Climate-Smart Agriculture and Food Security in Nigeria: Assessing Adaptation Strategies, Productivity and Resilience Among Smallholder Farmers

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Abstract
Climate change poses a significant threat to agricultural productivity, food security and rural livelihoods in Nigeria, particularly among smallholder farmers whose production systems depend largely on climate-sensitive natural resources. This paper reviews the concept and relevance of Climate-Smart Agriculture (CSA) as an approach for strengthening agricultural adaptation, productivity and resilience in Nigeria. The review examines major climate-smart adaptation strategies, the relationship between CSA and agricultural productivity and food security, the contribution of CSA to smallholder farmers' resilience, major constraints to adoption, and the policy and institutional framework supporting its implementation. Evidence from recent literature indicates that practices such as crop diversification, inter cropping, crop rotation, improved and climate-tolerant varieties, agroforestry, mulching, soil and water conservation, irrigation, improved climate information and adjustment of planting dates can reduce farmers' vulnerability to climate-related risks while improving production and household food-security outcomes. However, adoption remains constrained by limited access to credit, inadequate extension services, high costs of climate-smart technologies, insufficient climate information, weak infrastructure and limited technical capacity. The paper concludes that CSA provides an important pathway for building productive, food-secure and climate-resilient smallholder farming systems in Nigeria. It recommends strengthened agricultural extension, affordable climate finance, improved climate information services, investment in resilient infrastructure, context-specific technologies, farmer organizations and effective implementation of supportive agricultural and climate policies.

Keywords: *Climate-Smart Agriculture; Climate Change; Smallholder Farmers; Agricultural Productivity; Food Security; Adaptation Strategies; Resilience; Nigeria.*

1.0 Introduction

Agriculture occupies a central position in Nigeria's economy, food system and rural livelihood structure, with smallholder farmers constituting an important component of domestic food production. However, the sustainability of agricultural production is increasingly threatened by climate change and associated environmental stresses. Changes in temperature, rainfall variability, drought, flooding, prolonged dry spells and other extreme weather events have increased uncertainty in agricultural production and exposed smallholder farmers to considerable livelihood risks. Because many smallholder farmers depend substantially on rain-fed agriculture and operate with limited access to irrigation, finance, improved technologies and institutional support, their vulnerability to climatic shocks is particularly pronounced. A

recent review of climate-change adaptation in Nigeria identified agriculture as the dominant sector requiring adaptive capacity and emphasized the need for stronger social, structural and institutional responses to climate risks (Aigbe et al., 2024).

The implications of climate change for agriculture are closely connected with Nigeria's persistent food-security challenges. Climate-related disruptions can reduce crop yields, damage agricultural infrastructure, degrade soils and water resources, increase production costs and consequently affect food availability and affordability. These challenges are compounded by inflation, insecurity, high transportation costs and other socioeconomic pressures. The severity of the food-security situation is demonstrated by the Cadre Harmonisé assessment, which projected that 30.6 million Nigerians in 26 states and the Federal Capital Territory would face acute food and nutrition insecurity during the June–August 2025 lean season (FAO, 2025). Earlier projections had placed the figure at 33.1 million people, illustrating the continuing vulnerability of the national food system to interacting climatic and socioeconomic shocks (FAO, 2024). Smallholder farmers are particularly important in addressing this challenge because their production activities contribute significantly to local food supplies and rural livelihoods. However, their ability to respond effectively to climate variability depends on their adaptive capacity, access to resources and knowledge, and the availability of appropriate agricultural technologies. Evidence from Nigeria indicates that farmers employ various adaptation measures, including changes in planting dates, crop diversification, improved varieties, irrigation, soil-management practices and other adjustments to production systems. Nevertheless, the extent and intensity of adoption remain constrained by factors such as inadequate extension services, limited access to credit, insufficient climate information and socioeconomic characteristics. For example, a 2024 study of smallholder rice farmers in Kebbi State found that literacy, farm size, farming experience, extension contact, credit and access to climate information influenced farmers' choices and intensity of climate-change adaptation strategies (2024). Within this context, Climate-Smart Agriculture (CSA) has emerged as an important framework for transforming agricultural systems in response to climate change while maintaining food production and rural livelihoods. CSA is not a single agricultural technology but an integrated approach that seeks to achieve three interconnected objectives: sustainably increasing agricultural productivity and incomes, strengthening resilience and adaptive capacity to climate change, and reducing or removing greenhouse-gas emissions where possible. The approach therefore brings together agricultural development, climate adaptation and environmental sustainability. The World Bank (2024) identifies CSA as a pathway for achieving increased productivity, enhanced resilience and reduced emissions while contributing to food-security objectives. The application of CSA among smallholder farmers can involve a wide range of practices depending on local ecological and socioeconomic circumstances. These include the use of drought- and heat-tolerant crop varieties, crop diversification, intercropping, crop rotation, agroforestry, conservation agriculture, mulching, improved soil and water management, irrigation, integrated crop-livestock systems, efficient fertilizer management and adjustments to planting calendars. Such practices can help farmers reduce exposure and sensitivity to climatic hazards while maintaining or improving agricultural productivity. A recent systematic review of climate-induced food insecurity in Nigeria emphasized that adaptation strategies are central to reducing the effects of drought and flooding on agricultural production and strengthening the resilience of vulnerable farming communities (Akinkuolie et al., 2025). The potential contribution of CSA to agricultural productivity and food security is increasingly supported by recent literature. Evidence from Nigerian maize-based farming households indicates that integrated CSA practices can improve productivity and reduce vulnerability to climate-related risks. The 2025 study by Adetomiwa and Sieber found that combinations of climate-smart practices generated significant productivity gains and contributed to improved household dietary diversity, although the authors also identified

important trade-offs among different food-security indicators. This finding is significant because it demonstrates that the relationship between CSA and food security is multidimensional and cannot be assessed solely through crop yields (Adetomiwa & Sieber, 2025). Similarly, research among rural farming households in south-western Nigeria found that participation in climate-smart agricultural practices was associated with improved food consumption, dietary diversity and food-security outcomes (2024).

Beyond productivity and food availability, CSA has important implications for the resilience of smallholder farmers. Agricultural resilience refers broadly to the capacity of farming households and production systems to withstand, adapt to and recover from climatic and other shocks while maintaining essential functions and livelihoods. CSA contributes to resilience by reducing farmers' dependence on a single crop or production strategy, improving resource-use efficiency, diversifying income and strengthening their capacity to respond to climatic uncertainty. Recent research in Nigeria has also emphasized the importance of social networks, including farmers' associations, kinship systems, extension contacts and relationships with development organizations, in facilitating information exchange, collective action and climate adaptation among smallholder farmers (2025).

Despite the growing recognition of CSA, its adoption and outcomes in Nigeria are influenced by substantial institutional, financial, technological and socioeconomic constraints. The benefits of climate-smart practices may not be realized where farmers lack access to affordable credit, extension services, reliable climate information, markets, improved inputs and appropriate technologies. Furthermore, practices that are effective in one agro-ecological or socioeconomic setting may not produce similar outcomes elsewhere. This reinforces the need for context-specific approaches that recognize the diversity of Nigeria's farming systems. Recent reviews of climate-change adaptation in Nigeria have consequently emphasized that institutional support, education, infrastructure and enabling policies are essential for strengthening farmers' adaptive capacity and building climate-resilient agricultural systems (Aigbe et al., 2024; Akinkuolie et al., 2025).

Against this background, Climate-Smart Agriculture provides a potentially important pathway for reconciling the competing demands of agricultural productivity, food security, climate adaptation and environmental sustainability in Nigeria. Its importance extends beyond the adoption of individual farm practices to encompass access to knowledge, climate information, finance, markets, extension services, technology and supportive institutional and policy frameworks. A recent conceptual assessment of CSA in Nigeria argues that strengthening resilience through climate-smart practices can improve farmers' adaptive and coping capacities and contribute to reducing food insecurity (Ajie & Uche, 2025). Consequently, examining CSA through the interconnected dimensions of adaptation strategies, agricultural productivity, food security and resilience provides a useful basis for understanding how Nigeria can develop more sustainable and climate-resilient smallholder farming systems. This review therefore examines the concept and application of Climate-Smart Agriculture in Nigeria, with particular emphasis on adaptation strategies, productivity, food security and resilience among smallholder farmers.

2.0 Conceptual Understanding of Climate-Smart Agriculture

Climate-Smart Agriculture (CSA) is an integrated approach to agricultural development that seeks to address the interconnected challenges of climate change, food production, food security and environmental sustainability. Rather than representing a single farming technology, CSA provides a framework for identifying agricultural practices, technologies and management systems that can enable farmers to sustain production under changing climatic conditions. The concept emphasizes the need to make agricultural systems more productive while simultaneously strengthening their capacity to adapt to climate variability and, where

feasible, reducing greenhouse-gas emissions. Recent literature continues to position CSA as an important pathway for strengthening the sustainability and resilience of smallholder farming systems facing increasing climate risks (Izuogu et al., 2025; Rurii & Nzengya Daniel, 2026).

Conceptually, CSA is founded on three major objectives, often referred to as the CSA "triple win": sustainably increasing agricultural productivity and incomes, enhancing farmers' resilience and adaptive capacity, and reducing or avoiding greenhouse-gas emissions where possible. These objectives are interrelated but their relative importance may vary according to local environmental and socioeconomic circumstances. Thus, CSA does not prescribe a universal package of practices for all farmers; rather, it encourages the selection of practices that are appropriate to particular farming systems and climatic conditions. In Nigeria, this may include crop diversification, crop rotation, intercropping, mulching, organic manure application, minimum tillage, improved crop varieties, irrigation and adjustment of planting dates (Izuogu et al., 2025; Mbossoh & Udoh, 2026).

An important dimension of CSA is its emphasis on adaptation and resilience. Smallholder farmers, particularly those dependent on rain-fed agriculture, are highly exposed to droughts, floods, irregular rainfall, rising temperatures, pests and other climate-related stresses. CSA seeks to reduce such vulnerability by improving farmers' capacity to anticipate, withstand and recover from climatic shocks. Practices such as drought-tolerant varieties, water conservation, agroforestry, crop diversification and improved soil management can help stabilize production under variable climatic conditions. A recent review of CSA adoption among African smallholders emphasizes that the ultimate value of CSA should be assessed not only through increased production but also through its contribution to resilience, food security and livelihood stability (Rurii & Nzengya Daniel, 2026).

The concept of CSA also extends beyond individual farm practices to include institutional, technological and socioeconomic support systems. Farmers' ability to adopt climate-smart practices is influenced by access to credit, agricultural extension, climate information, markets, improved inputs, education and appropriate technologies. Recent evidence from Nigeria shows that access to credit, extension services, farming experience and education are important determinants of CSA adoption, while high implementation costs, inadequate technical skills and weak policy support remain significant barriers (Izuogu et al., 2025). Similarly, recent Nigerian research identified a range of climate-smart practices and demonstrated that farmers' choice of practices is influenced by location-specific socioeconomic and production conditions (Mbossoh & Udoh, 2026). In the context of this review, therefore, Climate-Smart Agriculture can be understood as a holistic approach to transforming Nigerian smallholder farming systems so that they can maintain or improve productivity, adapt effectively to climate change, strengthen food security and build long-term resilience while minimizing environmental impacts. This understanding is particularly relevant to Nigeria, where climate variability, food insecurity and rural livelihood vulnerability increasingly intersect. Recent conceptual and review literature indicates that CSA can contribute to food-insecurity reduction by strengthening farmers' adaptive and coping capacities, although its effectiveness depends heavily on appropriate practices, farmer awareness and supportive institutional conditions (Ajie & Uche, 2025; Izuogu et al., 2025).

3.0 Climate Change and Agricultural Production in Nigeria

Climate change has become a major threat to agricultural production in Nigeria because of the sector's strong dependence on climatic conditions, particularly rainfall and temperature. Changes in the timing, intensity and distribution of rainfall, together with increasing temperatures and more frequent extreme weather events, are altering the conditions under which crops and livestock are produced. These changes are particularly significant for smallholder farmers who depend largely on rain-fed agriculture and have limited capacity to

invest in irrigation, improved technologies and other risk-management measures. A recent review of climate change and agriculture in Nigeria identifies erratic rainfall, rising temperatures, droughts and floods as major factors undermining agricultural productivity and food security (Science in One Health, 2025). The effects of climate change on crop production occur through several interconnected pathways. Excessive rainfall and flooding can destroy crops, wash away fertile topsoil, damage farm infrastructure and delay planting and harvesting, while inadequate rainfall and prolonged dry spells can cause moisture stress and crop failure. Rising temperatures may also accelerate evapotranspiration, reduce soil moisture and adversely affect crop growth and development. The 2025 FAO country assessment reported that Nigeria's 2024 cereal production was about 28.5 million tonnes, approximately 3% below the five-year average, while expectations of below-average rainfall and dry spells in some regions were identified as potential constraints to 2025 production (FAO, 2025). The vulnerability of Nigerian agriculture is particularly evident among smallholder farmers because climate shocks interact with existing socioeconomic constraints. Limited access to agricultural credit, improved seeds, fertilizer, irrigation, extension services and reliable climate information reduces farmers' capacity to respond effectively to changing climatic conditions. Recent research in south-western Nigeria found that farmers perceived declining agricultural output in association with changing climatic conditions and identified high input costs, unpredictable weather and inadequate credit as important constraints to adaptation (Odelola et al., 2025). Similarly, recent evidence from Nigeria shows that drought, flooding and temperature variability constitute important threats to major food crops, particularly within predominantly rain-fed farming systems (Ayodele et al., 2025). Climate change also affects agricultural production indirectly by increasing the incidence of pests and diseases, altering growing seasons and affecting the availability of water and other productive resources. Changes in temperature and rainfall can create favourable conditions for some pests and pathogens while simultaneously weakening crops through heat and water stress. These effects can reduce yields and increase farmers' production costs. Recent evidence from Nigeria shows that farmers are already responding to climatic changes through measures such as changing planting dates, adopting improved crop varieties, using intercropping and seeking weather information. However, the effectiveness of these measures depends on farmers' access to resources, information and institutional support (Odelola et al., 2025). The implications of climate-related disruptions to agricultural production extend beyond individual farms to national food security and rural livelihoods. Reduced agricultural productivity can contribute to food shortages, rising food prices, declining farm incomes and increased vulnerability among rural households. FAO reported that 25.1 million Nigerians were acutely food insecure during the last quarter of 2024, while 30.6 million people were projected to face acute food and nutrition insecurity during the June–August 2025 lean season. Flooding alone affected more than 9.2 million people and submerged approximately 4.5 million hectares of land, including about 1.6 million hectares of farmland, during October 2024 (FAO, 2024, 2025). Consequently, addressing the effects of climate change on Nigerian agriculture requires a shift from conventional production approaches towards systems capable of maintaining productivity under climatic uncertainty. Climate-Smart Agriculture provides an important pathway by combining adaptation, productivity improvement and environmental sustainability. Its relevance is particularly strong for smallholder farmers because practices such as improved and drought-tolerant varieties, crop diversification, soil and water conservation, adjusted planting calendars, agroforestry and improved climate information can strengthen their capacity to withstand climatic shocks. Recent Nigerian research indicates that climate-smart practices can contribute to improved agricultural productivity and more sustainable food production when supported by appropriate institutional and socioeconomic conditions (Odelola et al., 2025; Science in One Health, 2025).

4.0 Climate-Smart Agricultural Adaptation Strategies among Smallholder Farmers

Climate-Smart Agricultural (CSA) adaptation strategies refer to the range of farming practices, technologies and management decisions employed by smallholder farmers to reduce their vulnerability to climate variability and maintain agricultural productivity. These strategies enable farmers to adjust their production systems to changing rainfall patterns, rising temperatures, droughts, floods, pests and other climate-related stresses. In Nigeria, commonly identified CSA practices include crop rotation, intercropping, mulching, organic manuring, cover cropping, minimum tillage, the use of resistant and early-maturing crop varieties, irrigation and adjustment of planting dates (Mbossoh & Udoh, 2026).

One important adaptation strategy is crop diversification, which involves growing different crops rather than relying on a single crop. Intercropping, crop rotation and the use of early-maturing or climate-resistant varieties can reduce production risks and improve the ability of farmers to cope with climatic uncertainty. Diversification may also contribute to household food security because farmers can obtain food and income from different crops when one crop performs poorly. Recent evidence from Nigeria indicates that crop rotation, intercropping, improved varieties and changes in planting dates are among the important adaptation practices used by smallholder farmers (Mbossoh & Udoh, 2026; Odelola et al., 2025).

Soil and water management constitutes another important dimension of climate-smart adaptation. Practices such as mulching, organic manure application, cover cropping, minimum tillage, soil conservation and efficient irrigation can improve soil moisture retention, reduce erosion and maintain soil fertility under changing climatic conditions. These practices are particularly relevant where rainfall is becoming increasingly unpredictable or where prolonged dry periods expose crops to moisture stress. Recent research in Nigeria identifies mulching, organic manuring, cover cropping, minimum tillage and irrigation among the principal CSA practices available to smallholder farmers (Mbossoh & Udoh, 2026).

Access to climate and agricultural information is also an important adaptation strategy because timely information enables farmers to make better decisions about planting dates, crop selection, fertilizer application, pest management and responses to extreme weather events. Farmers increasingly obtain such information through extension agents, farmer groups, radio, mobile phones and other communication platforms. Recent research in Ebonyi State identified climate information, appropriate fertilizer application, improved crop varieties and changes in planting dates among the predominant adaptation strategies, while education, income, extension access, training and previous experience with climate events influenced the adoption of multiple strategies (2025). In southwestern Nigeria, farmers similarly identified changes in planting dates, improved crop varieties and weather-forecast services as important responses to changing climatic conditions (Odelola et al., 2025).

The effectiveness of these adaptation strategies is strongly influenced by the institutional and socioeconomic environment in which smallholder farmers operate. Access to agricultural extension, credit, farmer organizations, training, improved inputs and markets can determine whether farmers are able to adopt and sustain CSA practices. Recent evidence from Nigeria shows that farmers' participation in producer organizations is positively associated with the adoption and combination of multiple CSA practices, particularly relatively low-cost practices such as intercropping and crop rotation (2026). Similarly, recent studies identify high input costs, inadequate credit, limited technical knowledge and insufficient extension support as important constraints to effective climate adaptation (Odelola et al., 2025; Mbossoh & Udoh, 2026).

5.0 Climate-Smart Agriculture and Food Security in Nigeria

Climate-Smart Agriculture (CSA) has emerged as an important approach for addressing the growing food-security challenges associated with climate change in Nigeria. Food security

depends on the availability, accessibility, utilization and stability of adequate and nutritious food, all of which can be affected by declining agricultural productivity, extreme weather events and changing climatic conditions. Since a large proportion of Nigeria's food production comes from smallholder farmers who depend substantially on rain-fed agriculture, strengthening their capacity to adapt to climate change is essential for maintaining food supplies. Recent literature identifies CSA as a potentially important strategy for reducing the vulnerability of agricultural households to climate-induced food insecurity by improving adaptive and coping capacities (Ajie & Uche, 2025; Izuogu et al., 2025).

CSA contributes to food security by encouraging practices that can improve and stabilize agricultural production under changing climatic conditions. Practices such as crop diversification, intercropping, agroforestry, drought-tolerant varieties, improved soil management, irrigation and adjustment of planting dates can reduce production losses associated with droughts, floods, excessive temperatures and irregular rainfall. Evidence from Nigerian farming households indicates that adoption of climate-risk adaptation strategies improves food security by increasing dietary diversity and reducing reliance on negative food-security coping mechanisms. Access to extension services, climate information, credit and climate-change awareness were also identified as important factors supporting the adoption of such strategies (2024). Recent evidence further demonstrates the relationship between CSA adoption and household food-security outcomes in Nigeria. Omotoso and Omotayo (2025) found that households adopting CSA practices were more likely to achieve higher food-consumption scores, greater dietary diversity and improved food-security outcomes. Their findings particularly highlighted crop diversification, agroforestry and the use of Fadama land as practices associated with improved household food security. Similarly, recent research among maize-based farming households in southwestern Nigeria found that integrated CSA practices improved maize productivity and household dietary diversity, while also reducing farmers' exposure and sensitivity to climate-related risks (Omotoso & Omotayo, 2025; Adetomiwa & Sieber, 2025). Despite these potential benefits, the contribution of CSA to food security in Nigeria is not automatic and may involve important trade-offs. Farmers' ability to adopt and sustain climate-smart practices is influenced by access to finance, extension services, climate information, improved inputs, labour, markets and appropriate technologies. Recent evidence indicates that integrated CSA strategies can enhance productivity and resilience, but some practices may produce different food-security outcomes depending on household circumstances and local production conditions (Adetomiwa & Sieber, 2025). Therefore, promoting CSA as a pathway to food security in Nigeria requires context-specific interventions, stronger agricultural extension systems, improved access to climate information and credit, and policies that enable smallholder farmers to adopt combinations of practices suited to their local environments.

6.0 Climate-Smart Agriculture and Resilience of Smallholder Farmers

Climate-Smart Agriculture (CSA) is increasingly recognized as an important pathway for strengthening the resilience of smallholder farmers whose livelihoods are exposed to climate variability and extreme weather events. Resilience refers to the capacity of farmers and farming households to anticipate, absorb, adapt to and recover from climatic shocks while maintaining their agricultural activities and livelihoods. Smallholder farmers in Nigeria are particularly vulnerable because of their dependence on rain-fed agriculture, limited financial resources and inadequate access to irrigation, improved technologies, extension services and climate information. Recent evidence indicates that CSA can reduce farmers' exposure and sensitivity to climate risks while improving their capacity to sustain production under changing climatic conditions (Adetomiwa & Sieber, 2025; Mbossoh & Udoh, 2026).

The resilience-building potential of CSA derives from practices that reduce farmers' dependence on a single production strategy and improve the stability of agricultural systems. Crop diversification, intercropping, crop rotation, drought-tolerant and early-maturing varieties, mulching, organic manure application, minimum tillage, irrigation and adjustment of planting dates can help farmers cope with drought, irregular rainfall, flooding, soil degradation and other climatic stresses. Recent research in Nigeria identifies these practices as important components of farmers' climate-smart responses, although their adoption varies according to farmers' resources and local conditions (Mbossoh & Udoh, 2026).

Recent empirical evidence demonstrates a connection between CSA adoption and farmers' resilience. Adetomiwa and Sieber (2025) found that integrated CSA practices among maize-based farming households in south-western Nigeria reduced exposure and sensitivity to climate risks, particularly drought and rainfall variability, while simultaneously improving productivity. Similarly, research among smallholder farmers in the Niger Delta highlights the role of agricultural extension services in supporting CSA adoption and improving farmers' livelihoods and resilience. These findings suggest that resilience is strengthened when farmers have access not only to climate-smart technologies but also to the knowledge and institutional support required to use them effectively (Adetomiwa & Sieber, 2025; Okringbo et al., 2025).

However, the capacity of smallholder farmers to build resilience through CSA is constrained by socioeconomic and institutional factors. Limited access to credit, high costs of climate-smart technologies, inadequate extension services, poor access to weather information and risk aversion can prevent farmers from adopting more resource-intensive practices. Recent research in Northeast Nigeria found that only about 53% of surveyed farmers reported preparedness to absorb climate-related shocks, with important gender and spatial differences in adaptive capacity (Peter et al., 2026). Consequently, strengthening smallholder resilience requires more than promoting individual CSA practices; it requires coordinated investments in agricultural extension, climate information, affordable finance, irrigation, farmer organizations and supportive policies.

7.0 Constraints to the Adaptation of Climate-Smart Agriculture in Nigeria

The adaptation of Climate-Smart Agriculture (CSA) among smallholder farmers in Nigeria is constrained by a combination of economic, institutional, technological, informational and environmental factors. Although CSA practices have considerable potential to improve agricultural productivity and resilience, many smallholder farmers operate with limited financial and material resources, making it difficult to adopt technologies that require substantial initial investment. High costs of improved seeds, irrigation equipment, fertilizers, machinery and other climate-smart inputs can discourage adoption, particularly among low-income farmers. A recent review of climate-change adaptation innovations among smallholders identified socioeconomic, financial, informational and institutional constraints as among the most important barriers to adoption, with financial limitations often interacting with other constraints (Obe et al., 2025).

Limited access to agricultural credit, insurance and other financial services is another significant constraint. Many smallholder farmers lack sufficient capital to invest in irrigation, improved crop varieties, water-conservation facilities and other CSA technologies. Where credit is available, high interest rates, stringent lending conditions and inadequate agricultural insurance may limit farmers' ability to use these financial services. Evidence from Kebbi State indicates that lack of access to farmer-based insurance constitutes an important economic barrier, while inadequate government support for agricultural inputs further constrains adoption (Danmaigoro et al., 2025). Similarly, evidence from Nigerian farmers indicates that financial constraints remain central to the limited uptake of climate-smart practices.

Another major constraint is inadequate extension services and limited access to reliable climate information. CSA practices often require technical knowledge concerning appropriate crop varieties, planting dates, soil management, water conservation and pest control. However, insufficient numbers of extension personnel, inadequate mobility and weak farmer-extension linkages limit the dissemination of such knowledge. Recent research in Yobe State found that extension agents and farmer groups were major sources of CSA information, demonstrating the important role of agricultural advisory services in facilitating adoption (Kyari et al., 2025). Earlier Nigerian evidence similarly identified inadequate extension services, insufficient climate information and limited technical capacity as major barriers to CSA adoption.

Low awareness, limited technical capacity and socioeconomic characteristics can also restrict the effective adaptation of CSA. Farmers may be aware of climate change but lack sufficient knowledge about specific CSA technologies or how to combine different practices effectively. Recent evidence from Plateau State, for example, reported relatively low levels of climate-change awareness among smallholder maize farmers and indicated that resource limitations restricted the widespread adoption of adaptation practices. The study emphasized improved extension services, climate education and access to financial and agricultural resources as important measures for strengthening farmers' adaptive capacity (2025). In addition, labour requirements can become a constraint where CSA practices such as manual soil conservation, mulching and diversified cropping require additional labour inputs.

Finally, environmental, institutional and policy-related constraints continue to affect CSA adaptation in Nigeria. Climate-related problems such as drought, flooding, soil infertility, pests and diseases can themselves undermine farmers' ability to implement and benefit from climate-smart practices. In Kebbi State, for example, farmers identified weeds, pests and diseases, farmers–herder's conflicts, infertile soils, limited extension services and inadequate government support as important constraints (Danmaigoro et al., 2025). In addition, inconsistent agricultural policies, inadequate infrastructure, weak implementation mechanisms and insufficient government funding can limit the scaling-up of CSA. Recent research therefore suggests that overcoming these constraints requires an integrated approach involving affordable agricultural finance, strengthened extension systems, reliable climate information, improved input delivery, farmer organizations, appropriate infrastructure and consistent government policies (Obe et al., 2025; Mbossoh & Udoh, 2026).

8.0 Policy and Institutional Framework for Promoting Climate-Smart Agriculture

Nigeria has established a number of policy and institutional frameworks that provide a basis for promoting Climate-Smart Agriculture (CSA), climate adaptation and resilient food systems. A major framework is the National Climate Change Policy (NCCP) 2021–2030, which recognizes agriculture and food security as highly vulnerable to climate change and specifically calls for climate-smart and gender-responsive approaches in agricultural production. The policy emphasizes the need to improve the resilience of agriculture, promote efficient use of land and water resources, strengthen farmers' access to markets and develop appropriate financial mechanisms for climate-resilient production (Federal Ministry of Environment, 2021). More recently, Nigeria's climate-policy architecture has been strengthened through the Third Nationally Determined Contribution (NDC 3.0) adopted in 2025, which provides updated national commitments for climate action (FAO, 2026).

The National Agricultural Technology and Innovation Policy (NATIP) 2022–2027 provides another important framework for advancing CSA in Nigeria. NATIP seeks to improve agricultural productivity, food security, employment and resilience through interventions covering agricultural research, priority value chains, mechanization, extension services, irrigation, rural infrastructure, agricultural finance and insurance. Importantly, digital and climate-smart agriculture is incorporated within the policy framework, demonstrating the

recognition of climate adaptation as an integral component of contemporary agricultural development. The policy also emphasizes inclusion of women and young people, whose participation is essential for sustainable transformation of Nigeria's agricultural sector (FAO, 2026). Institutionally, the promotion of CSA requires collaboration among government ministries, research institutions, agricultural extension organizations, financial institutions, farmer organizations, development partners and local communities. The Federal Ministry of Agriculture and Food Security has a central role in agricultural policy implementation, while the Federal Ministry of Environment and the National Council on Climate Change are important actors in climate-policy coordination and implementation. The National Agricultural Extension Policy (2023) also provides an important institutional mechanism for disseminating climate information, technologies and improved agricultural practices to farmers. In addition, FAO's Nigeria Country Programming Framework 2023–2027 places emphasis on climate-smart agrifood systems, improved productivity, resilience of food- and agriculture-based livelihoods and sustainable natural-resource and climate management (FAO, 2023).

Recent developments further indicate a move towards integrating climate-smart agriculture into broader national agricultural investment and food-system planning. Nigeria's National Agrifood Systems Investment Plan (NASIP) 2026–2027, for example, provides a major investment framework aimed at repositioning agriculture as a driver of agrifood resilience, rural development and structural transformation. The plan aligns its thematic programmes with NATIP and represents an important opportunity for directing public investment towards resilient agricultural infrastructure, technology, productivity and food security (FAO, 2026). However, policy existence alone does not guarantee effective CSA adoption. A 2025 FAO policy review emphasized the need for greater policy coherence and better alignment of public expenditure with agricultural priorities and NATIP objectives, indicating that implementation and coordination remain important challenges (Nwafor et al., 2025).

Effective promotion of CSA in Nigeria therefore requires stronger coordination between agricultural and climate policies, adequate and predictable financing, effective extension systems, climate information services, agricultural research, farmer organizations and private-sector participation. Policies should move beyond the formulation of strategies to ensure that smallholder farmers can actually access the technologies, finance, insurance, information and infrastructure required for climate-smart production. This is particularly important because CSA interventions are context-specific and must be adapted to Nigeria's diverse agro-ecological and socioeconomic conditions. Consequently, strengthening institutional coordination, monitoring policy implementation and directing agricultural investment towards resilience, adaptation and sustainable productivity will be essential for translating Nigeria's existing policy commitments into tangible benefits for smallholder farmers (FAO, 2025; FAO, 2026).

9.0 Conclusion

Climate-Smart Agriculture (CSA) has emerged as an important framework for responding to the interconnected challenges of climate change, agricultural productivity, food insecurity and livelihood vulnerability in Nigeria. The review has established that climate variability, including changing rainfall patterns, droughts, floods and increasing temperatures, poses significant threats to agricultural production, particularly among smallholder farmers who depend heavily on rain-fed agriculture. These challenges have implications not only for farm productivity but also for household livelihoods and national food security (Science in One Health, 2025). The review further demonstrates that CSA provides a holistic approach to strengthening the capacity of smallholder farmers to adapt to changing climatic conditions. Its three major dimensions—sustainable productivity improvement, climate adaptation and resilience, and mitigation of greenhouse-gas emissions—provide a basis for transforming

vulnerable agricultural systems into more sustainable and resilient systems. Practices such as crop diversification, intercropping, adjustment of planting dates, improved crop varieties, soil and water conservation, agroforestry and indigenous adaptation practices are already being implemented by Nigerian farmers, although their level of adoption varies considerably across locations (Izuogu et al., 2025). CSA also has considerable potential to improve agricultural productivity and household food security. Recent evidence indicates that farmers adopting climate-smart practices can achieve improvements in production, income, soil health and food-security outcomes. In Nigeria, the adoption of practices such as crop diversification, agroforestry and the use of suitable agricultural lands has been associated with improved food consumption, dietary diversity and reduced probability of household food insecurity (Omotoso & Omotayo, 2025). Similarly, recent evidence from maize-based farming households indicates that integrated CSA practices can contribute to improved productivity and reduced vulnerability to climate-related risks (Adetomiwa & Sieber, 2025). Despite these opportunities, the widespread adaptation of CSA in Nigeria remains constrained by several economic, institutional, technological and informational barriers. Limited access to agricultural credit, inadequate extension services, and high costs of climate-smart technologies, insufficient technical knowledge and weak institutional support can restrict farmers' ability to adopt and sustain appropriate practices. A recent synthesis of Nigerian CSA literature identified access to credit, extension contact, farming experience and education as important determinants of adoption, while high implementation costs, inadequate technical skills and weak government policy support remain significant barriers (Izuogu et al., 2025).

In conclusion, CSA represents a viable pathway for strengthening the productivity, food security and resilience of Nigeria's smallholder agricultural sector. However, its success depends on creating an enabling environment in which farmers can access affordable finance, reliable climate information, effective extension services, improved agricultural technologies, markets and appropriate infrastructure. Strengthening institutional coordination and policy implementation is equally important. Recent Nigerian literature emphasizes that increased investment in climate adaptation, stakeholder participation, improved infrastructure and digital technologies can strengthen the resilience of food systems to climate-related shocks (Akinkuolie et al., 2025). Therefore, CSA should be integrated into Nigeria's broader agricultural and food-security policies as a long-term strategy for building productive, sustainable and climate-resilient farming systems.

10.0 Recommendations

Based on the review of literature on Climate-Smart Agriculture (CSA), agricultural productivity, food security and resilience among smallholder farmers in Nigeria, the following recommendations are proposed: Strengthening agricultural extension and farmer education: Government and relevant agricultural institutions should strengthen extension services and organize regular practical training on CSA practices. Particular attention should be given to crop diversification, improved varieties, soil and water conservation, agroforestry, irrigation and climate-informed farm management. Recent evidence identifies inadequate awareness and technical skills as important barriers to CSA adoption in Nigeria (Izuogu et al., 2025). (jaeid.it) Improving access to affordable agricultural finance: Financial institutions and government agricultural programmes should develop accessible and affordable credit, insurance and other financial mechanisms specifically for smallholder farmers. Subsidized financing should support the acquisition of improved seeds, irrigation facilities, farm machinery, water-management technologies and other CSA inputs. This is important because access to credit is consistently identified as a major determinant of CSA adoption among Nigerian farmers (Izuogu et al., 2025).

Expanding access to reliable climate information: Government agencies, particularly agricultural extension institutions and meteorological services, should improve the dissemination of timely and location-specific weather and climate information. Information should be communicated through mobile phones, radio, farmer organizations, extension agents and other accessible platforms. Reliable climate information can assist farmers in making informed decisions concerning planting dates, crop selection, irrigation, fertilizer application and responses to extreme weather events. Recent evidence identifies inadequate climate information as one of the major constraints to CSA adoption among Nigerian farmers. (agris.fao.org) Promoting affordable and locally appropriate CSA technologies: Research institutions and agricultural development agencies should prioritize the development and dissemination of low-cost technologies suited to Nigeria's diverse agro-ecological zones. These should include drought- and flood-tolerant crop varieties, efficient irrigation systems, improved soil-management technologies, agroforestry systems and post-harvest technologies. CSA interventions should be context-specific rather than applying a uniform package across the country, consistent with the FAO's emphasis on locally appropriate CSA solutions. (fao.org)
Strengthening farmer organizations and collective action: Smallholder farmers should be encouraged and supported to participate in cooperatives, farmer associations and community-based organizations. Collective organization can improve farmers' access to information, credit, inputs, markets, extension services and climate-smart technologies. It can also facilitate peer learning, allowing farmers who have successfully adopted CSA practices to share knowledge and experience with other farmers. Evidence from Nigeria indicates that farmer groups can contribute to social capital formation and facilitate the adoption of CSA practices. (agris.fao.org) Improving agricultural infrastructure and market access: Government should increase investment in rural roads, irrigation, water-harvesting facilities, storage centres, processing facilities and electricity. Improved infrastructure will reduce post-harvest losses, facilitate access to markets and enable farmers to derive greater economic benefits from increased productivity. Such investments should form part of broader climate-resilient agricultural development programmes and should prioritize vulnerable smallholder farming communities. Strengthening policy implementation and institutional coordination: Existing agricultural and climate policies should be translated into adequately funded programmes with clearly defined implementation responsibilities and measurable outcomes. Federal and state agricultural institutions, climate-change agencies, research organizations, development partners, financial institutions and farmer organizations should work together to promote CSA. Recent evidence indicates that weak policy support and the absence of effective government incentives remain important barriers to CSA adoption in Nigeria (Izuogu et al., 2025). (jaeid.it)
Increasing investment in agricultural research and indigenous knowledge: Research institutions should intensify the development and testing of CSA practices appropriate to Nigeria's different agro-ecological zones. Indigenous knowledge should be integrated with scientific research because farmers possess valuable knowledge of local weather patterns, soils, crops and natural-resource management. Research should also examine the long-term effects of CSA practices on productivity, food security, household income, resilience and environmental sustainability.
Promoting inclusive and gender-responsive CSA programmes: CSA interventions should deliberately include women, young farmers and other vulnerable groups who may face greater constraints in accessing land, finance, technologies and extension services. Agricultural programmes should ensure equitable access to climate-smart inputs, training, credit and markets. This will improve the overall effectiveness and sustainability of CSA interventions and strengthen the resilience of vulnerable farming households.
Developing a coordinated national monitoring and evaluation system: Government and research institutions should establish mechanisms for monitoring CSA adoption and assessing its effects on agricultural productivity, food security, household income, resilience and

environmental sustainability. Such evidence will enable policymakers to identify successful interventions, discontinue ineffective approaches and allocate resources more efficiently. Given the diversity of Nigerian farming systems, monitoring should be conducted across different agro-ecological zones and socioeconomic groups.

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