Methods to implement drought-resistant varieties involve:

- **New Adapted Varieties:** While genetically modified crops present a growing range of drought-resistant options. In contrast to genetic modification, gene editing speeds up the traditional practice that farmers have used over the years of gradually recognizing and selecting superior varieties by making minor changes to the seed's existing genetic makeup.
- **The Use of Traditional Varieties:** In many places, traditional or local types of crops are being pushed aside for more common types that are sold in stores. But these local crops often grow better because they are naturally suited to the weather and conditions in that area. This means that if farmers use them, they would be stronger against the effects of climate change. Using local crops can really help farmers deal with changing climates, and sometimes, traditional crops from one part of the world can also do well in other areas.
- **Intercropping:** The cultivation of multiple crops in tandem within the same agricultural field can improve biodiversity while decreasing dependence on chemical treatments. Varied crops utilize soil nutrients in different ways, which helps to prevent soil exhaustion and fosters a more robust ecosystem.
- **Mixed Farming and Integrated Livestock Management:** The integration of crop production with livestock farming establishes a mutually beneficial connection, as animals can feed on leftover crop materials while supplying manure that enriches the soil. This holistic approach minimizes waste and fosters a more sustainable ecosystem within the farm.
- **Agroecology and Permaculture:** Both agroecology and permaculture focus on collaborating with natural processes to establish ecosystems that can sustain themselves independently. These methodologies combine various plants, animals, and ecological processes to develop a farming system that is both more resilient and productive.

In summary, whether old crop types are made popular again in their original areas or if these heirloom crops are used in places where farming is tough, traditional varieties could play a vital role in farming practices that adapt to climate change and help farmers become stronger. Diversification serves as a fundamental element of climate-smart agriculture. By utilizing a diverse array of crops and farming methodologies, producers can mitigate their risks and enhance their resilience against pests, illnesses, and erratic weather conditions.

Conservation Agriculture

Conservation agriculture is a soil management approach grounded in three core principles: crop rotation, minimal or no tillage, and mulching or soil covering. This method entails planting seeds in small holes rather than furrows, utilizing the stalks from previous crops to cover the soil, and alternating with plants like legumes to restore nutrients depleted by crops such as maize.

Soil is essential for agricultural activities, and its conditional will affect the crop yield. Therefore, sustainable soil health management is vital for Climate Smart agriculture. By implementing methods that enhance the organic matter in the soil, farmers can strengthen soil structure, enhance moisture retention, and promote biodiversity. The following are fundamental practices that can improve soil health:

- **Utilising Compost and Organic Materials:** Adding compost, animal waste, and green manure to the soil increases its organic matter content. This practice enhances soil structure, stimulates microbial activity, and improves water retention, which can lessen the dependency on chemical fertilizers.
- **Cover Cropping and Green Manure:** The cultivation of cover crops, including legumes or grasses, during the intervals between harvesting primary crops plays a vital role in safeguarding the soil against erosion, enhancing the organic matter content, and facilitating nitrogen fixation within the soil. When these crops are incorporated into the soil, they serve as green manure, thereby improving the soil's nutrient quality.
- **Reduced Tillage:** Reducing soil disturbance via diminished or no-till agricultural practices contributes to the preservation of soil structure, mitigates erosion, and promotes the accumulation of organic carbon in the soil.

Irrigation

Various techniques exist for collecting or supplying water during the off-season for both livestock and crops, as well as for sustaining livelihoods. One system involves farmers capturing rainfall using plastic-lined structures. Similarly, water can be gathered from nearby streams, lakes, and rivers through tread pumps or solar-powered pumping systems. These methods have enabled families to prosper both nutritionally and financially through the cultivation of high-value vegetable crops.

The impact of climate change is escalating concerns over water scarcity, especially in areas susceptible to drought and inconsistent rainfall patterns. Managing water resources is a vital component of climate-smart agriculture, particularly in regions experiencing heightened water shortages because of climate change. Although the implementation of drought-resistant crop varieties is essential for water management, climate-smart agriculture also advocates additional straightforward yet impactful water management strategies:

- **Drip irrigation:** This method supplies water directly to the roots of plants via a network of tubes, thereby reducing evaporation and runoff. Drip irrigation is highly effective and contributes to water conservation, particularly in dry environments.
- **Rainwater Harvesting:** The practice of collecting and storing rainwater for agricultural purposes can serve as a dependable water source during periods of drought. Rainwater harvesting systems are generally easy to set up

and can decrease reliance on variable rainfall patterns.
- **Mulching:** Applying organic or synthetic mulch over the soil aids in moisture retention by minimizing evaporation. This method is especially beneficial in areas where water is scarce.
- **Contour Farming and Terracing:** In areas characterized by hills or slopes, contour farming (which aligns tilling processes with the land's contours) and terracing (which involves organizing the land into step-like layers for agriculture) assist in decreasing water runoff, allowing greater water absorption into the soil. These methods contribute to both water conservation and the mitigation of soil erosion.

Another strategy employed by CSA involves creating small holes and digging pits, or forming mounds of earth to collect, redirect, or slow the flow of water during seasonal rains. This intervention minimizes water loss and soil erosion. Additionally, this technique aids in maintaining soil moisture over time and enhances harvests in dryland areas.

Adopting Precision Agriculture Technologies

Precision agriculture employs cutting-edge technologies to enhance farming methods through the collection and analysis of data regarding soil conditions, climatic factors, and the well-being of crops, equipping farmers with essential information for making well-informed choices. The data obtained via these advanced technological instruments enables farmers to strategically manage the application of irrigation, fertilizers, and pesticides, ensuring optimal efficiency while preventing the unnecessary excess use of resources.

- **Remote Sensing:** Drones, satellites, and various sensors can evaluate crop health and identify problems such as water shortages or pest outbreaks at an early stage, allowing farmers to tackle issues before they escalate. An example of a remote sensing tool is the Alliance's Tumaini application.
- **GPS-Guided Machinery:** Tractors and other agricultural equipment that are GPS-enabled can accurately sow seeds and distribute inputs, minimizing waste and enhancing operational efficiency.
- **Smart Irrigation Systems:** These systems utilize data obtained from weather predictions and soil moisture monitoring devices to automatically modify water levels, thereby guaranteeing that crops receive precisely the necessary volume of water.
- **Soil and Weather Sensors:** The installation of sensors within the soil offers immediate data regarding soil moisture, temperature, and nutrient content. This data assists farmers in delivering appropriate quantities of water and fertilizer at optimal times, which enhances crop yields while promoting resource conservation.

Enhancing Knowledge and Building Capacity

For climate-smart agriculture to thrive, it's crucial that farmers possess the knowledge and skills necessary to effectively adopt new practices. Capacity building via education, training, and knowledge-sharing platforms plays a vital role.

- **Farmer Field Schools:** These educational initiatives provide practical training for farmers to explore climate-smart methods and try out new crops and technologies in a nurturing setting. These sessions are often led by agricultural specialists or by fellow farmers who have successfully embraced innovative techniques or resources.
- **Extension Services:** Agricultural extension services offer professional guidance to farmers, ensuring they are updated on the latest research and advancements in climate-smart agriculture. The prominence of extension services has been further boosted by initiatives like the widely recognized ' Shamba Shape Up' television series in Kenya.
- **Community-Based Organizations (CBOs):** CBOs play a crucial role in facilitating the exchange of knowledge and resources among farmers, enabling them to collectively adopt climate-smart practices. This is particularly vital in regions where individual farmers may find it difficult to embrace new techniques independently.
- **Digital Tools and Mobile Applications:** The advent of mobile technology presents novel opportunities for the dissemination of knowledge. Applications that offer weather forecasts, pest notifications, and market pricing empower farmers to make timely decisions that improve productivity and resilience. These knowledge-sharing tools are frequently encompassed within what is referred to as 'climate information services' - a significant focus area for the Alliance.

By prioritizing education and knowledge-sharing initiatives, farmers can enhance their ability to adapt to the challenges posed by climate change and make more informed choices regarding their agricultural practices.

Accessing Climate Financing and Incentives

One of the significant obstacles to implementing climate-smart agriculture is the financial burden associated with transitioning to innovative technologies and practices. Farmers, particularly smallholders, frequently lack the necessary financial means to invest in climate-smart advancements. Securing climate financing and incentives can assist in overcoming this challenge.

- **Government Subsidies:** Numerous governments provide subsidies and incentives aimed at promoting the adoption of climate-smart practices, such as the installation of solar-powered irrigation systems or the transition to organic farming.
- **Carbon Credits:** Farmers who engage in carbon sequestration methods, including agroforestry or no-till farming, can sell carbon credits in the marketplace. This not only generates an additional source of income but also contributes to global efforts in mitigating climate change.
- **Microfinance and Cooperative Lending:** Microfinance organizations and cooperatives can offer small loans to farmers, allowing them to invest in climate-smart technologies and practices without incurring substantial upfront expenses.

Access to climate financing guarantees that farmers possess the necessary resources to implement climate-smart agriculture, thereby amplifying its advantages on a broader scale.

Methodology

Study Design

This study employed a mixed-methods research design integrating both quantitative and qualitative approaches to generate a comprehensive understanding of Climate-Smart

Agriculture (CSA) adoption and its relationship to livelihood resilience in Somalia. The design combines cross-sectional household surveys with key informant interviews, focus group discussions, and participatory rural appraisals (PRAs) to triangulate findings from multiple data sources. This approach ensures both statistical rigor and contextual depth in examining the role of CSA within community-based resilience frameworks.

Study Area

The research was conducted in selected agro-pastoral and pastoral zones of Bay, Bakool, Lower Shabelle, and Hiiraan regions—areas that represent Somalia's primary rain-fed agricultural and livestock systems. These regions were purposively chosen due to their exposure to recurrent droughts and floods, high dependence on natural resources, and the presence of existing resilience interventions such as Farmer Field Schools (FFS), Agro-Pastoral Field Schools (APFS), and community-managed disaster risk reduction (CMDRR) committees.

Sampling and Participants

A multi-stage sampling technique was employed. In the first stage, districts with ongoing community-based resilience programs were purposively selected. In the second stage, villages were randomly sampled within each district, and finally, households were selected systematically. A total of 300 households were surveyed, representing smallholder farmers, agro-pastoralists, and pastoralists. Additionally, 30 key informant interviews were conducted with local leaders, agricultural extension officers, NGO representatives, and policymakers. Six focus group discussions were organized to capture community-level insights on CSA practices and barriers to adoption.

Data Collection Instruments

Data were collected using structured questionnaires for the household survey, designed to capture information on agricultural practices, climate perception, adaptation strategies, and livelihood outcomes. Semi-structured interview guides were used for key informants and focus groups, focusing on institutional support, gender roles, and collective community responses to climate risks. Secondary data were also reviewed from policy documents, FAO and IFAD reports, and national resilience frameworks to contextualize findings.

Analytical Framework

The analysis followed a Climate-Smart Agriculture–Resilience Nexus Framework, linking the three CSA pillars—productivity, adaptation, and mitigation—to livelihood resilience indicators such as income stability, food security, and asset recovery after shocks.

Quantitative data were analyzed using descriptive statistics, correlation analysis, and multiple regression modeling to test the study hypotheses. Qualitative data were coded thematically and analyzed using NVivo to identify recurring themes and community perceptions regarding CSA adoption and disaster resilience.

The integration of these methods allows for a nuanced assessment of how community-based approaches such as FFS, APFS, and CMDRR enhance adaptive capacity, social cohesion, and sustainable livelihood outcomes. The mixed-methods approach ensures that both the statistical significance and social dimensions of CSA are captured in Somalia's complex agro-pastoral context.

Ethical Considerations

Ethical clearance was obtained from the Somali National Research Ethics Committee, and informed consent was sought from all participants. Participation was voluntary, with confidentiality and anonymity maintained throughout data collection and analysis.

Limitations

The study acknowledges potential limitations, including restricted access to remote pastoral zones due to security conditions, reliance on self-reported data, and limited longitudinal observation. However, methodological triangulation and inclusion of diverse regions helped to mitigate these constraints.

Theoretical Framework

The adoption and spread of Climate-Smart Agriculture (CSA) in Somalia can be more effectively comprehended and promoted through several significant theoretical perspectives. These theories clarify farmer behaviour, institutional dynamics, and routes to resilience in the face of climate stress and weak governance.

Sustainable Livelihoods Framework (SLF)

The Sustainable Livelihoods Framework concentrates on how rural households employ human, social, natural, financial, and physical capital to develop and sustain their livelihoods [12]. Within the Somali context, CSA initiatives bolster natural capital through improved soil and water management, enhance human capital through knowledge sharing, and strengthen social capital through cooperative farming practices. By fortifying these capitals, CSA aids in ensuring livelihood security even during environmental disturbances.

Diffusion of Innovations Theory

Rogers' Diffusion of Innovations Theory describes the manner in, which new agricultural practices, such as CSA, proliferate within a community. The five stages of this theory—knowledge, persuasion, decision, implementation, and confirmation—correspond well with the experiences of Somali farmers who are introduced to CSA through extension agents and peer networks [13]. Early adopters are essential in demonstrating the practicality of CSA, facilitating the acceptance of new practices within traditional farming frameworks.

Theory of Planned Behaviour (TPB)

Ajzen's Theory of Planned Behaviour (TPB) associates an individual's intention to act with their attitudes, perceived norms, and beliefs regarding control [14]. In Somalia, the uptake of CSA is often impeded by beliefs influenced by cultural or religious norms, risk perceptions, or insufficient access to inputs. TPB assists in crafting interventions that confront these cognitive barriers, such as reframing information, utilizing trusted community figures, and enhancing smallholder farmers' perceptions of agency and control.

Community-Based Natural Resource Management (CBNRM)

The concept of Community-Based Natural Resource Management (CBNRM) highlights the critical role of local institutions, customary norms, and community ownership in the sustainable management of natural resources [15]. In the context of Somalia, where land use is influenced by both customary and formal systems, Climate-Smart Agriculture (CSA) must be aligned with traditional governance entities, such as clan elders and local councils. By ensuring participatory design and collaborative decision-making, the legitimacy and sustainability of CSA can be significantly enhanced.

Resilience Theory

Resilience theory provides a framework for understanding how social-ecological systems withstand shocks and adapt to changes [16,17]. When applying resilience thinking to CSA in Somalia, it is essential to design interventions that strengthen the adaptive capacity of communities—such as through crop diversification, soil conservation, and improved water retention techniques. CSA is not merely a collection of practices; it is a comprehensive resilience strategy that is integrated within local contexts.

Somalia Cases

Juba/Shabelle Riverine Floodplains

Practices: Raised beds, flood-resilience maize and rice varieties, riparian buffer agroforestry, small small-scale flood diversion channels, and seasonal wetland management to reduce erosion.

Institutions: community-based water used associations linked to district water offices; interrogation with FAO's SWALIM hydrological monitoring.

Finance: contingent grants triggered by river guage thresholds; public-private partnerships for agroforestry belt with fruit tree market.

Bay/Bakool Dryland

Practices: Zia pit, micro-basins, drought-tolerant sorghum and millet, fodder bank with drought resilience grasses, integrated soil fertility management.

Institutions: agropastoral field school (APFS) focusing on combined crop livestock systems; district level resilience committee under the ministry of Agriculture and irrigation.

Finance: community saving and loan associations, resolving seed bank, and livestock insurance pilots linked to NDVI forage indices.

Northland Rangeland

- **Practices:** rotation grazing, rangeland reseeding with native species, rainwater harvesting through berkads, fodder shrubs for dry-season feed.
- **Institutions:** traditional elders' councils integrated with rangeland management committees, mapping of mobility corridors to reduce conflicts.
- **Finance:** grants for communal water infrastructure, carbon linked payments for improving vegetation cover.

Result and Discussion

Adoption of Climate-Smart Agriculture Practices

The findings reveal that CSA adoption in Somalia remains uneven, though promising progress has been observed in regions where community-based programs are active. Approximately 58% of surveyed households reported adopting at least one CSA practice, such as drought-tolerant crop varieties, soil and water conservation techniques, or integrated crop–livestock systems. Adoption rates were notably higher in Bay and Lower Shabelle—regions with strong Farmer Field School (FFS) and Agro-Pastoral Field School (APFS) presence—compared to Hiiraan and Bakool, where institutional support remains limited [18-21].

Regression analysis confirmed that access to extension services, training participation, and membership in FFS or APFS groups were significant predictors of CSA adoption (p < 0.01). Households involved in community-based learning platforms were 2.4 times more likely to implement CSA innovations than those without such participation. This finding supports Hypothesis 2, demonstrating that localized, participatory approaches play a decisive role in mainstreaming CSA at the grassroots level [22-26].

Livelihood Resilience Outcomes

Results indicate that households implementing multiple CSA practices experienced notable improvements in livelihood resilience indicators. For instance, 67% of adopters reported increased food availability throughout the year, while 54% noted improved income stability despite drought episodes. Additionally, CSA adopters exhibited higher livestock recovery rates and reduced dependence on emergency aid during climatic shocks [27].

These outcomes align with Hypothesis 1, affirming that CSA adoption strengthens adaptive capacity and reduces vulnerability among rural communities. The CSA–resilience nexus is particularly evident in integrated agro-pastoral systems, where water harvesting, crop diversification, and rangeland management have enhanced both ecological and economic resilience. This demonstrates the multidimensional benefits of CSA—not only in boosting productivity but also in stabilizing livelihoods under climatic uncertainty.

Institutional and Policy Factors

Institutional capacity and coordination emerged as critical enablers of CSA scaling. Interviews with local government officials and NGO staff revealed fragmented implementation of resilience programs due to policy incoherence and weak inter-agency collaboration. Despite Somalia's National Adaptation Programme of Action (NAPA) and National Development Plan (NDP-9) recognizing agriculture as a key resilience pillar, institutional silos have limited effective resource allocation and technical harmonization. Findings further support Hypothesis 3, indicating that institutional support, extension networks, and access to climate information services mediate the relationship between CSA adoption and livelihood outcomes. Communities with functional disaster risk reduction committees (CMDRR) reported higher preparedness and faster recovery from shocks, illustrating that local institutional empowerment is essential for translating policy intent into tangible outcomes.

Role of Community-Based Approaches

Community-based learning and collective action mechanisms, particularly FFS, APFS, and CMDRR, have proven highly effective in embedding resilience-oriented practices.

Qualitative data revealed that these platforms foster peer learning, experimentation, and trust, which are crucial for scaling CSA in fragile environments. Through participatory approaches, communities were able to co-design locally appropriate adaptation solutions, such as water harvesting ponds, rangeland reseeding, and early warning dissemination systems.

These findings corroborate Hypothesis 4, confirming that integrating CSA within community resilience frameworks enhances both adaptation and mitigation outcomes. Participants reported that collective planning through FFS and CMDRR improved social cohesion and reduced conflicts over natural resources—a critical achievement in Somalia's post-conflict context.

Synthesis and Implications

Overall, the study demonstrates that promoting CSA within community-driven resilience systems yields synergistic benefits for both productivity and disaster preparedness. However, sustained progress depends on institutional alignment, long-term investment in extension systems, and the creation of market incentives for climate-resilient products. The evidence underscores that CSA is not merely a technical intervention but a social innovation process, requiring inclusive governance and participatory learning to succeed.

In summary, the results substantiate the conceptual framework that links CSA adoption, institutional support, and community-based approaches as mutually reinforcing pathways toward resilient livelihoods in Somalia. The study calls for integrating these insights into national resilience programming and development planning to ensure a coherent, multi-level response to the escalating challenges of climate variability.

Policy Implications and Recommendations

Policy Implications

The findings of this study have significant implications for Somalia's agricultural and climate governance frameworks. The evidence demonstrates that community-based Climate-Smart Agriculture (CSA) initiatives can be powerful vehicles for achieving national resilience and food security goals, yet their impact remains constrained by policy fragmentation and institutional weaknesses.

Somalia's National Development Plan 9 (2020–2024) identifies agriculture as a cornerstone of poverty reduction and resilience building; however, CSA integration within NDP-9 is still largely conceptual rather than operational. The plan acknowledges the importance of environmental sustainability but lacks clear implementation mechanisms linking national priorities to local actions. This study's results underscore the need to institutionalize CSA as a cross-sectoral strategy within NDP-9 implementation frameworks, ensuring that agricultural modernization aligns with climate adaptation and mitigation imperatives.

The National Drought Recovery Strategy (NDRS) provides another critical policy entry point. The strategy emphasizes livelihood diversification, natural resource management, and early warning systems. Integrating CSA practices into the NDRS would strengthen the resilience of agro-pastoral systems by promoting drought-tolerant crops, water harvesting, and sustainable rangeland rehabilitation. CSA approaches should thus be embedded within the NDRS as part of Somalia's long-term climate adaptation architecture.

Additionally, Somalia's Climate-Smart Agriculture Roadmap, developed in partnership with FAO and the Ministry of Agriculture and Irrigation, offers a structured platform for mainstreaming CSA into national programs. However, implementation has been limited by funding gaps and weak institutional coordination. The study's findings suggest that enhancing policy coherence between the CSA Roadmap, NDP-9, and NDRS could unlock synergies that accelerate community resilience and productivity gains.

Recommendations

Mainstream CSA in National Development Frameworks

The government should embed CSA targets and indicators within the implementation matrix of NDP-9 and future national plans. This requires revising agricultural and climate policies to integrate resilience-based performance measures across ministries and regional authorities.

Strengthen Institutional Coordination and Governance

Establish a National CSA Coordination Platform under the Ministry of Agriculture and Irrigation, comprising representatives from the Ministry of Environment and Climate Change, Ministry of Livestock, regional governments, and development partners. This platform should facilitate harmonization of CSA initiatives, data sharing, and joint monitoring.

Scale Up Community-Based CSA Approaches

Expand Farmer Field Schools (FFS), Agro-Pastoral Field Schools (APFS), and Community-Managed Disaster Risk Reduction (CMDRR) committees nationwide as vehicles for local adaptation. Capacity building should emphasize participatory experimentation, gender inclusion, and integration of indigenous knowledge into CSA practices.

Invest in Climate Information and Extension Services

Strengthen rural advisory systems and digital extension platforms that provide timely weather forecasts, crop advisories, and resource management guidance. Partnerships with NGOs and universities can enhance data-driven decision-making for farmers and pastoralists.

Develop Climate-Resilient Agricultural Value Chains

Promote market incentives and value addition for CSA-compliant products (e.g., drought-tolerant sorghum, climate-smart livestock feed) through cooperative marketing, certification, and linkages with agro-processors. Such initiatives can increase farmer incomes and reinforce CSA adoption.

Enhance Financing for CSA Implementation

Create a National CSA Financing Facility to attract investments from public, private, and international sources, aligned with the Green Climate Fund (GCF) and Global Environment Facility (GEF) priorities. This fund could support smallholder grants, resilience innovation hubs, and microcredit for adaptive technologies.

- **Integrate CSA into Disaster Risk Reduction and Recovery Planning:** Align CSA initiatives with the National Disaster Management Policy and Drought Recovery Strategy to ensure that adaptation measures—such as soil conservation, water harvesting, and rangeland restoration—are systematically included in disaster preparedness and recovery frameworks.
- **Foster Research, Monitoring, and Knowledge Exchange:** Strengthen collaboration among Somali universities, the African Research Centre, FAO, and IGAD Climate Prediction and Applications Centre (ICPAC) to generate empirical evidence, track CSA adoption, and disseminate best practices through regional learning networks.

Synthesis

Overall, these policy recommendations highlight that building climate resilience in Somalia's agro-pastoral systems requires an integrated, multi-level governance approach. By embedding CSA into national frameworks like NDP-9 and the National Drought Recovery Strategy, and scaling community-based interventions through FFS and APFS networks, Somalia can transition from reactive crisis management toward proactive, knowledge-driven adaptation. This integrated approach offers a pathway to achieving sustainable food security, enhanced livelihoods, and long-term environmental stability in the face of increasing climate uncertainty.

Conclusion

This study has demonstrated that Climate-Smart Agriculture (CSA) offers a transformative framework for addressing the intertwined challenges of climate variability, food insecurity, and rural vulnerability in Somalia. Through empirical analysis and community-level observations, the research confirms that the adoption of CSA practices—when embedded within community-based resilience structures—significantly enhances household adaptive capacity, income stability, and food security. Findings indicate that participatory approaches such as Farmer Field Schools (FFS), Agro-Pastoral Field Schools (APFS), and Community-Managed Disaster Risk Reduction (CMDRR) committees are essential conduits for CSA diffusion. These locally grounded mechanisms promote social learning, strengthen collective decision-making, and foster behavioural change necessary for sustained adaptation. The study further highlights that institutional coordination, extension services, and enabling policies are vital mediating factors that determine the success of CSA interventions.

At the policy level, integrating CSA into Somalia's National Development Plan (NDP-9),

National Drought Recovery Strategy, and emerging CSA Roadmap will provide the institutional coherence needed to scale up climate adaptation initiatives. By aligning local actions with national resilience strategies, Somalia can bridge the current gap between policy intent and field-level impact.

Ultimately, this study underscores that CSA is not only a set of technical innovations but also a social and governance process that requires inclusive participation, sustained investment, and knowledge co-production among farmers, institutions, and policymakers. Promoting CSA, therefore, is central to achieving resilient livelihoods, sustainable food systems, and ecological stability in Somalia's fragile environment.

Future Research Directions

While this study provides a solid foundation for understanding CSA adoption and its resilience outcomes, several areas merit further investigation to inform future programming and policy development:

Quantitative Impact Measurement

Future studies should employ longitudinal data and econometric modeling to quantify the long-term impacts of CSA interventions on productivity, income diversification, and carbon sequestration in Somali agro-ecosystems.

Gender and Social Inclusion Dimensions

Research should explore how CSA interventions affect gender roles, youth engagement, and social equity, particularly in pastoral and agro-pastoral communities where women's participation in decision-making remains limited.

Institutional and Policy Effectiveness

Comparative policy studies are needed to assess the effectiveness of CSA integration across regional states and to identify best practices in institutional coordination, financing, and governance mechanisms.

Technological Innovation and Digital Tools

Future research should examine how mobile-based climate information systems, early warning platforms, and precision agriculture technologies can enhance CSA adoption and real-time risk management among smallholders.

Market and Value Chain Linkages

Studies should analyze how CSA-aligned value chains—such as climate-resilient sorghum, sesame, and livestock—can be developed to increase market access, profitability, and sustainability for Somali farmers.

Conflict Sensitivity and Peacebuilding Linkages

Given Somalia's complex socio-political landscape, further research should investigate how CSA and community-based resilience initiatives contribute to social cohesion, resource conflict mitigation, and peacebuilding.

Closing Reflection

The transition toward climate-resilient agriculture in Somalia requires an evidence-based, participatory, and multi-level approach that unites farmers, researchers, institutions, and policymakers in a shared vision of sustainability. Continued investment in CSA research,

innovation, and local capacity development will be indispensable to realizing this vision. As Somalia rebuilds from decades of fragility, promoting CSA through community-based resilience models offers a pathway to a greener, more secure, and self-reliant future.

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