

Proceedings of the Annual Conference of the Agricultural Extension Society of Nigeria
Number: Thirtieth Annual Conference
Theme: Agricultural Extension Policy, Practices and National Food Security
Date: 6 -10 April 2025
Venue: Taraba State University, Jalingo, Nigeria
ISSN: 1595 – 1421.
Website: <https://info@ajol.org>,
Email: agricultural.extension.nigeria@gmail.com ; editorinchief@aesonnigeria.org

Challenges of Climate Change on Food Security in Sub Saharan Africa

<https://dx.doi.org/10.4314/jae.v30i1.14S>

Ohwofasa, Wilson Onokohwomomo^{1*}, Goselle, Nantip Thomas² and Origho Thaddeus³

¹ University of Delta, Agbor, Delta State, Nigeria. Department of Urban and Regional Planning, Faculty of Environmental Science.

² Igbiniedion University, Okada, Edo State, Nigeria, Department of Geography and Regional Planning, Goodluck Ebele Jonathan College of Arts and Social Sciences.

³ University of Delta, Agbor, Delta State, Nigeria. Department of Geography and Environmental Management, Faculty of Environmental Science, University of Delta, Agbor, Delta State, Nigeria.

*Corresponding author's Email: ohwofasa.wilson@unidel.edu.ng , +2348038517448

²goselle.nantip@iuokada.edu.ng , +2348037325301

³origho.thaddeus@unidel.edu.ng , +2348033728266

Abstract

This study reviews the impact of climate change on food security in Sub-Saharan Africa. It focuses on how climate change affect critical dimensions of food security, including availability, accessibility, utilisation, and stability, while emphasising the implications for climate variability and regional resilience. Drawing upon a review of scholarly literature in humanities and environmental sciences, the paper employs an exploratory research methodology to investigate the far-reaching impacts of climate change on food security. Specific climate-related challenges, such as floods, droughts, altered rainfall patterns, increased heavy precipitation, and declining environmental quality, are highlighted as significant threats to food security. Policy directions to address climate change and mitigate food insecurity in Sub-Saharan Africa, with a particular focus on Nigeria must be made and strictly followed; the governments, international organizations, and local communities must collaborate to strengthen social safety nets and social protection programs, to ensure that vulnerable populations have access to the resources needed to navigate the impacts of climate change and safeguard its agricultural future.

Keywords: Climate Change, Food Security, Food Availability, Food System

Introduction

Environmental and climatic changes are marked by fluctuations in temperature, primarily driven by the release of greenhouse gases from human activities and other anthropogenic influences, ultimately resulting in global warming and its associated climatic impacts. Climate change denotes long-term alterations in the average weather patterns of a specific region, including variables such as temperature, humidity, precipitation, and sunlight exposure (FutureLearn, 2021). According to Ahmed et al. (2023), climate change refers to alterations in the average atmospheric conditions, which can be driven by both natural factors, such as the Earth's orbital variations, volcanic activity, and tectonic movements, as well as human-induced factors, including the rising concentration of greenhouse gases and aerosols. It leads to environmental catastrophes which negatively affect humans, animals and plant species (agricultural activities) and thus endanger their continuous existence and survival on the Earth. Climate change has been recognised as a multifaceted crisis

with far-reaching implications for agriculture and food security. It has been identified as one of the most critical environmental challenges of the 21st century, with far-reaching consequences that extend to sectors such as agriculture and food production (Calculliet al., 2021; Marx et al., 2021).

Climate change has a substantial impact on agriculture and food production in Sub-Saharan Africa, posing serious threats to food security and the livelihoods of millions across the region. The region is mainly populated by smallholder and subsistence farmers who are particularly susceptible to the impacts of climate change, primarily due to limited access to critical resources and a constrained adaptive capacity. Eradicating hunger and malnutrition remains a major obstacle to the pursuit of sustainable development in low-income countries. For example, an estimated 500 million individuals facing food insecurity continue to reside in Africa and Southern Asia. A significant proportion of this population relies, either directly or indirectly, on agriculture for their survival and economic sustenance (Wudiet al., 2022; WHO, 2021). Climate change adversely affects agricultural systems, leading to reductions in crop yields, livestock productivity, and the availability of fishery resources. Furthermore, variations in climate patterns pose serious threats to food security by undermining rural livelihoods, disrupting marine and freshwater ecosystems, and contributing to the disintegration of established food systems (Jinet al., 2021; Marques et al., 2021). Food security in sub-Saharan Africa faces serious risks as a result of climate change, particularly because a large portion of the population depends on agriculture for their livelihood. The region is especially susceptible to climate-related challenges, including shifts in temperature, alterations in rainfall patterns, and an increase in the occurrence and severity of extreme weather events (Derbile et al., 2021).

Climate change poses diverse and intricate challenges to ensuring food security across countries in sub-Saharan Africa. Such changes can severely undermine crop production, livestock outputs, and overall food availability, thereby increasing the risk of impoverishment for millions of small-scale farmers and low-income urban populations. Climate change manifests in various forms worldwide, including rising sea levels, shrinking glaciers, northward shifts in plant and animal habitats, elevated ocean temperatures, reduced rainfall, and the premature onset of dry seasons. These changes have direct and profound implications for farming systems and the availability of sufficient nutrition.

Climate change can result in a decline in the annual production of staple crops, exacerbating existing food shortages and worsening the socio-economic conditions of an already impoverished population. This underscores the argument that climate change can no longer be overlooked as a key development issue. Its effects on poor communities in sub-Saharan Africa are becoming increasingly evident, with the region at risk of becoming a central point of the global food crisis if climate change is not addressed at local levels. The reality of climate change is now broadly recognised, and growing evidence shows that it presents a major challenge to development efforts, especially within economically disadvantaged regions. This study therefore, examines how climate change influences crop production and access to adequate nutrition, utilising information gathered from existing publications

through a structured literature analysis, emphasising the use of empirical data as the chosen methodological approach.

This paper provides an outline of the research methodology and literature review concerning the varied consequences of climate variability on farming outputs and nutritional stability within the sub-Saharan African context. It further examines the difficulties that environmental changes introduce to the region's agricultural systems and food supply, and discusses approaches for both adaptation and mitigation.

Methodology

A scholarly evidence-based review of pertinent publications was carried out using databases such as Web of Science, Scopus, and Google Scholar to investigate how changing climate conditions affect farm productivity and the stability of food systems. The review followed the "Preferred Reporting Items for Systematic Reviews and Meta-Analysis" (PRISMA) guidelines (O'Dea *et al.*, 2021). The search focused on materials published between 2002 and 2024, including book chapters, encyclopedias, and conference abstracts. In ISI Web of Science, the search was conducted under "Topics," while in Scopus, it was limited to "Article title, Abstract, and Keywords," with no language restrictions and covering all available years. (Figure 1)

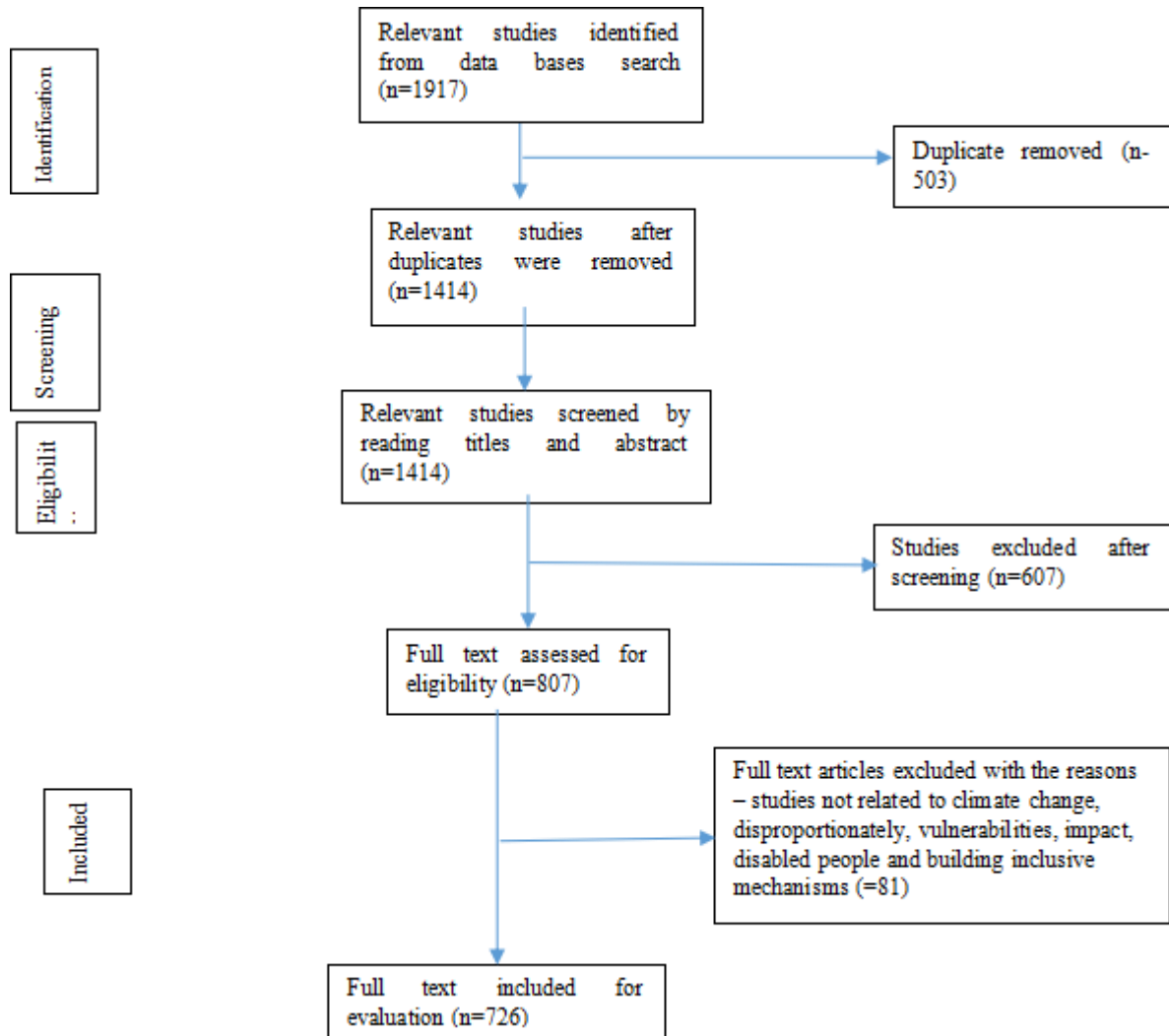


Figure 1: Schematic review of climate change impact research in Nigeria. [Okon et al., (2021)]

Many scholars have investigated the link between environmental changes and nutritional security, yielding varied findings. Some research points to negative effects on crop yields and the key aspects of food security, including supply, access, cost, and consistency, which could lead to food shortages. Conversely, other studies suggest that climate variability may have both beneficial and adverse effects on different types of crops. As a result, the extent of the adverse effects of climate variability on food security remains inconclusive (Farooq *et al.*, 2022; Picksonet *et al.*, 2022; Abdi et al., 2024).

Empirical research in Africa has examined the link between climate change and food security, particularly in North and East Africa. For instance, Kabubo-Mariara and Kabara (2015) analyzed the impact of climate change on food insecurity over the period from 1975 to 2012. Their findings suggest that climate change is likely to exacerbate food insecurity, with climate variables demonstrating a non-linear association with food insecurity outcomes.

The SSA region's high physical and social vulnerability, such as limited access to safety nets and dependence on rain-fed agriculture, makes it disproportionately susceptible to the adverse effects of climate change compared to other parts of the world, (Ndamani and Watanabe, 2017). Furthermore, available evidence suggests that the impact of climate change will be particularly severe in West Africa, where studies have indicated that the region's agriculture will be greatly affected, with declining grain yields anticipated as a result of climate-crop modelling projections (Derbileet *al.*, 2021; Chiawo and Otiende, 2021).

Kabubo-Mariara and Kabara (2015) found that while moderate increases in seasonal precipitation were linked to reductions in food insecurity, excessive rainfall could have the opposite effect by damaging crops. In Tunisia, Zaied and Zouabi (2015) assessed the long-term impact of climate variability on olive production across 24 regions using data from 1980 to 2012. Their findings indicated that rising temperatures and decreased rainfall had adverse effects on olive yields over the past three decades. Similarly, Geffersa (2014) examined the influence of climate change on household food security across 15 rural villages between 1994 and 2009, revealing a significant and negative impact over time. Supporting this, Demeke (2011) analyzed the role of rainfall variability in shaping food insecurity among rural households in Ethiopia from 1994 to 2004. Their results showed that both the level and variability of rainfall substantially affected food security and vulnerability. Moreover, factors such as household size and livestock ownership were recognized as a beneficial factor for food security in Ethiopia. The negative impacts of environmental change on farming extend beyond just crop cultivation, with studies also highlighting considerable effects on animal husbandry and fishing industries across sub-Saharan Africa.

The "cattle corridor" in Uganda experienced an intense and prolonged drought during 1999–2000, which resulted in substantial livestock losses, reduced milk production, rising food prices, increased food insecurity, and a notable decline in economic growth (Galemaet *al.*, 2024). Additionally, scientific research has shown a long-term decline in fisheries productivity in the region, attributed to climate-induced changes in lake ecosystems. These disruptions have led to reduced fish populations in East African lakes over the past two centuries (Yongoet *al.*, 2021).

Climate change has significant consequences for agriculture and food production in sub-Saharan Africa, with wide-ranging implications for food security and the livelihoods of millions across the region. The agricultural sector in this area relies heavily on rainfall, which makes it particularly susceptible to shifts in climate. Variations in rainfall patterns, increases in average temperatures, and a rise in the occurrence of extreme weather events have altered soil properties and contributed to reduced crop yields and disruptions to ecological balance (Omotosho, 2023; Goselle, 2024). Crops like maize, sorghum, and millet, which are staple foods in the region, have exhibited yield declines due to increased heat stress and drought (Neupaneet *al.*, 2022). Ecological niches for various crops are shifting due to rising temperatures and altered precipitation levels, forcing farmers to adjust their cropping patterns and because of limited access to resources and technology hamper their ability to adapt effectively. Sub-Saharan Africa's vulnerability to climate change is intensified by socioeconomic challenges, including widespread poverty, rapid population growth,

and a heavy dependence on subsistence agriculture. Studies conducted in West Africa indicate that women, who represent the majority of the agricultural workforce, experience unequal impacts due to restricted access to resources and limited participation in decision-making processes (Vincent, 2022; Israel, 2025). These inequalities have further aggravated food insecurity both in the region and across sub-Saharan Africa as a whole (Hlahla, 2022).

Climate change has a predominantly detrimental impact on agriculture, with research indicating that farming and food production in the region are likely to experience serious disruptions due to rising global temperatures. Investigations into what shapes farmers' awareness of climate risks in West Africa, especially in Ghana, show that agriculture is extremely vulnerable to environmental changes. Variations in climate patterns have contributed to a reduction in the yearly yield of essential crops (Baffour-Ata, 2021). In addition, the region's strong dependence on rain-fed agriculture, largely practiced by smallholder farmers with limited capacity for investment, makes it especially susceptible to the impacts of climate change (Ntuli, 2023; Msongaleli, 2024). Climate change, through its influence on temperature, rainfall distribution, and the occurrence of extreme weather events, is projected to reduce the productivity of staple crops such as maize, sorghum, and millet. This decline poses serious risks to food security. A meta-analysis on the impacts of climate change indicates that up to 70 percent of studies report declines in crop yields by the 2030s, with approximately half showing reductions ranging from 10 to 50 percent (van Dijk *et al.*, 2021; Li, 2024;). These yield reductions are linked to various factors, including more frequent droughts, altered rainfall patterns, and the increased spread of pests and diseases, all of which are intensified by climate change. Sub-Saharan Africa, which is already home to a significant number of smallholder and subsistence farmers, remains highly vulnerable due to limited access to resources and weak adaptive capacity. Climate change has the potential to worsen food shortages and low-income conditions, resulting in greater levels of hunger and malnutrition, particularly among vulnerable groups such as children and older adults.

According to the Food and Agriculture Organization, climate change is expected to cause an additional 71 million food-insecure people, with half of these coming from sub-Saharan Africa (Amegbore *et al.*, 2020; World Food Programme, 2021; Baptista *et al.*, 2022).

Onana(2023), reviewed water scarcity situation in Chad Republic , and posited that the drying of key water bodies, such as Lake Chad, highlights the growing water scarcity in the region according the author, is due to the negative impact of climate change . The impacts of climate change are expected to vary significantly depending on the extent of temperature increase and geographical location (Raupachet *et al.*, 2021). The report notes that even a temperature rise of less than one degree Celsius could result in natural disasters such as water shortages and flooding in certain regions. This highlights the fact that agricultural production is closely tied to climate conditions, as it involves selecting crop types suited to specific environmental contexts and applying appropriate farming practices. Therefore, agriculture can be understood as a climate-sensitive biological industry shaped by regional characteristics. Climate change disturbs the agricultural ecosystems, arising from

agricultural climatic elements, such as sunlight, temperature and precipitation, having negative influence on arable crops , livestock , and hydrology sectors (Gupta *et al.*, 2021). Nigeria is among the ten countries most vulnerable to the effects of climate change, with approximately six percent of its land area estimated to be exposed to extreme weather events (Raimi 2021; Balogun 2022). Agricultural activities are particularly affected, making the sector one of the most impacted by these climatic threats (Akinwumiet *al.*, 2020).

Crop production, which accounts for nearly 94 percent of Nigeria's agricultural sector, is significantly affected by climate change. Evidence of this impact is observed in certain regions of the country, where the length of the growing season has already decreased by approximately 20 percent (Alehileet *al.*, 2022). Furthermore, Ita and Ogbemudia (2023) observe that many forest resources are gradually disappearing due to the impacts of climate change. Projections by Jones and Thornton (2003) suggest that, by 2050, crop yields in sub-Saharan Africa, and Nigeria in particular, may decline by as much as 50 percent as a result of climate-related factors. This anticipated decline increases the likelihood of low agricultural output, crop failure, and livestock mortality. Studies conducted in southern Nigeria, especially in the rainforest zone, indicate that vegetation faces instability due to irregular rainfall. In the savannah region, high temperatures caused by climate change are a major concern. Similarly, in the Sahel region, there is a risk of losing approximately 30 hectares of farmland each year to desertification, which affects both crop and animal production directly and indirectly (Adamou *et al.*, 2021; Yang *et al.*, 2022; N'gobiet *al.*, 2022). Regarding livestock, rising temperatures linked to negative climate variability have been shown to reduce the productivity of animals such as goats, sheep, swine, cattle, and poultry (Gbengaet *al.*, 2020; Sakaet *al.*, 2021).

Climate Change Challenges and Implications

By 2080, agricultural output in developing countries may decrease by 20 percent due to climate change, while output in industrial countries is expected to decline by 6 percent (Solomon *et al.*, 2021). As a result of the negative impacts of climate change, Agricultural yields in developing countries could further decline by an average of 15 percent by 2080 (Farooqet *al.*, 2023). The report by Farooq et al (2023) further stated that, climate change poses significant challenges to food security by impacting agricultural production, food availability, access, and utilization, resolving this, demands a methodological approach that integrates climate risk analysis, adaptation strategies, and mitigation efforts.

i. Declining Agricultural Productivity

Changes in climatic conditions have resulted in reduced agricultural productivity across SSA. For instance, East Africa has experienced prolonged droughts, while West Africa faces erratic rainfall, both of which disrupt planting and harvesting cycles. Rise in temperatures and variations in rainfall patterns can directly lead to declines in crop yields, particularly for staple crops like maize, sorghum, and millet (Amegboret *al.*, 2020).

ii. Increased Food Insecurity and Water Scarcity

Sub-Saharan Africa is home to some of the most food-insecure populations globally. Climate-induced disruptions to agriculture worsen food shortages, particularly in rural areas where subsistence farming is the primary livelihood. The World Food Programme (2021) estimates that over 45 million people in sub-Saharan Africa are experiencing acute food insecurity due to climate-related factors. Additionally, the drying of key water bodies, such as Lake Chad, exacerbates the growing water scarcity in the region. Reduced water availability affects irrigation, livestock farming, and household consumption, creating resource competition and social tension

iii. Hunger and Malnutrition

Sub-Saharan Africa is home to some of the most food-insecure populations globally. Climate-induced disruptions to agriculture worsen food shortages, particularly in rural areas where subsistence farming is the primary livelihood. The World Food Programme (2021) estimates that over 45 million people in sub-Saharan Africa are facing acute food insecurity due to climate-related factors. Additionally, the drying of key water bodies, such as Lake Chad, contributes to the increasing water scarcity in the region.

iv. Threat to Fishing Activities and Aquaculture

Climate change is impacting water bodies such as marine environments, freshwater lakes, and rivers, along with the flora and fauna that inhabit these ecosystems. It has been established that climate change will impact approximately 200 million people worldwide who depend on fishing and aquaculture for their livelihoods. Some fish species will become less abundant, while important species may migrate to other areas, making them less accessible to fishers. This will create challenges for many fishing communities in maintaining their livelihoods and providing fish for their families (March & Failer, 2022).

v. Rising Patterns of Pests and Diseases

Humans, crops, livestock, and aquatic life are likely to face emerging pests and diseases that prosper under particular temperature and humidity levels, creating fresh risks for both food security and food safety.

Climate Change Mitigation/Adaptation Strategies

Given the challenges that climate change poses to food security in sub-Saharan Africa, it is essential for policymakers and stakeholders in the region to take prompt and coordinated action. A key strategy involves promoting the adoption of climate-resilient agricultural practices, including drought-resistant crop varieties, conservation agriculture, and agroforestry (Acevedo *et al.*, 2020; Zougmore *et al.*, 2021).

Clearly, climate change is no longer a remote issue; it is a current reality significantly affecting the planet, posing serious challenges to food security and agricultural productivity across both advanced and emerging economies globally. Below are

some mitigation and strategies that can be adopted in order to forestall food security globally and in SSA in particular.

- i. **Reduce Greenhouse Gas Emissions:** Implement policies and technologies to reduce greenhouse gas emissions from the agricultural sector and other sources can ameliorate adverse effects of climate change.
- ii. **Promote Sustainable Land Management:** Promote sustainable land management practices that improve soil health and enhance carbon sequestration, contributing to climate change mitigation and agricultural resilience.
- iii. **Invest in Renewable Energy:** Facilitate the transition to renewable energy sources to reduce dependence on fossil fuels and support efforts to mitigate the impacts of climate change.
- iv. **Irrigation and watershed management:** According to Dixit *et al.*, (2022), the negative impacts of climate change on both global and local food supplies can be addressed through measures such as improving irrigation systems, adopting efficient watershed management, promoting sustainable land use and livestock practices, and developing climate-resilient crop varieties and animal breeds
- v. **Monitoring and Evaluation:** Continuous monitoring and evaluation of adaptation and mitigation efforts are essential to ensure their effectiveness in achieving intended outcomes. Strategic investments in infrastructure, such as irrigation systems and storage facilities, can play a significant role in reducing the adverse effects of climate change on food production and distribution. Moreover, it is vital for governments and international bodies to enhance social safety nets and protection programs, ensuring that vulnerable populations have access to the resources needed to adapt and build resilience. Effectively addressing the impact of climate change on food security in sub-Saharan Africa will require a comprehensive and collaborative approach involving policymakers, researchers, and local communities in the design and implementation of sustainable adaptation strategies.
- vi. **Climate-Smart Agriculture:** In light of the significant challenges that climate change poses to food security in sub-Saharan Africa, it is essential for policymakers and relevant stakeholders in the region to take prompt and coordinated action to effectively address these concerns. One option is to promote the adoption of climate-smart agricultural practices or climate-resilient crops and farming practices, Capacity building and extension services are crucial to enabling farmers to access and implement climate - smart agriculture technologies.
- vii. **Technological Innovations:** The integration of innovative technologies, such as early warning systems, digital farming tools, and renewable energy solutions, can improve the adaptive capacity of agricultural communities. Policymakers and development agencies should give priority to investments in infrastructure, market integration, and social protection initiatives in order to address the complex challenges that climate change presents to agricultural production and food security in the sub-Saharan African region.
- viii. **Policy Reforms and Investments:** Governments must prioritize investments in agricultural infrastructure, irrigation systems, and rural development. International collaborations, such as the Green Climate Fund, that can provide much-needed financial and technical support. At the same time, policies that

promote sustainable land use, water management, and climate-resilient value chains are critical to enhancing food security in the SSA region.

- ix. **Community-Based Adaptation:** Empowering local communities through education, training, and participatory planning is crucial. Grassroots initiatives that incorporate indigenous knowledge with modern practices have shown promising results in enhancing resilience and addressing food security challenges in SSA, (Araya *et al.*, 2023).

Conclusion

The difficulties climate change creates for ensuring sufficient food in sub-Saharan Africa are intricate and deeply connected to existing socioeconomic weaknesses. Tackling these issues demands an integrated strategy that incorporates environmentally sustainable farming methods, technological advancements, and strong policy support. Enhancing resilience at community, national, and regional scales is vital for protecting food availability amid changing environmental conditions. Cooperation among governments, international agencies, and local groups is necessary to reinforce social support systems and protection programs, guaranteeing that vulnerable populations can access the necessary resources to cope with environmental challenges and secure the future of agriculture. Moreover, investing in essential infrastructure like irrigation networks and storage facilities plays a key role in reducing the negative effects of climate variability on food production and distribution. To confront the global challenge of climate change and its adverse effects on food systems and farming productivity, implementing both adaptive and preventive strategies is crucial. Promoting resilient farming practices is one effective way to boost agricultural output across sub-Saharan Africa.

References

- Abdi, A. H., Sugow, M. O., &Halane, D. R. (2024). Exploring climate change resilience of major crops in Somalia: implications for ensuring food security. *International Journal of Agricultural Sustainability*, 22(1), 2338030.
- Acevedo, M., Pixley, K., Zinyengere, N., Meng, S., Tufan, H., Cichy, K., Bizikova, L., Isaacs, K., Ghezzi-Kopel, K., &Porciello, J. (2020). A scoping review of adoption of climate-resilient crops by small-scale producers in low- and middle-income countries. *Nature plants*, 6(10), 1231–1241. <https://doi.org/10.1038/s41477-020-00783-z>
- Adamou, R., Ibrahim, B., Bonkaney, A. L., Seyni, A. A., &Idrissa, M. (2021). Niger-Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.
- Ahmed, M., Ahmad, S., &Kheir, A. M. (2023). Climate change: an overview. *Global Agricultural Production: Resilience to Climate Change*, 1-30.
- Amegbor, I. K., Badu-Apraku, B., Adu, G. B., Adjebeng-Danquah, J., andToyinbo, J. (2020). Combining Ability of Extra-Early Maize Inbreds Derived from a Cross between Maize and Zeadiploperennis and Hybrid Performance under Contrasting Environments. *Agronomy* (Vol. 10, Issue 8, p. 1069).Multidisciplinary Digital Publishing Institute. <https://doi.org/10.3390/agronomy10081069>
- Alehile, K. S., Njiforti, P. P., Duru, M. C., &Jibril, M. S. (2022). Impact of climate change on Nigerian agricultural sector crop production. *J. Econ. Allied Res*, 7, 105-115.
- Araya, A., Prasad, P. V. V., Gowda, P. H., Zambreski, Z. T., andCiampitti, I. A. (2020). Management options for mid-century maize (*Zea mays* L.) in Ethiopia. *The Science*

- of the Total Environment (Vol. 758, p. 143635). Elsevier BV. <https://doi.org/10.1016/j.scitotenv.2020.143635>
- Baffour-Ata, F., Antwi-Agyei, P., Nkiaka, E., Dougill, A. J., Anning, A. K., & Kwakye, S. O. (2021). Effect of climate variability on yields of selected staple food crops in northern Ghana. *Journal of Agriculture and Food Research*, 6, 100205.
- Balogun, V. S., & Onokerhoraye, A. G. (2022). Climate change vulnerability mapping across ecological zones in Delta State, Niger Delta Region of Nigeria. *Climate Services*, 27, 100304.
- Baptista, D. M. S., Farid, M. M., Fayad, D., Kemoe, L., Lanci, L. S., Mitra, M. P., ...& Unsal, M. F. D. (2022). *Climate change and chronic food insecurity in sub-Saharan Africa*. International Monetary Fund.
- Chiawo, D., and Otiende, V. (2021). Climate-Induced Food Crisis in Africa: Integrating Policy and Adaptation. Springer eBooks (p. 1789). Springer Nature. https://doi.org/10.1007/978-3-030-45106-6_75.
- Calculi, C., D'Uggento, A. M., Labarile, A., & Ribeco, N. (2021). Evaluating people's awareness about climate changes and environmental issues: A case study. *Journal of Cleaner Production*, 324, 129244.
- Derbile, E. K., Chirawurah, D., and Naab, F. X. (2021). Vulnerability of smallholder agriculture to environmental change in North-Western Ghana and implications for development planning. *Climate and Development* (Vol. 14, Issue 1, p. 39). Taylor and Francis. <https://doi.org/10.1080/17565529.2021.1881423>
- Dixit, A., Madhav, S., Mishra, R. et al. Impact of climate change on water resources, challenges and mitigation strategies to achieve sustainable development goals. *Arab J Geosci* **15**, 1296 (2022). <https://doi.org/10.1007/s12517-022-10590-9>
- Duchenne-Moutien, R. A., & Neetoo, H. (2021). Climate change and emerging food safety issues: a review. *Journal of food protection*, 84(11), 1884-1897.
- Fanzo, J., Davis, C., McLaren, R., and Choufani, J. (2018). The effect of climate change across food systems: Implications for nutrition outcomes. *Global Food Security* (Vol. 18, p. 12). Elsevier BV. <https://doi.org/10.1016/j.gfs.2018.06.001>
- Farooq, A., Farooq, N., Akbar, H., Hassan, Z. U., & Gheewala, S. H. (2023). A critical review of climate change impact at a global scale on cereal crop production. *Agronomy*, 13(1), 162.
- Farooq, M. S., Uzair, M., Raza, A., Habib, M., Xu, Y., Yousuf, M. & Ramzan Khan, M. (2022). Uncovering the research gaps to alleviate the negative impacts of climate change on food security: a review. *Frontiers in plant science*, 13, 927535.
- Galema, S., Male, D., Mbabazi, M., Mutambuka, M., Muzira, R., Namboze, J., ...& Dengerink, J. (2024). An overview of the Ugandan food system: outcomes, drivers & activities.
- Goselle, N. T. (2024). Alteration of Six Soil Physical Properties in the Equatorial Climatic (Koppen's Aw) Zone of the Niger Delta, Nigeria as determined by gas flaring activities. *OMANARP International Journal of Arts & Social Science*, 1(1), 1-16.
- Gupta, P., Singh, J., Verma, S., Chandel, A. S., & Bhatla, R. (2021). Impact of climate change and water quality degradation on food security and agriculture. In *Water Conservation in the Era of Global Climate Change* (pp. 1-22). Elsevier.
- Hlahla, S. (2022). Gender perspectives of the water, energy, land, and food security nexus in sub-Saharan Africa. *Frontiers in sustainable food systems*, 6, 719913.
- Igbe, I., & Goselle, N. T. (2025). GEO-ANALYSIS OF FEMALE AS DRIVERS OF RICE CULTIVATION IN ETSAKO, EDO STATE, NIGERIA. *OMANARP INTERNATIONAL JOURNAL OF ARTS & SOCIAL SCIENCE*, 1(1), 1-11.
- Isaacs, K., Ghezzi-Kopel, K., and Porciello, J. (2020). A scoping review of adoption of climate-resilient crops by small-scale producers in low- and middle-income countries. *Nature Plants*, 6(10), 1231. Nature Portfolio. <https://doi.org/10.1038/s41477-020-00783-z>

- Issahaku, G., Abdul-Rahaman, A., and Amikuzuno, J. (2021). Climate change adaptation strategies, farm performance and poverty reduction among smallholder farming households in Ghana. *Climate and Development* (Vol. 13, Issue 8, p. 736). Taylor and Francis. <https://doi.org/10.1080/17565529.2020.1860884>
- Ita, R. E., & Ogbemudia, F. O. (2023). Climate change impact on Nigerian ecology, vegetation/forest, carbon and biomass management. In *Climate Change Impacts on Nigeria: Environment and Sustainable Development* (pp. 303-316). Cham: Springer International Publishing.
- Jin, S., Zhang, B., Wu, B., Han, D., Hu, Y., Ren, C., ...& Chen, J. (2021). Decoupling livestock and crop production at the household level in China. *Nature sustainability*, 4(1), 48-55.
- Li, N., Zhao, Y., Han, J., Yang, Q., Liang, J., Liu, X., ...& Huang, Z. (2024). Impacts of future climate change on rice yield based on crop model simulation—A meta-analysis. *Science of The Total Environment*, 949, 175038.
- Lobell, D. B., and Gourdji, S. (2012). The Influence of Climate Change on Global Crop Productivity. *Plant Physiology*, 160(4), 1686. Oxford University Press. <https://doi.org/10.1104/pp.112.208298>
- March, A., & Failler, P. (2022). Small-scale fisheries development in Africa: Lessons learned and best practices for enhancing food security and livelihoods. *Marine Policy*, 136, 104925.
- Marques, R. Z., Wistuba, N., Brito, J. C. M., Bernardoni, V., Rocha, D. C., & Gomes, M. P. (2021). Crop irrigation (soybean, bean, and corn) with enrofloxacin-contaminated water leads to yield reductions and antibiotic accumulation. *Ecotoxicology and Environmental Safety*, 216, 112193.
- Marx, W., Haunschild, R., & Bornmann, L. (2021). Heat waves: a hot topic in climate change research. *Theoretical and applied climatology*, 146(1), 781-800.
- Morufu Olalekan Raimi, Tonye Vivien Odubo & Adedoyin Oluwatoyin Omidiji (2021) *Creating the Healthiest Nation: Climate Change and Environmental Health Impacts in Nigeria: A Narrative Review. Scholink Sustainability in Environment. ISS*
- Msongaleli, B. (2024). The Contribution of Climate-Smart Agriculture to Reducing Climate-Related Risks to Rain-Fed Maize Production: Insights from Tanzania's Semi-Arid and Sub-Humid Regions. *Ghana Journal of Geography*, 16(1), 28-58.
- Mulungu, K., and Ng'ombe, J. N. (2019). Climate Change Impacts on Sustainable Maize Production in Sub-Saharan Africa: A Review. IntechOpen eBooks. <https://doi.org/10.5772/intechopen.90033>
- Mzyece, A., and Ng'ombe, J. N. (2020). Does Crop Diversification Involve a Trade-Off Between Technical Efficiency and Income Stability for Rural Farmers? Evidence from Zambia. *Agronomy* (Vol. 10, Issue 12, p. 1875). Multidisciplinary Digital Publishing Institute. <https://doi.org/10.3390/agronomy10121875>
- Ndamani, F., and Watanabe, T. (2017). Determinants of farmers' climate risk perceptions in agriculture—A rural Ghana perspective. *Water* (Vol. 9, Issue 3, p. 210). Multidisciplinary Digital Publishing Institute. <https://doi.org/10.3390/w9030210>
- Neupane, D., Adhikari, P., Bhattarai, D., Rana, B., Ahmed, Z., Sharma, U., & Adhikari, D. (2022). Does climate change affect the yield of the top three cereals and food security in the world?. *Earth*, 3(1), 45-71.
- N'gobi, G. M. L., Danani, K., & Soulé, M. (2022). Climate change and biodiversity in West Africa Sahel: a review. *Restoration Ecology*, 4, 20-29.
- Ntuli, N. C. (2023). Adaptation strategies against drought: The case of rain-fed subsistence crop farmers in Mphego village in the Vhembe District of Limpopo province, South Africa.
- O'Dea, R. E., Lagisz, M., Jennions, M. D., Koricheva, J., Noble, D. W., Parker, T. H., ...& Nakagawa, S. (2021). Preferred reporting items for systematic reviews and meta-

- analyses in ecology and evolutionary biology: a PRISMA extension. *Biological Reviews*, 96(5), 1695-1722.
- Okon, E., M., Falana, B., M., Solaja, S., O. et al. (2021). Systematic review of climate change impact research in Nigeria: implication for sustainable development. *Heliyon*. 2021 Sep 6;7(9): e07941. doi: 10.1016/j.heliyon.2021.e07941
- Omotoso, A. B., Letsoalo, S., Olagunju, K. O., Tshwene, C. S., & Omotayo, A. O. (2023). Climate change and variability in sub-Saharan Africa: A systematic review of trends and impacts on agriculture. *Journal of Cleaner Production*, 414, 137487.
- Onanalbogo, F. M. (2023). *A framework for the sustainable management of water resources in Lake Chad* (Doctoral dissertation, Technische Universität Wien).
- Pickson, R. B., & Boateng, E. (2022). Climate change: a friend or foe to food security in Africa?. *Environment, Development and Sustainability*, 1-26.
- Raimi, M. O., Vivien, O. T., & Oluwatoyin, O. A. (2021). Creating the healthiest nation: Climate change and environmental health impacts in Nigeria: A narrative review. *N*.
- Raupach, T. H., Martius, O., Allen, J. T., Kunz, M., Lasher-Trapp, S., Mohr, S., ... & Zhang, Q. (2021). The effects of climate change on hailstorms. *Nature reviews earth & environment*, 2(3), 213-226.
- Saka, A. A., Awodola-Peters, O. O., Olaniyi, T. A., Adediji, O. Y., Bolarinwa, M. O., Yahaya, M. O., ... & Popoola, M. A. (2021). Climate change and its impact on livestock: A review. *Nigerian Journal of Animal Production*, 48(4), 185-193.
- Shikuku, K. M., Winowiecki, L., Twyman, J., Eitzinger, A., Perez, J. G., Mwongera, C., and Läderach, P. (2017). Smallholder farmers' attitudes and determinants of adaptation to climate risks in East Africa. *Climate Risk Management* (Vol. 16, p. 234). Elsevier BV. <https://doi.org/10.1016/j.crm.2017.03.001>.
- Siegel, F. R., & Siegel, F. R. (2021). Impact of global warming/climate change on food security 2020. *The earth's human carrying capacity: limitations assessed, solutions proposed*, 39-48.
- Solomon, R., Simane, B., & Zaitchik, B. F. (2021). The impact of climate change on agriculture production in Ethiopia: application of a dynamic computable general equilibrium model. *American Journal of Climate Change*, 10(1), 32-50.
- Thompson, H., Berrang-Ford, L., and Ford, J. D. (2010). Climate Change and Food Security in Sub-Saharan Africa: A Systematic Literature Review. *Sustainability* (Vol. 2, Issue 8, p. 2719). Multidisciplinary Digital Publishing Institute. <https://doi.org/10.3390/su2082719>
- vanDijk, M., Morley, T., Rau, M. L., & Saghai, Y. (2021). Systematic review and meta-analysis of global food security projections to 2050.
- Vincent, K. (2022). A review of gender in agricultural and pastoral livelihoods based on selected countries in west and east Africa. *Frontiers in Sustainable Food Systems*, 6, 908018.
- Waongo, M., Laux, P., and Kunstmann, H. (2015). Adaptation to climate change: The impacts of optimized planting dates on attainable maize yields under rainfed conditions in Burkina Faso. *Agricultural and Forest Meteorology* (Vol. 205, p. 23). Elsevier BV. <https://doi.org/10.1016/j.agrformet.2015.02.006>
- Wudil, A. H., Usman, M., Rosak-Szyrocka, J., Pilař, L., & Boye, M. (2022). Reversing years for global food security: A review of the food security situation in Sub-Saharan Africa (SSA). *International Journal of environmental research and Public Health*, 19(22), 14836.
- World Health Organization. (2021). *Asia and the Pacific Regional Overview of Food Security and Nutrition 2020: Maternal and child diets at the heart of improving nutrition* (Vol. 2020). Food & Agriculture Org..
- Yang, Z., Gao, X., Lei, J., Meng, X., & Zhou, N. (2022). Analysis of spatiotemporal changes and driving factors of desertification in the Africa Sahel. *Catena*, 213, 106213.

- Yongo, E., Cishahayo, L., Mutethya, E., Alkamoi, B. M. A., Costa, K., & Bosco, N. J. (2021). A review of the populations of tilapiine species in lakes Victoria and Naivasha, East Africa. *African Journal of Aquatic Science*, 46(3), 293-303.
- Zougmore, R. B., Läderach, P., and Campbell, B. M. (2021). Transforming Food Systems in Africa under climate change Pressure: Role of climate-smart agriculture. *Sustainability* (Vol. 13, Issue 8, p. 4305). Multidisciplinary Digital Publishing Institute. <https://doi.org/10.3390/su13084305>
- Zvobgo, L., Johnston, P., Williams, P. A., Trisos, C. H., and Simpson, N. P. (2022). The role of indigenous knowledge and local knowledge in water sector adaptation to climate change in Africa: a structured assessment. *Sustainability Science* (Vol. 17, Issue 5, p. 2077). Springer Science+Business Media. [https://doi.org/10.1007/s11625-](https://doi.org/10.1007/s11625-022-01118-)022-01118-