ADDRESSING CLIMATE CHANGE FOR SUSTAINABLE FOOD PRODUCTION IN NIGERIA

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ABSTRACT
This study investigated the impacts of climate change on food production systems in Nigeria and examines sustainable adaptation strategies to ensure food security. Through a systematic review and extensive literature analysis of peer-reviewed publications, government reports, and policy documents, the study identified key climate related challenges affecting Nigerian agriculture. Findings reveal that rising temperatures, irregular rainfall patterns, and increased frequency of extreme weather events have significantly reduced crop yields across major agricultural zones, with smallholder farmers experiencing disproportionate impacts due to limited adaptive capacity. The study identified several promising adaptation strategies, including climate-smart agriculture techniques, improved irrigation systems, drought-resistant crop varieties, and indigenous knowledge integration. Policy recommendations include strengthening agricultural extension services, developing weather-based insurance schemes, establishing early warning systems, improving access to climate finance, and integrating climate considerations into national agricultural policies.
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1. INTRODUCTION

Climate change represents an existential threat to Nigeria's agricultural sector, with profound implications for food security and economic stability in a nation where agriculture has historically served as the backbone of economic sustainability (Auwal, et al., 2025; Tajudeen et al., 2022; Ani et al., 2021). In 2024, extreme weather events such as floods and droughts destroyed over 1 million tons of crops in Nigeria, enough to feed 13 million people for a year; while the collapse of the Alau Dam alone inundated 700,000 hectares of farmland (Jaiyesimi, 2025). Pest outbreaks, including the devastating "Tomato Ebola" (Tuta Absoluta), caused tomato prices to surge above ₦100,000 per basket in 2024, and ginger blight resulted in ₦12 billion in losses in 2023 (Jaiyesimi, 2025). Additionally, erratic rainfall patterns reduced yields for 88.4% of smallholder farmers dependent on rain-fed agriculture (Okonkwo et al., 2024), with projections indicating a potential 30% decline in productivity by 2050 if no interventions are implemented (Orji, 2025).

Similarly, recent empirical studies highlight the impacts of climate variability on Nigeria's agricultural productivity, with evidence suggesting that increased temperatures, erratic rainfall patterns, and extreme weather events significantly undermine crop yields and disrupt food production systems (Abbah et al., 2025; Ezekwe et al., 2024; Amaefule et al., 2023). Notably, research by Idoko et al. (2022) demonstrates that rising temperatures correlate with declining food production, while Ojo et al. (2022) established that climate change adaptation strategies can improve household food security by approximately three units. These findings are particularly concerning in the Nigerian context, where Akinkuolie et al. (2025) observe that frequent flooding destroys critical infrastructure, erodes valuable topsoil, and reduces agricultural productivity, while prolonged droughts, especially in the semi-arid northern regions, deplete vital water resources and drastically reduce crop yields.

The emerging body of literature underscores the critical importance of climate-smart agriculture (CSA) as a sustainable approach to mitigating the adverse effects of climate change on food production in Nigeria (Onyebuchi et al., 2025; Amarachi et al., 2024; et al., 2024; Idisi Balogun et al., 2024). Recent research by Mbanasor et al. (2024) reveals that while cooperative societies and extension workers serve as primary sources of CSA awareness, factors such as gender, education level, access to credit, and risk orientation significantly influence adoption rates among farmers. Similarly, Onyeneke et al. (2021) identified several climate-smart practices employed by rice farmers, including crop diversification, soil and water conservation techniques, and reliance on climate information and forecasts. However, despite these adaptive strategies, Ojo et al. (2024) emphasize that sustainable land management practices have substantial potential to minimize climate change impacts on food security, particularly when farmers implement complementary practices rather than isolated interventions. This aligns with findings from Oduntan and Obisesan (2022), and Anugwa et al. (2021), that determined that farmers express preferences for specific CSA technologies such as drip irrigation and drainage management, though their willingness to pay remains constrained by socioeconomic factors.

Despite the growing body of research on climate change and agriculture in Nigeria, significant qualitative gaps persist in the current literature. Most existing studies employ quantitative methodologies (Idoko et al., 2022; Gbenga et al., 2021), failing to capture the intricate lived experiences of farmers and the sociocultural barriers to adaptation. Additionally, the institutional and political constraints on climate-smart agriculture implementation remain understudied, while the policy implications of climate-related farmer-herder conflicts receive insufficient qualitative analysis despite their significance. Furthermore, gender dynamics and traditional knowledge systems in adaptation remain underexplored areas of inquiry. Given these critical gaps, this systematic literature review aims to evaluate the impact of climate change on sustainable food production in Nigeria and identify effective adaptation strategies, policies, and innovations that enhance climate resilience, food security, and agricultural sustainability, with particular attention to the sociopolitical dimensions of adaptation and the development of more inclusive resilience strategies in Nigeria's food systems using a systematic review process.

2. LITERATURE REVIEW

2.1. Conceptual Review

2.1.1. Climate Change

Climate change has been variously defined within scientific literature, reflecting evolving understanding. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC, 2014). Similarly, the United Nations Framework Convention on Climate Change (UNFCCC) offers a causally oriented definition, describing it as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (UNFCCC, 1992). Furthermore, Dessler and Parson (2019) define climate change as significant variations in the mean state of climate or in its variability, persisting for an extended period, encompassing both natural internal processes and external forcings such as solar cycles, volcanic eruptions, and persistent anthropogenic modifications to atmospheric composition or land use. The IPCC definition represents the strongest conceptualization for this study because it encompasses both anthropogenic and natural causes without bias, acknowledges climate variability alongside mean changes crucial for agricultural planning, and emphasizes the long-term nature of climate effects that agricultural adaptation strategies must address.

2.1.2. Sustainable Food Production

Pretty et al. (2018) defined sustainable food production as agricultural practices that meet society's food needs in the present while preserving the capacity of future generations to meet their own needs by maintaining ecological balance, promoting social equity, and ensuring economic viability. On the other hand, Garnett (2014) conceptualizes it as a system of food production that generates adequate nutrition while simultaneously reducing environmental impacts, adapting to climate change, improving livelihood resilience, and enhancing social justice across food value chains. Similarly, the Food and Agriculture Organization [FAO] (2020) defines sustainable food production as the implementation of agricultural methods that protect the environment, ensure economic profitability, and promote social and economic equity among food producers and consumers, while maintaining the productive capacity of natural resources. The definition proposed by Garnett (2014) represents the most comprehensive conceptualization of sustainable food production for this study in Nigeria because it explicitly acknowledges the need of adaptation to climate change, emphasizes the nutritional outcomes rather than merely yields, addresses social dimensions including justice and equity considerations critical for Nigerian smallholder farmers, and recognizes the importance of systemic resilience across the entire food value chain, which is particularly relevant given Nigeria's vulnerability to climate shocks and stressors.

2.2. Empirical Review

This review examines empirical studies on the impact of climate change on Nigerian agriculture, adaptation strategies, and policy gaps.

In assessing climate change impacts on crop yields and food production in Nigeria, several studies highlight the adverse effects of climate change on staple crops. Idoko et al. (2022) conducted a quantitative time-series analysis (1990-2020) using OLS regression and found that rising temperatures negatively affect food production, while increased rainfall enhances yields. Furthermore, their findings align with Gbenga et al. (2021), who used co-integration and regression models to demonstrate that temperature fluctuations reduce rice output, whereas rainfall variability has mixed effects. In contrast, Ezekwe et al. (2024) employed ARDL modelling (1990-2023) and found that carbon dioxide (CO_2) emissions and methane (CH_4) surprisingly increased food production, suggesting complex interactions between greenhouse gases and agricultural productivity.

However, Amaefule et al. (2023) challenge this view, using an environmental Kuznets curve model (1960-2019) to argue that CO_2 emissions negatively impact crop yields in the long run. Similarly, Anyaegbu et al. (2022) applied an ARDL bound approach to cassava production and found methane to be particularly detrimental, emphasizing the need for climate-smart agriculture (CSA). These contrasting findings suggest that while some climatic variables may temporarily boost yields, long-term sustainability requires mitigation strategies.

Regional disparities and sector-specific vulnerabilities; in looking at regional differences in climate impacts are evident; Ojo et al. (2022) used probit and endogenous switching models in Ogun State and found that farmers adopting climate adaptation strategies (e.g., improved seeds, irrigation) had higher food security. Conversely, Tajudeen et al. (2022) analyzed Lagos State cassava and maize farmers (1998-2018) and noted minimal yield losses for cassava but significant declines for maize, underscoring crop-specific vulnerabilities. Also, Northern Nigeria faces distinct challenges. Akinkuolie et al. (2025) conducted a systematic review (PRISMA-based analysis of 104 studies) and found droughts and floods disproportionately affect semi-arid regions, exacerbating food insecurity. Additionally, Gershon and Mbajekwe

(2020) reinforced this with ARDL modelling (1981-2017), showing temperature spikes reduce crop yields but not livestock production, highlighting sectoral resilience differences.

Assessing adaptation strategies; farmers employ diverse adaptation measures, but adoption barriers persist. Mbanasor et al. (2024) surveyed 270 Southeast Nigerian farmers using Heckman's two-stage model and found cooperative societies and extension services critical for CSA awareness. However, risk aversion and limited credit access hinder adoption. Furthermore, Onyebuchi et al. (2025) qualitatively assessed renewable energy's role and noted policy inertia, with elites resisting fossil fuel phase-outs despite climate risks. In addition, Onyeneke et al. (2021) used multivariate probit regression on 347 Ebonyi State rice farmers and identified CSA practices (e.g., agro-advisories, crop diversification) as effective but highlighted cost and infrastructure barriers. Similarly, Anugwa et al. (2021) employed contingent valuation and found farmers willing to pay $115 annually for CSA technologies, though affordability remains a constraint.

A review of socioeconomic and institutional factors demonstrates that institutional support is pivotal. Ojo et al. (2024) applied Poisson endogenous treatment models in Ogun State and found education and training enhance sustainable land management (SLM) adoption, improving food security by 27%. On the other hand, Amare & Balana (2023) used panel data to show extreme heat reduces agricultural income, pushing farmers into wage labour, a livelihood shift with long-term food security implications. Additionally, conflicts over resources further complicate adaptation. Ikhuoso et al. (2020) reviewed farmer-herder clashes and linked them to climate-induced resource scarcity, advocating for integrated land-use policies. Additionally, Wahab & Iyiola (2023) extended this to fisheries and wildlife, noting shrinking aquatic ecosystems due to erratic rainfall, which threatens protein sources.

In synthesizing these findings into an empirical gap, the empirical review shows that while existing studies provide valuable insights into climate change impacts on Nigerian agriculture, key qualitative gaps remain. First, most research employs quantitative methods (Idoko et al., 2022; Gbenga et al., 2021), lacking in-depth exploration of farmers' lived experiences and sociocultural barriers to adaptation. Second, institutional and political constraints on climate-smart agriculture implementation remain understudied (Ojo et al., 2024; Mbanasor et al., 2024). Third, despite recognition of climate-related farmer-herder conflicts (Ikhuoso et al., 2020), few studies qualitatively analyze their policy implications. Fourth, gender dynamics and traditional knowledge systems in adaptation remain underexplored (Onyeneke et al., 2021). This qualitative review addresses these gaps by synthesizing sociopolitical dimensions of adaptation, offering intricate insights for more inclusive resilience strategies in Nigeria's food systems.

3. METHODOLOGY

3.1 Theoretical Framework

The Climate Vulnerability and Resilience Theory provides a structured approach to understanding how agricultural systems respond to climate stressors through three key components; exposure (the nature and degree of climate-related stressors), sensitivity (the susceptibility of systems to harm), and adaptive capacity (the ability to adjust to climate change impacts) (Intergovernmental Panel on Climate Change [IPCC], 2014; Adger, 2006). This framework systematically analyzes vulnerable elements within food production systems while concurrently identifying factors that enhance resilience against climate threats.

The Climate Vulnerability and Resilience Theory stands distinctively suited for this systematic literature review on Nigeria's climate-impacted agricultural systems because it enables a detailed and comprehensive breakdown of the research objective through its component parts.

The exposure component will facilitate analysis of region-specific climate stressors affecting Nigerian agriculture, including changing rainfall patterns, temperature increases, and extreme weather events. The sensitivity component will guide examination of how various farming systems, crops, and agricultural practices in Nigeria respond differently to these stressors, identifying particularly vulnerable production methods and regions. Meanwhile, the adaptive capacity component provides analytical structure for evaluating existing and potential interventions, from indigenous knowledge systems to technological innovations and policy frameworks that strengthen Nigerian farmers' ability to maintain productive agricultural systems despite climate challenges. This theory's inherent flexibility allows it to incorporate socioeconomic dimensions of resilience while maintaining focus on practical adaptation pathways, making it ideally suited to fulfill the research objective of identifying effective strategies that enhance both climate resilience and food security in Nigeria's agricultural sector.

3.2. Method of Analysis

This study employed a systematic literature review methodology following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021) to evaluate the impact of climate change on sustainable food production in Nigeria and identify effective adaptation strategies. A comprehensive literature search was conducted across multiple electronic databases including PubMed/MEDLINE, Web of Science, Scopus, Google Scholar, African Journals Online (AJOL), and Directory of Open Access Journals (DOAJ). The search strategy incorporated Boolean operators to combine keywords related to climate change ("climate change," "climate variability," "climate adaptation"), food production ("food security," "agricultural productivity," "sustainable agriculture"), and geographic terms ("Nigeria," "Nigerian," "West Africa"). Studies were included if they were empirical research published between 2020-2025, written in English, focused on Nigeria, and addressed climate change impacts on food production with sufficient methodological rigor (Booth et al., 2016).

The study selection process followed a four-stage approach consistent with systematic review best practices (Moher et al., 2009). Initial database searches yielded 303 records, which were reduced to 268 unique records after duplicate removal. The review processs screened titles and abstracts, resulting in 85 potentially relevant studies for full text assessment. Following rigorous full text evaluation against inclusion and exclusion criteria, 22 studies met all requirements and were included in the final review. Data extraction was conducted using a standardized form capturing study characteristics, climate variables, food production outcomes, adaptation strategies, and policy recommendations. Given the heterogeneity of study designs and outcome measures, a narrative synthesis approach was employed to analyse findings and identify common themes related to climate change impacts and adaptation strategies in Nigerian agriculture. Refer to Figure 1 for the RISMA Flow.

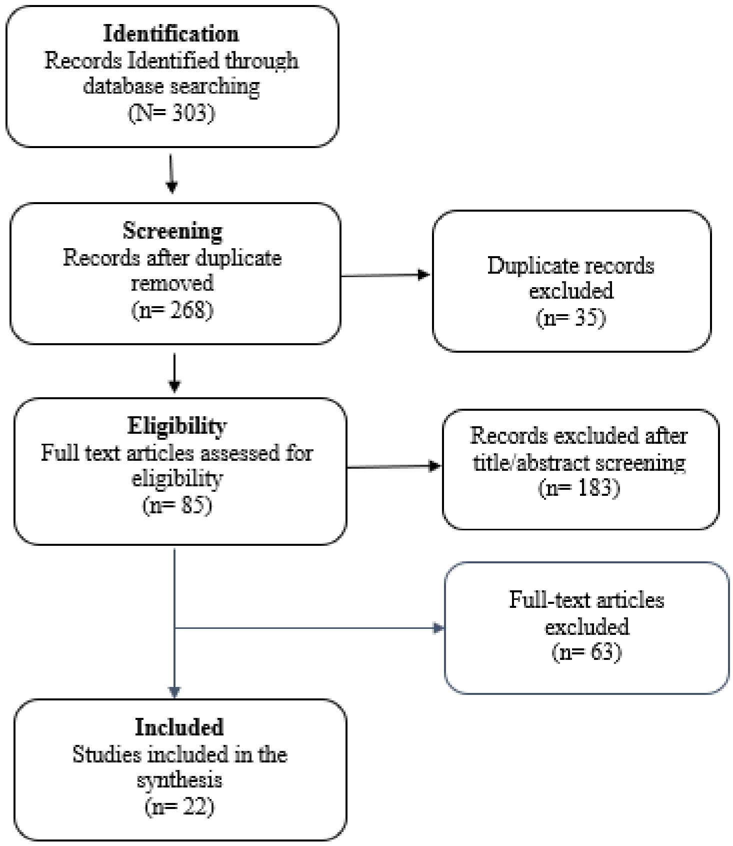

Figure 2: *PRISMA Flow Diagram*

4. RESULTS AND DISCUSSION OF FINDINGS

The findings and discussions re organized into themes and subthemes.

4.1 Impacts of Climate Change on Food Production Systems in Nigeria

4.1.1 Temperature and Rainfall Variations

The systematic review of literature reveals that Nigeria's food production systems are experiencing significant disruptions due to climate change, with consistent evidence of adverse impacts on agricultural productivity. Analysis of time series data from multiple studies indicates that rising temperatures have a negative correlation with crop yields across various agroecological zones (Idoko et al., 2022; Tajudeen et al., 2022). For instance, Idoko et al. (2022) found that increased annual temperatures led to decreased food production in Nigeria, while increased annual rainfall generally corresponded with improved agricultural output during the period 1990-2020. This finding is consistent with Ezekwe et al. (2024), who reported that average temperature negatively affected food production in the long run, although this relationship was not statistically significant at the 5% level.

The impact of temperature variations appears to be crop-specific. Tajudeen et al. (2022) found that climate change had little impact on cassava yield but significantly reduced maize yield in Lagos State. This differential impact suggests varying levels of resilience among staple crops, with some showing greater adaptability to changing climatic conditions than others. O'Keefe (2020) projected that average crop yields in Nigeria for maize, sorghum, wheat, and pulses would likely increase under both Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 emissions scenarios, primarily due to CO_2 fertilization effects, though this finding contrasts with other studies showing yield reductions.

4.1.2 Extreme Weather Events

The increasing frequency and intensity of extreme weather events emerged as a critical factor undermining food security in Nigeria.

Importantly, the geographic distribution of climate impacts varies significantly across Nigeria's diverse agroecological zones. O'Keefe (2020) found that crop yields were generally highest in the north and lowest in the south of Nigeria, with the exception of pulse crops where the opposite pattern prevailed. This spatial variability in climate change impacts necessitates regionally tailored adaptation strategies rather than one-size-fits-all approaches.

4.1.3 Carbon Emissions and Agricultural Productivity

The review identified significant relationships between carbon emissions and agricultural productivity. Amaefule et al. (2023) demonstrated that CO2 emissions and carbon intensity negatively impacted crop and food production in Nigeria through physical risk channels, causing a decline in agricultural productivity that disrupts food security and poverty reduction strategies. However, Ezekwe et al. (2024) found that carbon dioxide emissions positively and significantly affected food production in both the long and short run, indicating that during their study period, carbon dioxide emissions did not adversely affect food crop production.

The complex relationship between greenhouse gas emissions and agricultural productivity is further illustrated by Anyaegbu et al. (2022), who found that methane caused long-term significant damage to cassava yield more than any other greenhouse gas or climatic variable in their study. This finding is particularly relevant given Nigeria's large cattle population, with Ikhuoso et al. (2020) noting that a cow on average contributes between 70 and 120 kg of methane per year, and Nigeria has approximately 20 million cattle.

4.2 Vulnerability Patterns and Adaptive Capacity

4.2.1 Differential Vulnerability among Farmers

The systematic review revealed clear patterns of differential vulnerability to climate change impacts across farmer demographics. Smallholder farmers, particularly those with limited access to resources, emerged as the most vulnerable group (Ojo et al., 2022). This vulnerability is exacerbated by socioeconomic factors including education level, gender, access to credit, and risk orientation, which significantly influence farmers' adaptive capacity (Mbanasor et al., 2024).

Similarly, gender emerged as a particularly important determinant of climate vulnerability. Mbanasor et al. (2024) identified gender as a key factor influencing CSA adoption, while Onyeaka et al. (2024) emphasized that women who face gender inequalities and socioeconomic limitations are particularly susceptible to climate change impacts. These findings underscore the importance of gender-sensitive approaches to climate adaptation in Nigeria's agricultural sector.

4.2.2 Socioeconomic Determinants of Adaptive Capacity

The literature consistently identified several socioeconomic factors as critical determinants of farmers' adaptive capacity. Education level was frequently cited as a significant factor influencing climate change perception and adaptation. Ojo et al. (2024) concluded that knowledge in the form of formal education, vocational training, and training to access weather information were key to influencing sustainable land management adoption among smallholder farmers.

Also, access to credit and financial services also emerged as a crucial determinant of adaptive capacity. Anugwa et al. (2021) found that farmers' willingness to pay for CSA technologies remains constrained by socioeconomic factors, with access to credit being a significant predictor of farmers' choices. This financial constraint limits the implementation of potentially effective adaptation strategies, highlighting the importance of credit facilities and economic incentives in promoting climate resilience.

Furthermore, institutional factors, particularly membership in cooperative societies and access to extension services, were identified as important enablers of adaptation. Mbanasor et al. (2024) found that cooperative societies and extension workers are the primary sources of CSA awareness, while Ojo et al. (2022) showed that access to market information, access to extension agents, and membership in cooperatives all contribute to variations in food security experienced by both adopters and non-adopters of climate change adaptation strategies.

4.3 Effective Adaptation Strategies and Practices

4.3.1 Climate-Smart Agriculture Adoption

CSA emerged as a promising approach for enhancing climate resilience in Nigeria's food production systems. Balogun et al. (2024) established that CSA can increase agricultural productivity, farm incomes, and food security while building resilience to climate change and reducing greenhouse gas emissions. Noticeable CSA practices adopted by farmers in Nigeria include the use of improved crop varieties, laser land leveling, zero tillage, residue management, nutrient management, and crop diversification.

However, the review identified significant gaps in CSA implementation. Mbanasor et al. (2024) concluded that while CSA practices are recognized and adopted to some extent, their implementation is insufficient to comprehensively combat the effects of climate change. Key barriers to CSA adoption included high costs of inputs (particularly fertilizer), insufficient land and capital, pests and diseases, and poor extension services (Onyeneke et al., 2021). Risk aversion among farmers was also identified as a significant barrier, with Mbanasor et al. (2024) finding that risk-averse farmers are less likely to adopt CSA practices.

4.3.2 Sustainable Land Management Practices

Sustainable Land Management (SLM) practices were identified as having substantial potential to minimize climate change impacts on food security. Ojo et al. (2024) found that SLM practices have the potential to alleviate food insecurity among rice farmers if well combined and used to a large extent. Importantly, their study demonstrated that the effect of SLM adoption on food security improved when farmers used a package consisting of a variety of practices, indicating the importance of complementary rather than isolated interventions.

The review also highlighted farmers' preferences for specific adaptation technologies. Anugwa et al. (2021) determined that farmers express preferences for specific CSA technologies such as drip irrigation and drainage management, while Onyeneke et al. (2021) identified several climate-smart practices employed by rice farmers, including crop diversification, soil and water conservation techniques, and reliance on climate information and forecasts.

4.3.3 Renewable Energy Integration

Renewable energy emerged as a potentially transformative but underutilized adaptation strategy. Onyebuchi et al. (2025) argued that renewable energy solutions are essential to reduce ecosystem vulnerability and advance technological innovations for food security in Nigeria. However, their study found that the Nigerian government has yet to adopt renewable energy as a dependable resource for agricultural activities, highlighting a significant gap between potential and implementation in this area.

4.4 Policy Implications and Institutional Frameworks

4.4.1 Extension Services and Information Access

The systematic review consistently highlighted the importance of agricultural extension services and climate information access in enhancing adaptive capacity. Ojo et al. (2024) recommended that farm level policy efforts aimed at equipping farmers through education, training, and disseminating information on climate change would be a significant step toward promoting sustainable land management practices, which eventually leads to increased food security. Similarly, Onyeneke et al. (2021) identified reliance on climate information and forecasts as an important climate-smart practice employed by rice farmers. Similarly, the role of extension services in facilitating climate adaptation is particularly emphasized by Mbanasor et al. (2024), who recommended providing increased support for extension services to improve CSA adoption and effectiveness. Tajudeen et al. (2022) also noted that a lack of access to farming technology reduces overreliance on rain-fed farming systems and subsistence agriculture, highlighting the role of extension services in technology transfer.

4.4.2 Financial Mechanisms and Incentives

Financial mechanisms and incentives emerged as critical components of effective climate adaptation policies. Anugwa et al. (2021) recommended that given farmers' low willingness to pay for CSA technologies, incentives such as subsidies and interest-free loans should be provided to boost uptake. They further suggested committing a substantial amount of money to credit facilities to help scale up CSA technologies' adoption. Furthermore, insurance schemes were also identified as important risk management tools. Mbanasor et al. (2024) recommended providing insurance schemes and other risk management tools to reduce risk aversion among farmers, which was identified as a significant barrier to CSA adoption. This aligns with findings from Onyeneke et al. (2021), who identified insurance as one of the climate-smart practices used by rice farmers to respond to perceived climate events.

4.4.3 Policy Integration and Coordination

The review identified policy fragmentation as a significant barrier to effective climate adaptation. Balogun et al. (2024) noted that despite advancements in adaptation strategies, fragmented policies and inadequate infrastructure continue to hinder effective responses to climate change impacts on food security. This finding highlights the importance of integrated policy approaches that coordinate across sectors and levels of government. As such, Onyebuchi et al. (2025) recommended that the Nigerian government move beyond geopolitical constraints and enact effective legislation to prioritize renewable energy as the primary source for ensuring food security. This suggestion underscores the need for policy coherence across energy, agriculture, and climate sectors to achieve sustainable food production in the face of climate change.

5. CONCLUSION AND POLICY RECOMMENDATIONS.

5.1. Conclusion

This systematic review revealed that climate change poses significant threats to food production in Nigeria through rising temperatures, irregular rainfall patterns, and increased extreme weather events that have demonstrably reduced crop yields across diverse agroecological zones. The impacts are unevenly distributed, with smallholder farmers, particularly women and those with limited resources, experiencing disproportionate vulnerability due to socioeconomic constraints that limit their adaptive capacity. While Climate-Smart Agriculture (CSA) and Sustainable Land Management (SLM) practices show promise in enhancing resilience, their adoption remains constrained by financial limitations, risk aversion, insufficient extension services, and fragmented policy frameworks. The evidence demonstrates that complementary adaptation approaches combining improved crop varieties, soil and water conservation techniques, and climate information utilization are more effective than isolated interventions, highlighting the need for integrated adaptation strategies that address Nigeria's complex agricultural vulnerabilities.

5.2. Recommendation

To strengthen climate resilience in Nigeria's food production systems, this study recommends a comprehensive policy approach with five key elements. First, enhancing agricultural extension services to improve climate knowledge transfer and technology adoption among smallholder farmers. Second, developing accessible weather-based insurance schemes and credit facilities to reduce risk aversion and facilitate CSA technology uptake. Third, establishing strong early warning systems for extreme weather events, particularly in vulnerable northern regions. Fourth, improving smallholders' access to climate finance through targeted subsidies and interest-free loans for adaptation technologies like irrigation systems and drought resistant crop varieties. Fifth, integrating climate considerations into national agricultural policies while promoting cross-sectoral coordination between energy, water, and agricultural sectors. These measures, combined with gender-sensitive approaches that recognize women farmers' specific challenges and greater inclusion of indigenous knowledge systems, can significantly enhance Nigeria's agricultural resilience to climate change while ensuring sustainable food security.

REFERENCES

Abbah, E. U., Doki, N. O., & Andohol, J. T. (2025). Climate change and food production: Investigating agriculture-induced greenhouse gas emissions in Nigeria. *Journal of Economics and Allied Research*, 10(1), 361-373.

Adger, W. N. (2006). Vulnerability: *Global environmental change*, *16*(3), 268-281.

Akinkuolie, T., Ogunbode, T., & Adekiya, A. (2025). Resilience to climate-induced food insecurity in Nigeria: A systematic review of the role of adaptation strategies in flood and drought mitigation. *Frontiers in Sustainable Food Systems*, *8*(1), 1-13. https://doi.org/10.3389/fsufs.2024.1490133

Amaefule, C., Shoaga, A., Ebelebe, L., & Adeola, A. (2023). Carbon emissions, climate change, and Nigeria's agricultural productivity. *European Journal of Sustainable Development Research*, *7*(1), 1-36. https://doi.org/10.29333/ejosdr/12572

Amarachi, O. C., Ihuoma, E. C., Ojiugo, A. C., Osmond, O. N. (2024). Assessing the socio-economic consequences of climate change in Nigeria. *Journal of Economics and Allied Research*, 9(4), 29-37.

Amare, M., & Balana, B. (2023). Climate change, income sources, crop mix, and input use decisions: Evidence from Nigeria. *Ecological Economics*, 211(1), 1-14. https://doi.org/10.1016/j.ecolecon.2023.107892

Ani, K., Anyika, V., & Mutambara, E. (2021). The impact of climate change on food and human security in Nigeria. *International Journal of Climate Change Strategies and Management*, *14*(2), 148-167. https://doi.org/10.1108/ijccsm-11-2020-0119

Anugwa, I., Onwubuya, E., Chah, J., Abonyi, C., & Nduka, E. (2021). Farmers' preferences and willingness to pay for climate-smart agricultural technologies on rice production in Nigeria. *Climate Policy*, *22*(1), 112-131. https://doi.org/10.1080/14693062.2021.1953435

Anyaegbu, C., Okpara, K., Taweepreda, W., Akeju, D., Techato, K., Onyeneke, R., Poshyachinda, S., & Pongpiachan, S. (2022). Impact of climate change on cassava yield in Nigeria: An autoregressive distributed lag bound approach. *Agriculture*, *13*(1), 1-14. https://doi.org/10.3390/agriculture13010080

Auwal, U., Hassan, Y. A., & Abubakar, A. (2025). Testing for long-run elasticities in the presence of structural change: Evidence from climate change for South Africa. *Journal of Economics and Allied Research*, 10(1), 454-467

Balogun, O. S., Nwahia, O. C., & Nwebor, E. (2024). Climate-Smart agriculture for sustainable agricultural development in Nigeria: An empirical review. *Journal of Applied Sciences* *and Environmental Management*, *28*(6), 1853-1858. https://doi.org/10.4314/jasem.v28i6.26

Booth, A., Sutton, A., & Papaioannou, D. (2016). *Systematic approaches to a successful literature review* (2nd ed.). SAGE Publications.

Dessler, A. E. and Parson, E. A. (2019). *The science and politics of global climate change: A guide to the debate*. 3rd edn. Cambridge: Cambridge University Press.

Ezekwe, C., Humphrey, J., & Esther, A. (2024). Climate change and food security in Nigeria: Implications for staple crop production. *International Journal of Environment and Climate Change*, 14(12), 486-495. https://doi.org/10.9734/ijecc/2024/v14i124639

Food and Agriculture Organization (2020). *Sustainable food and agriculture*. Rome: Food and Agriculture Organization of the United Nations.

Garnett, T. (2014). Three perspectives on sustainable food security: Efficiency, demand restraint, food system transformation. What role for life cycle assessment? *Journal of Cleaner Production*, *73*(1), 10-18.

Gbenga, O., Ibrahim, O., & Ayodele, O. (2021). Analysis of the effect of climate change on rice production in Nigeria. *International Journal of Agriculture System*, *8*(1), 119-129.

Gershon, O., & Mbajekwe, C. (2020). Investigating the nexus of climate change and agricultural production in Nigeria. *International Journal of Energy Economics and Policy*, *10*(6), 1-8. https://doi.org/10.32479/ijeep.9843

Idisi, P. O., Otitoju, M. A., Emmanuel, A. U. (2024). The long run relationship of climate change and sugarcane production in Nigeria. *Journal of Economics and Allied Research*, 9(1), 279-291.

Idoko, C. U., Umoru, O., & Inedu, H. (2022). Impact of climate change on food production in Nigeria. *International Journal of Scientific Development and Research*, *7*(8), 731-737.

Ikhuoso, O., Adegbeye, M., Elghandour, M., Mellado, M., Al-Dobaib, S., & Salem, A. (2020). Climate change and agriculture: The competition for limited resources amidst crop farmers-livestock herding conflict in Nigeria- A review. *Journal of Cleaner Production*, *272*(1), 1-16. https://doi.org/10.1016/j.jclepro.2020.123104

Intergovernmental Panel on Climate Change (2014). *Climate Change 2014: Impacts, adaptation, and vulnerability*. https://www.ipcc.ch/report/ar5/wg2/

Jaiyesimi, F. (2025). *Top 5 issues to shape Nigeria's agriculture in 2025*. https://businessday.ng/agriculture/article/top-5-issues-to-shape-nigerias-agriculture-in-2025/

Mbanasor, J., Kalu, C., Okpokiri, C., Onwusiribe, C., Nto, P., Agwu, N., & Ndukwu, M. (2024). Climate smart agriculture practices by crop farmers: Evidence from South East Nigeria. *Smart Agricultural Technology*, *8*(1), 1-12. https://doi.org/10.1016/j.atech.2024.100494

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, *6*(7), 1-6. https://doi.org/10.1371/journal.pmed.1000097

O'Keefe, I. (2020). *Increasing crop yields under climate change scenarios in Nigeria*. https://api.semanticscholar.org/CorpusID:226533468

Oduntan, O., & Obisesan, A. A. (2022). Factors influencing adoption of climate smart agricultural practices among maize farmers in Ondo State, Nigeria. *Journal of Economics and Allied Research*, 7(4), 164-177.

Ojo, T., Adesiyan, O., Ige, A., Emenike, C., Kassem, H., Elhindi, K., Kitole, F., & Sesabo, J. (2024). The role of sustainable land management practices in alleviating household food insecurity in Nigeria. *Frontiers in Sustainable Food Systems*, *8*(1), 1-19. https://doi.org/10.3389/fsufs.2024.1414243

Ojo, T., Ogundeji, A., & Emenike, C. (2022). Does adoption of climate change adaptation strategy improve food security? A case of rice farmers in Ogun State, Nigeria. *Land, 11*(11), 1-16. https://doi.org/10.3390/land11111875

Okonkwo, W. I., Ojike, O., Anabaraonye, B., Okafor, E. W., & Kolawole, E. O. (2024). *Enhancing food production through climate resilient-smart agriculture for sustainable development in Nigeria.* https://kosmospublishers.com/enhancing-food-production-through-climate-resilient-smart-agriculture-for-sustainable-development-in-nigeria-2/

Onyeaka, H., Nwauzoma, U., Akinsemolu, A., Tamasiga, P., Duan, K., Al-Sharify, Z., & Siyanbola, K. (2024). The ripple effects of climate change on agricultural sustainability and food security in Africa. *Food and Energy Security*, *13*(5), 1-15. https://doi.org/10.1002/fes3.567

Onyebuchi, A., Sanubi, F., & Etemike, L. (2025). Renewable energy in Nigeria: A backbone for agriculture in a climate change era. *IOSR Journal of Agriculture and Veterinary Science*, 18(1), 17-22. https://doi.org/10.9790/2380-1801011722

Onyeneke, R., Amadi, M., Njoku, C., & Osuji, E. (2021). Climate change perception and uptake of climate-smart agriculture in rice production in Ebonyi State, Nigeria. *Atmosphere*, *12*(11), 1-21. https://doi.org/10.3390/atmos12111503

Orji, I. (2025) *Scaling up climate finance for sustainable agriculture: Strategies for adaptation and mitigation.* https://www.verivafrica.com/insights/scaling-up-climate-finance-for-sustainable-agriculture-strategies-for-adaptation-and-mitigation

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *PLoS Medicine*, 371(72), 1-9. http://dx.doi.org/10.1136/bmj.n71

Pretty, J., Benton, T. G., Bharucha, Z. P., Dicks, L. V., Flora, C. B., Godfray, H. C. J., Goulson, D., Hartley, S., Lampkin, N., Morris, C., & Pierzynski, G. (2018). Global assessment of agricultural system redesign for sustainable intensification. *Nature Sustainability, 1*(8), 441-446.

Tajudeen, T., Omotayo, A., Ogundele, F., & Rathbun, L. (2022). The effect of climate change on food crop production in Lagos State. *Foods*, *11*(24), 1-15. https://doi.org/10.3390/foods11243987

United Nations Framework Convention on Climate Change. (1992) *United Nations framework convention on climate change*. New York: United Nations.

United Nations Framework Convention on Climate Change. (1992) *United Nations framework convention on climate change*. New York: United Nations.

Wahab, M., & Iyiola, A. (2023). Climate change, wildlife and fisheries: A review of impact on Nigeria's food security. *Proceedings of the Nigerian Academy of Science*, *16*(1), 25-40. https://doi.org/10.57046/vzhe8024