REVIEW OF CLIMATE CHANGE-RESILIENT AGRICULTURE FOR ENSURING FOOD SECURITY IN NIGERIA

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Abstract
Climate change poses weighty threats to food security in Nigeria, worsening existing vulnerabilities within the agricultural sector. This review examines climate-resilient agricultural practices as essential strategies for mitigating the impacts of climate variability and ensuring sustainable food production. By examining the various adaptive measures including the adoption of drought-resistant crop varieties, improved soil management techniques, agroforestry, and efficient water resource management. The study highlights their effectiveness in enhancing agricultural productivity and resilience. The review also discusses the socio-economic implications of implementing these practices, emphasizing the need for policies that support farmers through access to technology, periodic training on climate smart agricultural practices, and financial resources among others. Furthermore, it addresses the importance of stakeholder collaboration, including government, non-governmental organizations, and local communities, in fostering an enabling environment for climate-resilient agricultural practices. Finally, the paper recommended that integrating these climate-resilient practices into Nigeria's agricultural policy framework will serve as an important strategy for achieving food security amidst the challenges posed by climate change.
Keywords: Food-security, climate-resilience, agriculture.

Introduction

Climate change poses a significant threat to agricultural productivity and food security globally, with developing countries like Nigeria being particularly vulnerable due to their reliance on rain-fed agriculture and limited adaptive capacity (Nwafor, 2018). The Intergovernmental Panel on Climate Change (IPCC) has projected those rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events will adversely affect crop yields and threaten the livelihoods of millions of farmers in Nigeria (IPCC, 2014). As a result, the need for climate change-resilient agricultural practices has become increasingly urgent.

In Nigeria, agriculture is a cornerstone of the economy, contributing about 24% to the national GDP and employing over 70% of the rural population (FAO, 2020). However, the sector is facing numerous challenges worsened by climate change, including soil degradation, water scarcity, and pest outbreaks (Adebayo, 2019). These challenges not only threaten food production but also endanger food security for a growing population projected to reach over 400 million by 2050 (World Bank, 2012).

To address these challenges, researchers have emphasized the importance of adopting climate-smart agricultural practices that enhance resilience while ensuring sustainable food production (Adeleke, and Olaniyan, 2020). Such practices include crop diversification, agroforestry, conservation agriculture, and the use of improved seed varieties that are more tolerant to climatic stresses (Ogunlela, 2019). These strategies not only help mitigate the impacts of climate change but also contribute to improving soil health and increasing farmers' adaptive capacity (Adegun, 2022).

Furthermore, effective policy frameworks and technological innovations are crucial for promoting climate-resilient agriculture in Nigeria. In recognition of this therefore, there is an urgent need for government support in implementing policies that encourage sustainable agricultural practices and provide farmers with access to relevant technologies. By fostering an environment conducive to innovation and adaptation, Nigeria can enhance its agricultural resilience and ensure food security.

This review aims to synthesize existing literature on climate change-resilient agricultural practices in Nigeria, exploring their potential to enhance food security amidst the challenges posed by climate change.

The paper is organized as follows: following this introduction, the paper defined concepts of climate, resilient agriculture and food security for proper understanding, Furthermore, the paper reviewed the various adaptive strategies and their social economic implications for agricultural sustainability, the study further seeks to provide insights on importance of stakeholder collaboration in creating enabling environment for climate-resilience agricultural practices that can inform policy decisions and promote effective interventions in the Nigerian agricultural sector. Finally, the conclusion and recommendations were drawn based on the context herein

Definition of concepts

Climate change

Climate change refers to any systematic alteration in the long-term patterns of climate variables, such as temperature, precipitation, pressure, or wind, that lasts for several decades or more. This change can result from natural external factors, like variations in solar radiation or shifts in the Earth's orbit, as well as natural internal processes within the climate system, or it may be driven by human activities. Significant statistical changes in the average state of the climate or its variability that persist for decades or longer are classified as "climate change (Mustapha, Timothy, and Shehu, 2024). IPCC (2021) define climate change as that which encompasses any alteration in climate over time, whether stemming from natural variability or human actions. Climate variability, on the other hand, refers to fluctuations in the average state of the climate across different temporal and spatial scales that exceed those of individual weather events; examples include prolonged droughts and floods (WMO, 2023).

Resilient agriculture

Resilience is becoming an increasingly critical consideration in agriculture due to the need to adapt to the unpredictable conditions brought about by climate change. Resilient Agriculture (RA), also known as Climate Resilient Agriculture (CRA), is an approach that focuses on sustainably utilizing existing natural resources through crop and livestock production systems to achieve long-term productivity and farm income, even amidst climate variability. This approach aims to reduce hunger and poverty for future generations in the context of climate change. CRA involves integrating adaptation, mitigation, and other practices into agriculture, thereby enhancing the system's ability to respond to various climate-related disturbances by minimizing damage and facilitating rapid recovery (Food and Agriculture Organization, 2021). Such disturbances may include droughts, floods, heatwaves, erratic rainfall patterns, prolonged dry spells, pest outbreaks, and other threats associated with a changing climate. In essence, it refers to the system's capacity to rebound from challenges.

CRA incorporates a built-in mechanism that enables the system to recognize threats and evaluate the effectiveness of its responses. The primary objective of climate-resilient agriculture is to sustainably enhance long-term farm incomes and productivity by effectively utilizing available natural resources through crop and livestock production systems. This entails prudent management of resources such as land, water, soil, and genetic diversity by adopting best practices. Implementing CRA practices can transform current agricultural scenarios and sustain production from local to global levels in a sustainable manner. Outcomes of climate-resilient practices include improved access to technology, greater use of resource conservation techniques, and enhanced adaptation of crops and livestock to climatic stress.

The resilience of agricultural systems is essential for thriving in a changing climate (Lepper *et al.,* 2020). Agricultural resilience is a key component of overall agricultural sustainability. Presently, the emphasis within agricultural sustainability is on developing technologies and farming methods that are environmentally friendly, easy to implement, effective for farmers, and capable of increasing food productivity while enhancing surrounding ecosystems (Pretty, 2001). Resilient agriculture should not only boost land productivity but also promote environmental health in the face of climate-related challenges that affect soil and water quality due to weather uncertainties (United States Department of Agriculture, 2022). It is believed that localizing food systems can enhance resilience and make food production more sustainable since the farming practices of smaller, local farms tend to be more ecologically sound than those employed by large conventional farms (Jones *et al.*, 2021).

Food security

Food security is a many-sided concept that refers to the availability, accessibility, utilization, and stability of food for all individuals at all times. It encompasses not only the physical availability of food but also the economic and social factors that affect individuals' ability to obtain sufficient, safe, and nutritious food to meet their dietary needs for an active and healthy living (FAO, 1996). Food security anchors on four (4) pillars represented in Figure 1.

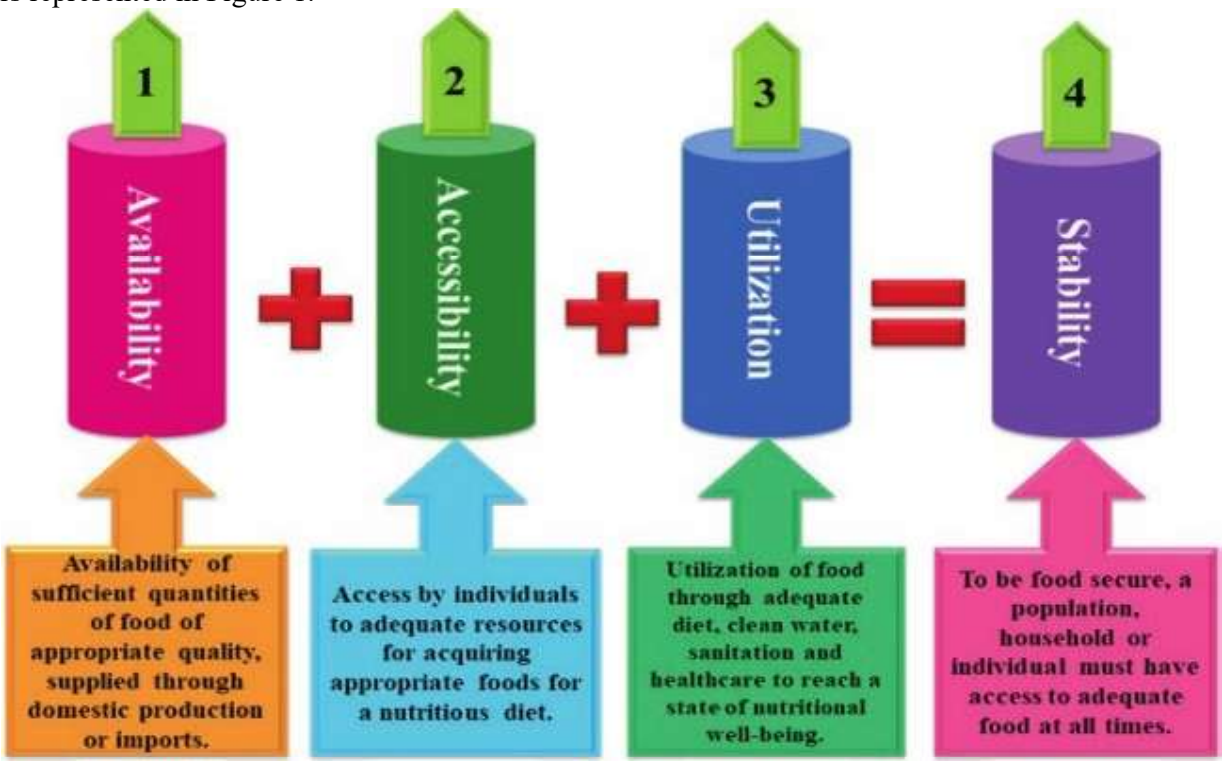

Fig. 1: An illustration of 4 pillars of food security. Source: Majhi, *et al* (2023)

Review of Climate-Change Resilience Agricultural Practices

Climate resilience in agricultural practices refers to the ability of farming systems to withstand, adapt to, and recover from the adverse impacts of climate change. As climate variability increases, implementing resilient agricultural practices is essential for ensuring food security, protecting livelihoods, and promoting sustainable development. Climate threats, resilient agricultural practices, description, and benefits are presented in Table 1.

Table 1: Climate threats, resilient technologies/practices, their description, and benefits

Threats	Practices	Description and Adaptation/Mitigation Benefits
Extreme Heat	Heat tolerant crops (e.g. quinoa, pearl millet, sorghum) or crop varieties	▪ Promote crops and/or crop varieties with a higher heat tolerance and/or optimal heat range. ▪ Enhance yields in areas where temperature is expected to exceed heat thresholds that are harmful to existing cropping systems.
	Short cycle crop varieties	▪ Reduce the effect of heat stress at key phonological phases (germination and flowering) and improve final yields. ▪ Reduce plants' exposure to heat by shortening the growing cycle. ▪ Reduce the total water requirements during the growing season.
Strong Winds	Windbreakers	▪ Rows of trees can protect crops by breaking strong winds, reducing soil erosion, increasing crop yields and protecting livestock from heat and cold conditions

Drought	Agroforestry	▪ Root systems stabilize the ground and reduce soil erosion. ▪ Improves soil health by increasing soil organic matter, nutrient availability and microbial activity.
	Agronomic practices (e.g. weeding, harrowing, grafting, mulching)	▪ Weeding and defoliation reduce soil water losses from plant transpiration. ▪ Cover crops reduce soil erosion by increasing soil organic matter, water, air, and nutrient availability. ▪ Harrowing (breaking the soil into small fragments) can prevent the loss of land moisture by evaporation.
Flooding	Raised bed system	▪ Removes excess water during plant growth by better draining the water retained in the soil. ▪ Promotes optimal growth of root systems through soil aeration. ▪ Improves soil structure by limiting the compaction from human feet
Land Degradation and Greenhouse Gas Emissions	Agronomic (e.g. sub-soiling)	▪ Sub-soiling can break possible hard pans and improve soil aeration. ▪ Introduction of root crops (e.g. horseradish) for deep root penetration and soil structure improvement
	Crop rotation, crop association and fallow	▪ Increase soil fertility as each crop has different nutrient requirements and plant-soil dynamics. ▪ Increase crop yields with the diverse nutrient availability.
	Mulching	▪ Increases soil moisture by reducing losses from direct evaporation. ▪ Reduces weed growth by keeping light from reaching the soil surface. ▪ Moderates soil temperatures by keeping the soil warmer during cold nights and cooler in hot days. ▪ Reduces irrigation requirements by reducing losses from direct evaporation

Source; Alvar-Beltrán *et al.* (2021)

Thus, the following climate resilience agricultural practices were reviewed;

Adoption of drought-resistant crop varieties: The adoption of drought-resistant crop varieties is a key strategy for enhancing climate resilience in agriculture. These varieties are specifically bred or genetically modified to withstand periods of low water availability, which is increasingly important as climate change leads to more frequent and severe droughts. These varieties can maintain productivity under drought conditions, thereby reducing vulnerability to climate variability. According to Reynolds *et al*., (2007), the development and adoption of drought-tolerant crops can significantly enhance food security in arid and semi-arid regions by ensuring stable yields despite changing climatic conditions. Blum (2005) while writing on drought resistance, water-use efficiency, and yield potential observed that drought-resistant crops typically have mechanisms that allow them to use water more efficiently, reducing the overall demand for irrigation. The author further discovered that the use of drought resistant crop variety is very crucial especially in regions where water scarcity is becoming more pronounced due to climate change. In a similar development, Bhandari and Ranjan (2018) in their study on impact of climate change on agriculture and food security observed that with the use of drought-resistant varieties, farmers can achieve more stable yields during dry periods. This stability is vital for food security as climate variability increases.

Improved soil management techniques: Effective soil management is crucial for enhancing soil health, fertility, and moisture retention, all of which contribute to increased resilience against climate extremes. Practices such as cover cropping, reduced tillage, and the application of organic amendments can improve soil structure and nutrient availability. According to Lal (2015), improved soil management techniques not only enhance agricultural productivity but also increase the soil's capacity to sequester carbon and mitigate climate change impacts. improved soil management techniques are essential for building resilience in agricultural systems against the impacts of climate change. By enhancing soil health, water retention, and biodiversity while reducing erosion and increasing carbon sequestration, these practices contribute to more sustainable and productive agricultural systems in the face of changing climatic conditions (Lal, 2004). Thus, improved soil management techniques are essential for building resilience in agricultural systems against the impacts of climate change. By enhancing soil health, water retention, and

biodiversity while reducing erosion and increasing carbon sequestration. These practices according to according to Lal (2015) contribute to a more sustainable and productive agricultural systems in the face of changing climatic conditions.

Agroforestry: Agroforestry integrates trees and shrubs into agricultural landscapes, providing multiple benefits such as improved biodiversity, enhanced soil quality, and increased resilience to climate change. According to Nair (2012), agroforestry systems can improve water retention in soils, reduce erosion, and provide shade for crops, thereby mitigating the effects of extreme temperatures and droughts. Agroforestry presents a multifaceted approach to enhancing climate resilience in agriculture by improving soil health, increasing biodiversity, optimizing water management, sequestering carbon, regulating microclimates, and providing economic stability for farmers (Place and Dewees, 2015).

Efficient water resource management: Efficient water resource management practices are essential for adapting agriculture to climate variability, especially in water-scarce regions. Techniques such as rainwater harvesting, drip irrigation, and the use of soil moisture sensors can optimize water use efficiency and reduce wastage. According to Rockström *et al.* (2010), improving water management is critical for enhancing agricultural resilience and ensuring sustainable food production in the face of increasing water scarcity due to climate change. Assessing the irrigation practices in Nigeria, Ojo and Adeyemo (2015) discovered that the adoption of modern irrigation systems, such as drip and sprinkler irrigation, significantly enhanced water use efficiency. The authors further observed that these methods minimize water loss through evaporation and runoff, ensuring that crops receive the necessary moisture even during dry spells. Efficient irrigation is particularly important in Nigeria's northern regions, where rainfall is inconsistent. Abubakar and Abba (2019) in their study on rainwater harvesting for sustainable agriculture suggested that in most northern part of Nigeria, implementing rainwater harvesting systems can help farmers capture and store rainwater for agricultural use. They further observed that the practice is particularly beneficial in areas prone to drought, as it provides an alternative water source for irrigation during dry periods, thus reducing dependence on unreliable rainfall. Thus, efficient water management practices are fundamental to building climate resilience in Nigerian agriculture by optimizing water use, enhancing soil moisture retention, implementing rainwater harvesting systems, adopting integrated resource management strategies and ensuring water quality.

Socio-Economic Implication of Implementing Climate Change Resilience Agricultural Practices

Implementing climate resilience agricultural practices has significant socio-economic implications for communities, farmers, and broader economies. These implications can be both positive and negative, depending on various factors such as local context, governance structures, and the level of investment in these practices. For the purpose of this study, the following socio-economic implications of implementing climate change resilience agricultural practices were reviewed. They include;

Improved food security and livelihoods: It has been observed that adopting climate-resilient agricultural practices can enhance food security by stabilizing crop yields in the face of climate variability. Practices like drought-resistant crops and improved soil management contribute to more reliable food production, which is essential for rural communities that rely heavily on agriculture for their livelihoods. The Food and Agriculture Organization (2012) reported that improving agricultural resilience is crucial for reducing hunger and enhancing the nutritional status of vulnerable populations. The FAO (2012) report further stated the implementation of climate change resilient in agricultural practices can lead to increased income for farmers by reducing losses from climate impacts and enhancing productivity. Thus, adopting such practices can improve farmers' economic stability, enabling them to invest in their families' education and health. In similar development, the transitioning to climate-smart agriculture according to FAO (2012) annual report can create new employment opportunities especially in rural areas. The FAO (2012) report

strongly advised that focusing on sustainable agriculture can stimulate local economies by providing jobs in areas such as agro-processing, marketing, and sustainable farming techniques thereby ensuring food security.

Economic diversification and income stability: The implementation of climate-resilient practices can lead to economic diversification in rural areas. By integrating agroforestry or diversifying crop systems, farmers can create multiple income streams, reducing dependence on a single crop and enhancing overall economic stability. According to a study by Oxfam (2016), diversified farming systems are better positioned to withstand market fluctuations and climate impacts, thereby contributing to more stable incomes for farmers. The author further observed that the adoption of climate-resilient practices enhances farmers' ability to withstand climate shocks, leading to more stable income levels over time. Therefore, farmers who adopt sustainable practices experience fewer income fluctuations compared to those who rely on traditional farming methods, as they are better equipped to manage adverse conditions.

Access to financial resources: Investing in climate-resilient agricultural practices often requires access to financial resources, including credit, grants, and insurance products. However, many smallholder farmers face barriers to accessing these financial resources due to lack of collateral or financial literacy. According to a report by the International Fund for Agricultural Development (2016), improving access to finance for smallholders is critical for enabling them to adopt climate-resilient practices that can enhance their productivity and resilience. Studies have shown that access to financial resources is a crucial socio-economic implication of implementing climate change-resilient agricultural practices in Nigeria. Thus, as farmers adopt these practices, their financial stability and creditworthiness improve, enabling them to secure funding for investments that enhance productivity and sustainability (Adebayo and Ojo, 2019).

Gender dynamics: The implementation of climate-resilient agricultural practices can also have implications for gender dynamics within rural communities. Women often play a crucial role in agricultural production but may have limited access to resources, training, and decision-making power. In recognition of this, Meinzen-Dick *et al*. (2014) advised that empowering women through targeted interventions in climate-resilient practices can lead to improved household food security and economic stability. However, without intentional gender-sensitive approaches, existing inequalities may worsen. Thus, addressing gender disparities in access to resources, knowledge, decision-making power, and social support systems, stakeholders can promote more effective and equitable agricultural development strategies (FAO, 2011). World Bank (2012) also emphasizes that empowering women in agriculture can lead to economic growth and improved livelihoods, particularly when they adopt climate-resilient practices.

Community cohesion and social capital: The implementation of climate-resilient practices in agriculture often requires collective action among farmers and community members, fostering social capital and community cohesion. Collaborative efforts in adopting practices such as water management or shared agroforestry initiatives can strengthen community ties and enhance collective bargaining power. According to Pretty and Ward (2001), social capital enhances collective efficacy, which is crucial for implementing sustainable agricultural practices. The authors further observed that, strong community ties enable farmers to work together, share resources, and adopt innovations more effectively. The research by FAO (2011) indicates that social capital plays a significant role in enhancing food security through collaborative efforts in agriculture. Communities that work together are better equipped to implement climate-resilient practices that ensure stable food supplies.

Importance of Stakeholders Collaboration in Creating Enabling Environment for Climate-Resilience Agricultural Practices

Stakeholder collaboration is very important in creating an enabling environment for climate change resilient agricultural practices, as it leverages diverse knowledge, resources, and capacities to address complex climate-related issues. These collaborative approaches involve farmers, government agencies, non-governmental organizations (NGOs), research institutions, and the private sector working together to enhance resilience in agriculture. The importance of stakeholder collaboration in creating an enabling environment for climate- resilience agricultural practices were reviewed under the following headings:

Holistic knowledge sharing: One of the primary benefits of stakeholder collaboration is the pooling of knowledge and expertise from various sectors. Fletcher (2019) stated that collaborative networks facilitate the sharing of local and scientific knowledge, which is essential for developing effective climate-resilient practices. Farmers possess valuable insights into local conditions and traditional practices, while researchers can provide evidence-based strategies and innovations. By combining these perspectives, stakeholders can design more effective interventions that are context-specific and culturally appropriate. It encompasses both scientific and local indigenous knowledge. In recognition of this therefore, Berkes (2009) observed that integrating traditional ecological knowledge with scientific research can enhance understanding of local ecosystems and improve resilience to climate change. This integration allows stakeholders to make informed decisions that consider ecological, social, and economic dimensions. Thus, it can be concluded that holistic knowledge sharing facilitates the integration of diverse perspectives, enhances adaptive capacity, builds trust among stakeholders, and supports effective policy development that address the complex challenges posed by climate change in agriculture.

Resource mobilization: Collaboration among stakeholders can enhance resource mobilization for climate-resilient initiatives. Mastrorillo et al. (2016) highlight that partnerships between public and private sectors can lead to increased investment in sustainable agricultural technologies and practices. For example, NGOs often have access to funding and technical expertise that can support farmers in implementing new practices. Government policies that incentivize collaboration can further enhance resource availability, making it easier for farmers to adopt climate-resilient strategies.

Policy advocacy and implementation: Stakeholder collaboration plays a vital role in advocating for supportive policies that create an enabling environment for climate resilience. Berkes (2009) emphasizes that multi-stakeholder platforms can effectively influence policy decisions by presenting a unified voice that represents diverse interests. Collaborative efforts can lead to the development of policies that prioritize climate resilience in agriculture, such as subsidies for sustainable practices or investment in research and development. Furthermore, involving stakeholders in policy implementation ensures that strategies are grounded in local realities and are more likely to be accepted by communities.

Capacity building: Building the capacity of stakeholders is another critical aspect of collaboration. Peters (2017) argue that partnerships can facilitate training and knowledge exchange, empowering farmers to adopt new technologies and practices. Workshops, field demonstrations, and peer-to-peer learning opportunities foster an environment where stakeholders can learn from each other's experiences. This capacity building is essential for ensuring that agricultural communities are equipped to respond to climate challenges effectively.

Enhancing resilience through innovation: Collaboration fosters innovation by bringing together diverse perspectives and expertise. Klerkx and Leeuwis (2009) note that interactive learning processes among stakeholders can lead to the co-creation of innovative solutions tailored to local contexts. For instance, collaborative research projects involving farmers and scientists have led to the development of new crop varieties that are more resilient to

climate stressors. Such innovations are critical for enhancing food security and sustaining livelihoods in the face of climate change.

Conclusion and Recommendations

In conclusion, this paper has demonstrated the urgent need for adaptive strategies to ensuring food security in the face of increasing environmental challenges. The findings indicate that climate change poses significant threats to agricultural productivity, worsening food insecurity among vulnerable populations. However, the adoption of climate-resilient agricultural practices, including use of improved crop varieties, sustainable land management, and innovative water conservation techniques among others offer viable solutions to mitigate these impacts. Furthermore, integrating traditional knowledge with modern agricultural practices in the form of holistic knowledge sharing, policy advocates and implementation, resource mobilization among others were considered as important approaches of stakeholder collaboration in creating enabling environment for climate-resilience agricultural practices and sustainability in farming systems thereby ensuring food security. In line with the foregoing, the following recommendations were considered, they include;

i. integrating these climate-resilient agricultural practices into Nigeria's agricultural policy framework will serve as an important strategy for achieving food security amidst the challenges posed by climate change;
ii. increased funding and support for agricultural research institutions are necessary to develop and disseminate climate-resilient crop varieties and technologies tailored to local conditions;
iii. implementation of training programs for farmers on climate-smart agricultural practices, including soil management, use crop and efficient water management, to enhance their adaptive capacity.
iv. enhancing collaboration between local communities, agricultural extension services, and NGOs to promote knowledge sharing and the adoption of best practices in climate-resilient agriculture.

References

Abubakar, I.R. & Abba, A. (2019). Rainwater harvesting for sustainable agriculture in Nigeria. *Journal of Agricultural Science and Technology,* 19(3), 305-315. Link (http://www.academicjournals.org/journal/JAST/article-full-text-pdf/9F0A8D461049)

Adebayo, A. A and Ojo, J. A. (2019). Climate Change Adaptation Strategies among Farmers in Nigeria: A Review. *Journal of Agricultural Science and Technology*, 21(2), 103-116.

Adegun, J. A and Ojo, J. A. (2022). Climate-Smart Agriculture: *A Pathway to Sustainable Agricultural Development in Nigeria. Sustainable Agriculture Research,* 11(1), 45-58.

Adeleke, A. A and Olaniyan, A. T. (2020). The Role of Technology in Climate-Resilient Agriculture in Nigeria: A Review. *Journal of Agricultural and Environmental Ethics*, 33(2), 215-229.

Alvar-Beltrán, J., Elbaroudi, I., Gialletti, A., Heureux, A., Neretin, L. and Soldan, R. (2021). Climate Resilient Practices: typology and guiding material for climate risk screening. Rome, FAO.

Berkes, F. (2009). Evolution of co-management: Role of knowledge generation, bridging organizations and social learning. *Journal of Environmental Management*, 90 (5), 1692-1702.

Bhandari, H and Ranjan, R. (2018). Impact of Climate Change on Agriculture and Food Security. *International Journal of Current Microbiology and Applied Sciences*, 7(1), 147-157. DOI: 10.20546/ijcmas.2018.701.018.

Blum, A. (2005). Drought resistance, water-use efficiency, and yield potential—are they compatible, disallowed, or mutually exclusive? *Australian Journal of Agricultural Research*, 56(11), 1159-1168. DOI: 10.1071/AR04208.

Fletcher, S (2019). The role of stakeholder engagement in enhancing resilience in the agricultural sector. Agricultural Systems, 176, 102655.

Food and Agriculture Organization (FAO). (1996). Rome Declaration on World Food Security and World Food Summit Plan of Action. FAO.

Food and Agriculture Organization (2011). "The State of Food and Agriculture 2010-2011: Women in Agriculture – Closing the Gender Gap for Development.

Food and Agriculture Organization (2020). Nigeria: Country Fact Sheet on Food and Agriculture Policy Trends. Retrieved from (FAO website).

Food and Agriculture Organization (FAO). (2021). Climate-smart agriculture and agricultural extension services. Food and Agriculture Organization of the United Nations, 1-102. [https://www.fao.org/3/cb5197en/cb5197en.pdf]

Intergovernmental Panel on Climate Change (IPCC). (2021). *Mitigation of climate change. Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change.* WG III contribution to the Sixth Assessment Report. Vol. 1453, p. 147.

Intergovernmental Panel on Climate Change. (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Retrieved from (IPCC website).

International Fund for Agricultural Development (2016). Financing Climate Resilience in Agriculture: The Role of Smallholder Farmers. IFAD.

Jones, P. G., Thornton, P. K., and Dimes, J. (2021). The impact of climate change on global food security. Food Security Journal, 13(4), 787-802. [https://doi.org/10.1007/s12571-021-01190-4

Klerkx, L., Leeuwis, C. (2009). Establishing the European Innovation Partnership for Agricultural Productivity and Sustainability: A multi-actor perspective. Agricultural Systems, 101(3), 135-143.

Lal, R. (2004). Soil carbon sequestration to mitigate climate change. *Geoderma* 123(1-2), 1-22. DOI: 10.1016/j.geoderma.2004.01.032.

Lal, R. (2015). Restoring Soil Quality to Mitigate Soil Degradation. Sustainability, 7(5), 5875-5895.

Lepper, C., Barbour, J., and Ernst, M. (2020). Community-based approaches to climate resilience. *Journal of Environmental Management*, 263, 110392.

Mastrorillo, M (2016). The role of public–private partnerships in enhancing climate resilience in agriculture. Environmental Science Policy, 66, 1-10.

Meinzen-Dick, R., Quisumbing, A., Behrman, J. (2014). Gender in Agriculture: Closing the Knowledge Gap. In Gender in Agriculture: Closing the Knowledge Gap. Food and Agriculture Organization.

Mustapha, S. B., Timothy, E. and Shehu, H (2024). Emerging Role of Extension Services in Strengthening the Capacity of Farmers' resilience to climate change in Nigeria. Proceedings of the 29th Annual Conference of the Agricultural Extension Society of Nigeria Number: https://dx.doi.org/10.4314/jae.v29i1.12S

Nair, P. K. R. (2012). Agroforestry Systems in the Tropics. Springer Science Business Media.

Nwafor, J. (2018). The Effects of Climate Change on Agriculture in Nigeria: Implications for Food Security. *Global Journal of Agricultural Sciences,* 17(1), 1-8.

Ojo, J.A., Adeyemo, A.J. (2015). Assessment of irrigation practices in Nigeria: A case study of some selected States. *International Journal of Agricultural Science and Research*, 5(4), 1-12. DOI: 10.5958/2231-4490.2015.00001.6.

Oxfam. (2016). From Farm to Market: How Climate Resilience Can Boost Rural Livelihoods. Oxfam International.

Majhi, P. K; Raza B; Behera,P. P; Singh, S. K; Shiv, A ; Mogali, S.C T; Bhoi, T.K; Patra, B and Behera, B (2023). Biodiversity, Functional Ecosystems and Sustainable Food Production Future-Proofing Plants Against Climate Change: A Path to Ensure Sustainable Food Systems Retrieved: https://www.researchgate.net/publication

Peters, J (2017). Building capacity for climate-resilient agriculture: The role of partnerships. Climate Policy, 17(5), 637-649.

Place, F. And Dewees, P.A. (2015). The role of trees in sustainable land management. In The Role of Trees in Sustainable Land Management, World Bank Publications.

Pretty, J and Ward, H. (2001). Social Capital and the Environment." World Development'', 29(2), 209-227.

Reynolds, M. P., Tuberosa, R., Wang, H. (2007). The Role of Drought-Tolerant Varieties in Enhancing Agricultural Resilience to Climate Change. In Climate Change and Food Security: Risks and Responses (pp. 81-98). Food and Agriculture Organization.

Rockström, J., Falkenmark, M., Karlberg, L. (2010). Increasing Water Productivity to Feed the World. Agricultural Water Management, 97(4), 555-566.

United States Department of Agriculture (USDA). (2022). Climate change and agriculture: Adaptation strategies. United States Department of Agriculture 1-78.

World Bank. (2012). World Development Report 2012: Gender Equality and Development.

World Meteorological Organization (WMO). (2023). State of the global climate 2022. World Meteorological Organization, 1-60 https://library.wmo.int/doc_num.php?explnum_id=11178]