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NAVIGATING NIGERIA'S CHANGING AGRO-ECOLOGICAL REALITIES THROUGH CLIMATE-SMART AGRICULTURE FOR ENHANCED FOOD SECURITY

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Abstract

This work, Navigating Nigeria's Changing Agro-Ecological Realities through Climate-Smart Agriculture for Enhanced Food Security, investigates the multifaceted impact of climate change on agriculture in Nigeria and evaluates the role of Climate-Smart Agriculture (CSA) as a mitigation and adaptation strategy. Guided by the Sustainable Livelihood Framework (SLF) and Systems Theory, this research underscores how agricultural systems are dynamically influenced by climate variability and socioeconomic structures. Employing a qualitative-descriptive methodology, data were sourced from relevant literature, institutional reports, and policy documents to assess the effectiveness and adoption challenges of CSA practices across Nigeria's agro-ecological zones. Findings reveal that rising temperatures, erratic rainfall, and extreme weather events—such as floods and droughts—are severely disrupting agricultural productivity, particularly in the northern and coastal regions. Crop failures, livestock mortality, and resource conflicts are compounding food insecurity and rural poverty. CSA practices—such as conservation agriculture, agroforestry, and drought-tolerant crops—have shown promise in improving resilience, especially in the Kaduna and Katsina States. However, adoption remains low because of cultural resistance, limited access to finance, poor infrastructure, and policy fragmentation. The study concludes that CSA presents a transformative and people-centered approach to climate adaptation and food security in Nigeria. However, its success hinges on institutional coherence, rural infrastructure investment, and inclusive governance. The study recommends, among other things, the integration of CSA principles into national agricultural extension programmes.

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Introduction

Nigeria, often referred to as the "Giant of Africa," is largely dependent on agriculture for livelihood sustenance, employment, and food supply. According to the National Bureau of Statistics (2023), agriculture employs approximately 70% of Nigeria's labor force and contributes approximately 25% to its Gross Domestic Product (GDP). The sector is the backbone of rural livelihoods and a significant source of income for millions of Nigerians, particularly women and smallholder farmers (FAO, 2022). Despite the country's vast natural resources and agricultural potential, food security is a critical challenge. Several factors—including land degradation, outdated farming practices, and post-harvest losses—contribute to persistent food insecurity. However, in recent decades, climate change has emerged as a multiplier of major threats, worsening vulnerabilities in the agricultural sector.

Climate change, characterized by rising temperatures, erratic rainfall, increased frequency of extreme weather events and desertification, directly undermines agricultural productivity and food systems. The Intergovernmental Panel on Climate Change (IPCC, 2022) identified sub-Saharan Africa as one of the most vulnerable regions to climate-induced food insecurity. In Nigeria, changing rainfall patterns have disrupted planting and harvesting seasons, while prolonged droughts and floods have led to the destruction of farmlands and loss of biodiversity (Olaniyi et al., 2021). These changes have not only reduced crop yields but have also heightened tensions over land and water resources, compounding threats to national and household food security.

Ecological transformations across Nigeria's agro-ecological zones are a growing concern. From the arid Sahelian north to the tropical rainforest in the south, ecosystems are undergoing rapid degradation because of overexploitation, deforestation, and climatic shifts (Ezenwaji et al., 2020). For instance, Lake Chad, which once supported millions of farmers, fishers, and herders, has shrunk by over 90% since the 1960s because of a combination of climate change and human activity (UNEP, 2021). In the Middle Belt and southern regions, increased rainfall variability has led to gully erosion and soil nutrient depletion, reducing land productivity and threatening rural livelihoods. These ecological transformations signal an urgent need for adaptive agricultural strategies that enhance resilience and sustain food production.

In light of these challenges, the concept of Climate-Smart Agriculture (CSA) has gained international and national recognition as a transformative approach to address food insecurity under climate change. CSA, as defined by the Food and Agriculture Organization (FAO, 2013), aims to increase agricultural productivity sustainably, enhance resilience (adaptation), reduce greenhouse gas emissions (mitigation), and achieve national food security and development goals. In the Nigerian context, CSA involves the adoption of practices such as agroforestry, conservation agriculture, water harvesting, integrated soil fertility management, and climate-resilient crop varieties. However, the level of CSA adoption remains uneven, and there is a critical need for contextualized strategies to ensure its effective implementation.

The purpose of this study, therefore, is to explore how Climate-Smart Agriculture can respond to the rising threats posed by climate change and ecological transformations across Nigeria's agro-ecological zones. By identifying CSA's potential to buffer climate risks and improve food system sustainability, the study contributes to the growing discourse on adaptive agricultural development and national food security planning.

Literature Review

Climate Change and Agriculture in Nigeria

Nigeria has been undergoing significant climatic changes over recent decades, which have been characterized by rising temperatures, unpredictable rainfall, and more frequent extreme weather conditions. The Nigerian

Meteorological Agency (NiMet, 2020) reported a temperature increase of 1.1°C since 1901, with northern regions experiencing greater warming. Rainfall patterns have shifted, with late rainfall onset and early withdrawal disrupting the traditional agricultural calendar. These climate shifts have raised concerns among farmers and policymakers alike. The increasing irregularity of weather patterns has increased the difficulty of planning and sustaining agricultural activities more challenging.

Extreme weather events, such as floods, droughts, heatwaves, and windstorms, have become more common and intense. In 2012, devastating floods affected over seven million Nigerians and destroyed large swathes of farmland (UNDP Nigeria, 2013). Climate models suggest that these severe events are likely to continue and worsen, posing grave risks to agriculture and food availability. The destruction caused by these events has undermined years of agricultural efforts, increased poverty, and threatened food systems. Farmers are now faced with the daunting task of rebuilding and adapting to an ever-changing climate.

Given that most agriculture in Nigeria is rain-fed, it is especially vulnerable to climatic changes. Crops such as maize and sorghum, which are vital in northern Nigeria, have seen reduced yields due to prolonged droughts and erratic rainfall (Apata, Samuel, & Adeola, 2009). The reduction in planting windows and the frequency of crop failures, especially in semi-arid regions, have increased food insecurity (Sowunmi & Akintola, 2010). Farmers in these regions find it increasingly difficult to maintain productivity. The need for climate-resilient farming methods has never been more urgent.

Climate change has also significantly affected livestock farming in Nigeria. Rising temperatures and reduced access to water have placed animals under stress, while desertification continues to diminish available grazing land, especially in the Sahel belt. These factors contribute to increased livestock deaths and reduced meat and dairy production. As pastoralist communities struggle with limited resources, tensions between herders and farmers over land and water have intensified (FAO, 2019). The impact of climate change on rural livelihoods and social stability is becoming more pronounced.

In southern Nigeria, rising sea levels, water pollution, and warmer aquatic environments have negatively impacted fishing activities. Fishers in the Niger Delta are reporting declining catches and species losses, which threaten their incomes and food sources (Olaniyi et al., 2014). Desertification in the north, driven by deforestation and poor land use, is pushing farming communities to migrate southwards, adding to social and economic pressures (Federal Ministry of Environment, 2014). Meanwhile, recurrent flooding in states like Bayelsa, Rivers, and Anambra continues to destroy farmland and displace thousands, with the 2022 floods affecting over 1.4 million people (NEMA, 2022). These combined effects of climate change demand urgent adaptation and mitigation strategies to safeguard Nigeria's agricultural future.

Climate-Smart Agriculture Practices in Nigeria

Climate-Smart Agriculture (CSA) refers to strategies designed to sustainably boost agricultural productivity, strengthen resilience to climate change, and reduce greenhouse gas emissions where feasible (FAO, 2013). With Nigeria facing growing climate-related challenges, such as unpredictable rainfall, rising temperatures, and extreme weather, CSA has become increasingly crucial. Across various regions in Nigeria, farmers are adopting CSA practices, including conservation agriculture, agroforestry, improved irrigation, drought-tolerant crops, organic farming, and the use of Information and Communication Technologies (ICTs). These practices aim to secure food production while protecting the environment. As climate variability worsens, CSA offers a viable path for safeguarding livelihoods and promoting sustainable development.

Conservation agriculture (CA), which includes minimal soil disturbance, permanent soil cover, and crop rotation, is gaining traction in parts of Nigeria. It has been introduced by organizations like IITA and AfricaRice

in states such as Kaduna, Kano, and Oyo (Akinbile & Yusuff, 2018). According to Erenstein et al. (2012), CA practices have led to improved soil fertility, lower labor costs, and improved yields for crops like maize and legumes. Nevertheless, its widespread adoption is hindered by cultural norms favoring traditional tillage and limited access to training and inputs. More extensive awareness campaigns and support systems are needed to increase the uptake of awareness among smallholder farmers.

Agroforestry, the integration of trees into farming systems, provides multiple benefits, including improved soil structure, enhanced biodiversity, and better microclimatic conditions. In northern states like Katsina and Sokoto, farmers have introduced tree species such as *Faidherbia albida* to rehabilitate degraded lands and increase productivity (Ajayi & Akinnifesi, 2007). Efforts by the World Agroforestry Center (ICRAF) have led to the regeneration of over 5 million hectares of tree cover across the Sahel (Garrity et al., 2010). Agroforestry also generates non-timber forest products such as fruit and medicinal plants, contributing to income diversification. These practices play a vital role in carbon sequestration and environmental protection.

Given Nigeria's underutilized irrigation potential—with just 1% of cultivated land under formal irrigation—climate-smart irrigation techniques like drip irrigation and rainwater harvesting are being piloted in Bauchi, Niger and Ogun states. Support from FMARD, USAID, and GIZ has enabled farmers to access affordable irrigation systems, such as drip kits, which help conserve water and enhance productivity (Ayoade et al., 2019). These systems are particularly effective for managing water resources during dry spells. Meanwhile, drought-tolerant crops developed by institutions like IAR and NASC, such as improved varieties of maize and sorghum, have significantly enhanced food security, especially in arid regions like Kaduna and Zamfara (Setimela et al., 2017).

Other CSA strategies include organic farming and Integrated Pest Management (IPM), which reduce the dependence on synthetic inputs and enhance ecological balance. Programmes led by PROLINNOVA-Nigeria and the Green Sahel Initiative have promoted composting, the use of green manure, and biological pest control, particularly in Benue and Plateau States (Ogbene et al., 2020). ICTs also play a vital role in CSA, enabling farmers to access weather forecasts, market prices, and farming advice. NiMet's Seasonal Rainfall Prediction (SRP) and CIRDA's training initiatives have improved farmers' ability to plan and make informed decisions (Akinyele & Dauda, 2021). Digital platforms such as Esoko and FarmCrowdy further support precision farming and market access, helping farmers cope with climate uncertainties and improve yields.

CSA and the Nigerian Food Security Nexus

Climate-Smart Agriculture (CSA) offers a promising solution to the complex challenge of food security in the face of climate change. As defined by the Food and Agriculture Organization (FAO, 2013), CSA aims to sustainably increase agricultural productivity, strengthen resilience to climate impacts, and lower greenhouse gas emissions. In Nigeria, where unpredictable weather patterns have disrupted traditional farming cycles, CSA has emerged as a crucial strategy. It supports food security across four pillars: availability, access, utilization, and stability. By integrating adaptive and sustainable farming practices, CSA ensures that Nigeria's food systems can thrive despite climatic uncertainties.

Regarding food availability, CSA enhances productivity by introducing resilient crop varieties and conservation farming. Nigerian farmers in drought-affected regions, such as Kaduna and Katsina, have benefitted from drought-tolerant maize developed under the Drought Tolerant Maize for Africa (DTMA) initiative, achieving yield increases of up to 40% during dry spells (Setimela et al., 2017). Furthermore, conservation agriculture practices like minimal tillage and mulching have improved soil quality and water retention, especially in states

like Zamfara and Niger. These methods ensure consistent food production and help reduce losses due to erratic rainfall. By boosting output, CSA directly supports the availability of essential staple crops.

Food access is also improved through CSA, as it stabilizes incomes and broadens market opportunities for smallholder farmers. Integrated systems—combining crops, trees, and livestock—have enabled farmers in states such as Benue and Kogi to generate income throughout the year (Ajayi & Akinnifesi, 2007). Dry-season farming supported by solar-powered irrigation in states like Kano and Bauchi has further expanded farmers' income streams (FMARD, 2017). Digital platforms like FarmCrowdy and AgroMall now connect farmers to financing, inputs, and buyers, improving financial inclusion and strengthening purchasing power (Akinyele & Dauda, 2021). As such, CSA empowers rural households to access nutritious food more reliably.

CSA also enhances food utilization by promoting the use of nutrient-rich crops and diversified farming. Initiatives supporting the cultivation of biofortified crops like Vitamin A-rich cassava and orange-fleshed sweet potatoes in Imo, Ogun, and Nasarawa have improved dietary intake, especially among vulnerable groups (HarvestPlus Nigeria, 2020). Integrated farming that includes vegetables, legumes, and poultry contributes to household food diversity and better nutrition. Research by Olatunji and Oladele (2020) showed that CSA adopters in southwestern Nigeria reported higher dietary diversity than conventional farmers. Given Nigeria's ongoing struggle with malnutrition—where nearly four in ten children under five are stunted (UNICEF Nigeria, 2023)—these benefits are particularly critical.

Finally, CSA contributes to food systems' stability by building resilience against environmental and socio-economic shocks. Farmers in Oyo and Ekiti who use climate information services have improved their planting decisions by maintaining steady yields despite erratic weather (Akinyele & Dauda, 2021). In flood-prone areas, such as Bayelsa and Anambra, innovative solutions such as raised-bed farming and floating gardens have helped to minimize seasonal crop losses. Community seed banks in the North ensure continued access to adaptive varieties during crises. Additionally, CSA mitigates conflict risks in regions affected by farmer-herder tensions by reducing dependency on rain-fed agriculture (Blench, 2021). Altogether, CSA serves as a stabilizing force for Nigeria's food systems in an era of climate uncertainty.

Challenges to CSA Implementation in Nigeria

Despite the acknowledged role of Climate-Smart Agriculture (CSA) in promoting food security and resilience against climate change, several significant challenges hinder its effective implementation in Nigeria. These barriers span socio-economic, institutional, technical, and infrastructural dimensions, posing complex difficulties for smallholder farmers who make up the majority of Nigeria's agricultural workforce. Without adequately addressing these challenges, CSA's potential to deliver sustainable agricultural development under changing climatic conditions cannot be fully realized. Furthermore, the urgency of climate change demands prompt action to make farming more adaptive and sustainable. Hence, understanding these impediments is vital for designing effective interventions.

One critical challenge to CSA adoption in Nigeria is the low level of awareness and capacity among smallholder farmers. Many rural farmers are unfamiliar with CSA principles, confusing them with conventional farming methods because of the absence of tailored sensitization programmes. Studies such as Abdullahi et al. (2021) and Eze et al. (2018) revealed that knowledge of conservation agriculture is minimal, particularly in Northern and Southeastern Nigeria. This gap is intensified by widespread illiteracy and the lack of access to agricultural training, which restricts farmers' ability to benefit from weather-based advisory services and

improved technologies. Addressing this knowledge gap through education and training is necessary to improve farmers' resilience and productivity.

Another pressing obstacle is limited access to finance, extension services, and climate-resilient technologies. Credit facilities are largely inaccessible to smallholder farmers due to high interest rates and rigid collateral requirements, limiting their ability to invest in CSA innovations. Nwankwo and Agbo (2020) reported that a very small fraction of farmers in Southeast Nigeria can access loans for agricultural improvement. Compounding this issue is the insufficient number of extension agents, with a ratio far below the FAO's recommendation. In many rural areas, the absence of reliable digital infrastructure also prevents farmers from receiving timely agro-advisories, further weakening their capacity to adopt CSA practices. These systemic shortcomings limit the scale and impact of CSA interventions.

Institutional and policy challenges also play a significant role in slowing CSA implementation. While CSA is referenced in national policies and Nigeria's Nationally Determined Contributions (NDCs), no dedicated national strategy with clearly defined roles, financing plans, and monitoring mechanisms exists. Akudugu et al. (2019) highlighted the fragmented nature of CSA-related policies, with overlapping mandates across ministries and poor coordination between federal and state governments. The lack of policy coherence undermines the effectiveness of CSA promotion efforts. Additionally, existing policies, such as the Agricultural Promotion Policy (2016–2020), have not adequately prioritized climate adaptation, leaving gaps in planning and implementation.

Furthermore, insecure land tenure systems farmers—especially discourage women and youth—from investing in long-term CSA measures such as agroforestry or soil regeneration. Many rural farmers lack formal land ownership, leading to uncertainty and reluctance in adopting practices that require sustained commitment. Gender disparities in land access and agricultural resources are particularly pronounced. As Meinzen-Dick et al. (2017) and Babalola et al. (2022) observed, women contribute significantly to food production but often lack the rights and resources to fully participate in CSA. Empowering women and ensuring equitable access to land and climate information are key to improving household food security and CSA adoption.

Finally, the lack of supporting infrastructure and market access hinders the economic viability of CSA practices. Poor road networks, limited storage facilities, and unreliable electricity make it difficult for farmers to preserve and market their produce. Post-harvest losses, which remain alarmingly high in regions like Northern Nigeria, discourage investment in CSA practices that could otherwise boost yields. Moreover, unstable market linkages and fluctuating prices reduce incentives to diversify into high-value crops. As Okolo and Ogbonna (2020) suggested, unless farmers are assured of market opportunities and stable prices, they will continue to favor short-term survival strategies over climate-resilient practices.

Policy and Institutional Framework for Climate-Smart Agriculture in Nigeria

Over time, Nigeria has introduced several agricultural policies aimed at improving climate resilience, boosting productivity, and addressing food insecurity. The National Agricultural Resilience Framework (NARF), developed by the Federal Ministry of Agriculture and Rural Development (FMARD) in 2014, integrates climate adaptation directly into agricultural planning. It promotes strategies such as weather-indexed insurance, water conservation, and the cultivation of climate-resilient crops. NARF also champions community-based and participatory approaches in line with global Climate-Smart Agriculture (CSA) principles. Complementing this is the Agricultural Promotion Policy (APP) 2016–2020, which, although primarily focused on productivity and private sector participation, acknowledges climate resilience as a critical component.

In alignment with international climate commitments, Nigeria's Nationally Determined Contributions (NDCs) under the Paris Agreement incorporate CSA to help reduce agricultural emissions. Despite strong policy intentions, actual implementation has been inconsistent due to challenges such as limited funding, poor coordination between agencies, and weak monitoring mechanisms. These issues hinder the full realization of the climate goals embedded in these frameworks. Experts like Ifejika Speranza (2017) have emphasized the need for more robust and coordinated efforts to translate these policies into tangible results for farmers and agribusiness.

Several Nigerian institutions play vital roles in supporting CSA programmes. FMARD leads policy formulation and coordinates projects that promote mechanization, sustainable land management, and climate-resilient farming. The Nigerian Meteorological Agency (NiMet) contributes by offering climate predictions and agro-meteorological updates through accessible channels such as radio and television. Additionally, the National Agricultural Seeds Council (NASC) regulates and certifies quality seeds, encouraging the use of improved varieties suitable for varying climate conditions. Research institutions like NAERLS and NRCRI also assist in CSA implementation through training, extension services, and adaptive research.

International agencies have significantly contributed to Nigeria's CSA advancement by offering technical support, funding, and knowledge-sharing platforms. The Food and Agriculture Organization (FAO) has helped develop Nigeria's CSA profile and supports various projects in conservation agriculture and drought resilience. The International Fund for Agricultural Development (IFAD) funds initiatives that promote irrigation, agro-processing, and soil conservation. Through TRIMING and APPEALS projects, the World Bank improves irrigation infrastructure and enhances farmers' access to climate information, helping them better adapt to changing environmental conditions.

Other international partners, such as USAID, GIZ, and the African Development Bank (AfDB), are also instrumental in promoting CSA practices. Their efforts span rural electrification, climate financing, and gender-sensitive programming, ensuring broader inclusion and impact. Collectively, these agencies and institutions form a critical support system that aids Nigeria's transition toward a climate-resilient agricultural sector. Nevertheless, stronger institutional synergy, consistent policy enforcement and enhanced stakeholder engagement are necessary to maximize the potential of these interventions.

Proposed Conceptual Model: Linking CSA to Food Security Outcomes in Nigeria

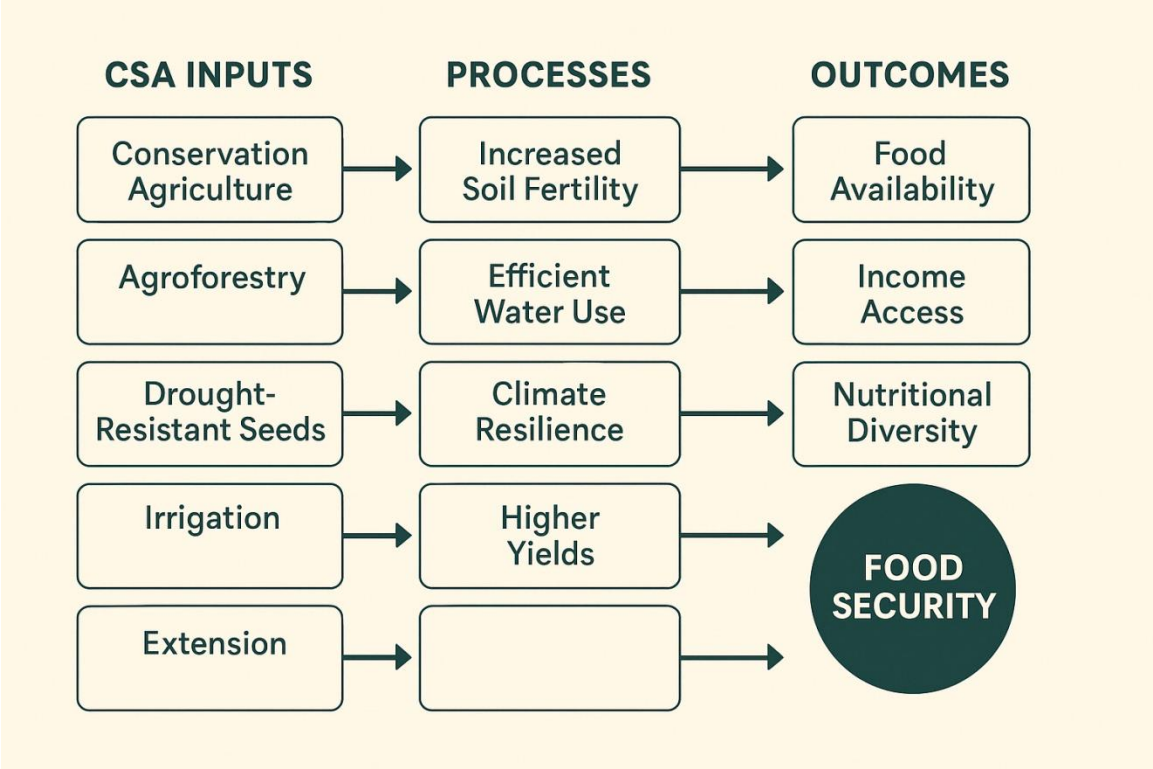
A conceptual model is vital for understanding how Climate-Smart Agriculture (CSA) operates, particularly in terms of aligning agricultural inputs, processes, and outcomes. The model offers a logical progression from CSA interventions to improved agricultural resilience and productivity, which, in turn, leads to enhanced food security in Nigeria. The study also highlights the collaborative roles of various stakeholders, including farmers, government institutions, researchers and the private sector. Each of these actors contributes to creating a sustainable agricultural system capable of enduring climate change. This model serves as a strategic framework for policymakers and practitioners in the field of agriculture.

The foundation of this model rests on specific CSA inputs, such as conservation agriculture, agroforestry, drought-tolerant crops, improved irrigation, and soil health management. It also incorporates support mechanisms like climate information services, extension training, and access to finance. These interventions are designed to minimize climate-related risks while boosting productivity. According to FAO (2013), these inputs must be aligned with national development goals to achieve maximum impact. The use of such resources will ensure a robust starting point for building climate-resilient farming systems.

The processes triggered by these inputs lead to increased resilience and agricultural productivity. Conservation techniques improve soil and water retention, whereas agroforestry provides ecological and economic benefits. Drought-resistant crops ensure stable yields under erratic rainfall conditions. Resilience here refers to a farm's ability to withstand climatic shocks, while productivity focuses on better yields using fewer resources. The IITA (2020) reported that CSA trials in Northern Nigeria achieved significant yield gains, underscoring the model's practical benefits.

These processes lead to improved food security across four dimensions: availability, access, utilization, and stability. Higher yields contribute to a stable food supply, whereas increased incomes allow households to afford more diverse and nutritious food. CSA practices also help reduce post-harvest losses and food supply fluctuations, ensuring long-term stability. Akinseye et al. (2020) found that using smart irrigation and climate-aware planting schedules in Northern Nigeria not only boosted yields but also enhanced food stability. These findings demonstrate the broad and lasting impact of CSA strategies.

For the success of CSA, the integration of stakeholders is crucial. Farmers play a central role through their engagement and local knowledge. Government bodies offer policy and infrastructure support, whereas the private sector provides access to markets, inputs and financing. Research institutions generate evidence-based, locally adapted solutions, and development partners offer technical and financial aid, especially to vulnerable areas. The cooperation of all these groups is essential for scaling up CSA and ensuring food security in Nigeria's climate-challenged regions.



This conceptual model illustrates that Climate-Smart Agriculture, when embedded within a supportive ecosystem of stakeholders, contributes significantly to agricultural sustainability and national food security. By linking CSA inputs with measurable productivity and resilience outcomes, policymakers and practitioners can better allocate resources, design effective programmes and monitor impacts. The model provides a framework not only for understanding current efforts but also for planning and scaling CSA interventions in Nigeria's diverse agro-ecological zones.

Theoretical Framework

Sustainable Livelihood Framework (SLF)

The Sustainable Livelihood Framework (SLF)**,** developed by the UK Department for International Development (DFID, 1999), is widely used in rural development research to understand how individuals and households use various assets to achieve livelihood outcomes. The SLF identifies five categories of capital assets: human capital (skills, knowledge, health), natural capital (land, water, biodiversity), financial capital (savings, income, credit), physical capital (tools, infrastructure), and social capital (networks, relationships, access to institutions). These assets interact within a vulnerability context—characterized by shocks (e.g., droughts, floods), trends (e.g., climate variability), and seasonality (e.g., crop cycles)—and are influenced by transforming structures and processes**,** including government policies, market access, and social norms.

In the Nigerian context, the SLF provides a valuable framework for analyzing how rural households cope with climate-related challenges. For example, Yusuf et al. (2020) applied the SLF to assess the livelihood impacts of climate variability on farming households in Northern Nigeria. Their study found that access to extension services, credit, and climate-resilient seed varieties significantly influenced farmers' adaptive capacity. Similarly, Olanrewaju et al. (2019) argued that the integration of CSA practices into the SLF can enhance livelihood sustainability by increasing productivity while reducing vulnerability to environmental shocks. The framework's flexibility allows for identifying leverage points for policy intervention, especially in designing targeted support for resource-poor farmers most affected by climate change.

Moreover, SLF emphasizes livelihood strategies**,** which are the means by which people combine their assets and respond to external factors to achieve outcomes such as income, food security and resilience. For instance, the adoption of agroforestry or mixed cropping in Nigeria's Middle Belt can be seen as a livelihood strategy that supports both adaptation and food availability. This approach enables a holistic assessment of resilience-building efforts and informs the design of integrated rural development programmes.

Systems Theory

In complementing the SLF, Systems Theory provides an equally critical lens through which to understand agricultural development as an interrelated web of components functioning within larger ecological, socioeconomic, and political systems. Originating from the work of Ludwig von Bertalanffy in the mid-20th century, Systems Theory views agriculture not in isolation but as a sub-system within a broader system—comprising input-output flows, feedback loops, external drivers, and adaptive mechanisms (Checkland, 1999). In agricultural development, the theory stresses that farming systems are dynamic and complex and are, influenced by changes in climate, policy, market forces and technology.

In practice, Systems Theory has been applied in agricultural systems research to design sustainable interventions that account for the interconnectedness of farming practices, environmental sustainability, and socioeconomic realities. For example, Tittonell and Giller (2013) used systems thinking to explore the heterogeneity of smallholder farms in Sub-Saharan Africa, including Nigeria, and found that interventions must be context-specific, considering both biophysical and socioeconomic differences. Likewise, Adejuwon (2016) emphasized the value of systems-based analysis for understanding the impact of climate change on Nigerian agriculture, advocating for integrated adaptation strategies that span water resource management, seed systems, land use, and institutional support.

Systems Theory also encourages participatory approaches to agricultural development in which local knowledge is incorporated into planning and implementation processes. This aligns with recent efforts in Nigeria to promote farmer-centered innovation platforms, where extension agents, researchers, and farmers

collaborate to test and refine agricultural innovations suited to local conditions (Agwu, Dimelu, & Madukwe, 2008).

When combined, the SLF and Systems Theory offer a robust analytical foundation for understanding and improving agricultural resilience in Nigeria. While SLF provides a people-centered, asset-based approach to livelihood sustainability, Systems Theory offers a macro-level perspective that integrates environmental feedback and system-wide interactions. Together, these theories facilitate a comprehensive understanding of the complex, multi-scalar dynamics of agricultural development under climate change stressors.

Methodology

This study adopts a qualitative approach to explore the challenges faced by farmers in adapting to shifting climatic conditions, as well as the effectiveness of Climate-Smart Agriculture (CSA) strategies in mitigating these impacts. Secondary data will be gathered from a range of sources, including government reports, academic journals, and publications from international organizations such as the Food and Agriculture Organization (FAO), the Nigerian Meteorological Agency (NiMet), and the United Nations Development Programme (UNDP). These sources will provide valuable historical data on climate patterns, extreme weather events, and current agricultural policies aimed at enhancing climate resilience.

Discussion of Findings

This discussion reveal the multifaceted impact of climate change on agriculture in Nigeria and highlight the critical role of Climate-Smart Agriculture (CSA) in mitigating these effects. Climate change, marked by rising temperatures, erratic rainfall, and more frequent extreme weather events, has significantly disrupted agricultural activities in the country. For example, increases in temperature and changes in rainfall patterns affect the timing of planting and harvesting, making traditional farming methods increasingly unreliable (NiMet, 2020). This unpredictability in weather conditions has led to crop failures, especially in the semi-arid northern regions, exacerbating food insecurity (Apata, Samuel, & Adeola, 2009). Furthermore, extreme weather events like floods and droughts have intensified the vulnerability of agricultural systems, leading to massive destruction of crops and increased poverty (UNDP Nigeria, 2013).

In addition, climate change has severely impacted livestock farming, particularly due to higher temperatures and desertification. This has resulted in water shortages and reduced grazing land, contributing to a rise in livestock deaths and conflicts between pastoralists and farmers over resources (FAO, 2019). In southern Nigeria, rising sea levels and polluted water bodies have further threatened fishing communities, particularly in the Niger Delta, where declining fish catches are disrupting livelihoods (Olaniyi et al., 2014).

In response to these challenges, CSA practices have gained traction in Nigeria, with various initiatives aimed at increasing agricultural resilience. These include conservation agriculture, agroforestry, improved irrigation systems, and the use of drought-tolerant crops (FAO, 2013). The implementation of CSA practices has led to improvements in soil fertility, water retention, and overall agricultural productivity, as evidenced in states like Kaduna and Katsina (Erenstein et al., 2012). However, adoption of these practices has been slow, largely due to cultural preferences for traditional farming methods and limited access to resources such as training, finance, and technology (Abdullahi et al., 2021; Nwankwo & Agbo, 2020).

Despite the promising potential of CSA, several challenges have impeded its effective implementation. Key obstacles include a lack of awareness among farmers, limited access to financial resources and extension services, and poor infrastructure (Akinyele & Dauda, 2021). The absence of cohesive policies and poor coordination between government institutions also hampers progress (Akudugu et al., 2019). Moreover,

insecure land tenure, particularly for women and youth, reduces the incentive to invest in long-term CSA practices, further undermining food security efforts (Meinzen-Dick et al., 2017).

The policy and institutional framework supporting CSA in Nigeria includes the National Agricultural Resilience Framework (NARF) and the Agricultural Promotion Policy (APP), which emphasize climate adaptation strategies such as weather-indexed insurance and the promotion of climate-resilient crops. However, these policies need to be better coordinated and aligned with grassroots needs for more effective implementation.While climate change poses a significant threat to agriculture in Nigeria, CSA offers a promising pathway to enhance resilience and food security. However, overcoming the challenges of limited awareness, inadequate infrastructure, and poor policy coordination is crucial for maximizing the benefits of CSA.

Conclusion

Climate-Smart Agriculture (CSA) offers a transformative and people-centered strategy for addressing climate change, enhancing resilience, and ensuring food security in Nigeria. It aligns with national priorities such as the Agricultural Promotion Policy and the country's climate commitments, yet its adoption remains limited due to challenges like low awareness, weak infrastructure and insufficient investment. To unlock CSA's full potential, there is an urgent need for coordinated investments in innovation, infrastructure, and institutional capacity are urgently needed. A multi-stakeholder approach involving the government, private sector, development partners, and local communities—especially youth and women—is essential for scaling up CSA. With inclusive and integrated action, Nigeria can transform the challenge of climate change into a pathway toward sustainable agricultural transformation.

Recommendations

To fully harness the potential of Climate-Smart Agriculture (CSA) in Nigeria and ensure long-term food security in the middle of the growing threat of climate change, the following recommendations are crucial:

1. Incorporating CSA principles into national agricultural extension programs and curricula is essential to enhance farmers' knowledge and skills. Training extension officers in CSA practices and facilitating participatory learning will significantly increase adoption rates and improve climate resilience among farmers.
2. Providing localized climate information services and expanding financial support mechanisms such as index-based insurance and low-interest loans will empower smallholder farmers to make informed decisions. This approach will help farmer's access resilient technologies and recover from climate shocks.
3. Creating a cohesive policy framework and improving coordination among key agricultural and meteorological agencies will enhance the effectiveness of CSA initiatives. A unified national CSA implementation roadmap with robust monitoring and evaluation will ensure better alignment with national development goals.
4. Leveraging private sector involvement through PPPs can accelerate the adoption of CSA by mobilizing investments in climate-resilient technologies. Successful collaborations, like the NIRSAL-IFAD programme, demonstrate how private sector participation can drive innovation and improve market access.
5. Designing CSA interventions that address gender disparities is crucial for empowering women farmers, who play a vital role in food production. Providing targeted training, access to finance, and secure land rights will promote greater gender equity and enhance the effectiveness of CSA in rural areas.

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