Climate smart agriculture in food insecurity mitigation in nigeria: a conceptual evaluation

**Abstract**

*Climate-Smart agriculture and its impact on food security have been topical issues in policy and food security discusses by successive governments in Nigeria however, the extent of its awareness among the farmers as a food insecurity mitigation measure has not been adequately represented in contemporary local literature hence the need for this research to ascertain the extent of awareness through: an examination of literary works by scholars in the field, assessing the extent of climate-smart procedures in agriculture and suggest where possible ideas to enhance its adoption. The study therefore evaluated secondary data and studies on the impacts of climate change on agriculture and how it can be mitigated through the adoption of climate smart approaches. Climate-Smart Agriculture is an emerging agricultural strategy initiated to tackle the consequences of climate change in food security and sustain agriculture. It involves the combination of approaches in the management of agricultural lands, forests, fisheries and livestock. The study in this regard took a holistic view of the adoption of climate smart agriculture by the farmers, its benefits and approaches and considered objectives such as accessing and assessing other scholars works and views on climate smart agricultural practices utilized by rural farmers in parts of Nigeria, discussing climate smart agriculture and food security, deliberating on climate smart agriculture and resource use efficiency and, viewing the constraining factors hampering the adoption of Climate Smart Agricultural practices in Nigeria. This is because climate change presently is one of the challenges and problems facing the world and an important factor in agricultural productivity. Variations in climatic factors will have ripple effects on crop yield and animal production. Farmers may have been facing weather variability and uncertainty patterns, however, the increasing pace of these uncertainties caused by climate change exacerbate food insecurity and hunger incidences and will require some degree of flexibility and rapid response capacity that climate smart agriculture offers. Building resilience in agricultural and farming practices will reduce the risk of food insecurity outside increasing the adaptive capacity and coping capabilities of the farmers*

**Key words:** Climate change, Climate smart, Agriculture, Food security.

**Introduction**

In Nigeria, climate-Smart Agriculture is an emerging agricultural strategy initiated to tackle the consequences of climate change in food security and sustain agriculture. It involves the combination of approaches in the management of agricultural resources and practices. Climate-Smart agriculture is been highlighted in recent times in effort to combat the effects of climate change and ensure food security. It highlights long-term mitigation and adaptive initiatives and acknowledges the critical roles farmers play in navigating through the challenges of climate change to ensure a resilient and sustainable future. A vital focus of climate-smart agriculture is the application of varieties of practices that enhance sustainable agriculture and stable ecosystem and biodiversity. Climate-Smart Agriculture has the potential to modify

farming systems and these modifications underline significant respect for the ecosystem and biodiversity. The adoption of Climate-Smart Agriculture can enable the global food system become more resilient, sustainable, and equitable thus assisting in dealing with the problem of food security and climate change challenges (Mekyassi & Kızıldeniz, 2023).

Farmers have been tackling the variability and uncertainty in weather patterns. In contemporary times however, the frequency in the uncertainties that climate change births calls for much more enhanced flexible and response capacity. Enhanced capacity and resilience may reduce the risk of food insecurity and increase adaptive capacity. This therefore will need incremental and transformative actions. Incremental changes will comprise information provision; changes in production techniques that are ecosystem friendly and maintaining productivity under climate shocks amongst others. Transformative changes will include significant shifts in agricultural production or sources of livelihoods (Lipper et al, 2014). Climate change presently is one of the serious challenges and problems facing agriculture and an important factor in its productivity. Any variation in climatic factors will have significant effect on crop yield (opeyemi et al, 2021 & Ashalatha et al., 2012).

Muller et al., (2011) observed many African countries are impacted by the vagaries of climate change because of reliance on rain-fed Agriculture that is dependent on weather and climate factors. Climate smart agriculture may be an option towards ensuring resilient and productive agriculture. However, FAO (2013) noted that in spite of the rapid uptake of CSA by national organizations and the international community; implementation is still limited and challenging due to inadequate tools, low capacity and experience especially in developing countries. FAO (2013) noted that it is still an evolving practice and faces challenges that include awareness, adoption, practice and environment, social and economic issues amongst others. It is very apparent that there is limited and inadequate knowledge on climate smart agriculture especially among the rural people or communities.

In many Sub- Saharan Africa countries and in Nigeria in particular, climate change has manifested in extended drought periods, inadequate and erratic rainfall patterns, flooding incidences in a scale never known before now, high temperatures, etc. These weather conditions have significantly impacted agriculture and will result in the loss of two- thirds of arable land by 2025 (Masipa, 2017). Crop yields have declined in numeric values and with limited output of food staples such as maize, rice, sorghum, and wheat, we may be incapable of feeding the teeming population. Consequently, food security crisis will worsen if there are no effective solutions to mitigate the impact of climate change and the resulting effect on the region's agriculture (Akinsemolu, et al, 2023). As we try to proffer solutions to the problems of climate change, popular interest favours adaptation possibilities especially for farmers in poor countries. An adaptation strategy that has shown promise in recent times is climate-smart agriculture (CSA) (Bazzana et al, 2022).

Rehman (2023) believes any Agricultural practice that sustainably increases productivity, enhances resilience to climate change, limits the effects of greenhouse gases (mitigation), and promotes the attainment of national food security and development goals is smart. Agriculture in Nigeria needs transformation through the adoption of smart practices to meet the challenges of achieving food security, reduction in poverty and response to climate change without depleting the natural resource base. Climate smart agriculture suggests proven practical techniques and strategies (opeyemi et al, 2021) and should be adopted to tackle contemporary biophysical and socioeconomic stressors that are climate related in the country. Adopting CSA practices may result in greater resilience that can lower risks to food security however; a laissez faire attitude may lead to higher risks of food security and lower resilience that may impact food and agricultural systems (Lipper et al, 2014).

CSA schemes employ resource- use efficiency and conservation approaches to a great extent and showcase the potential to restore lost soil fertility, optimize water storage, usage and enhance crop productivity (Branca et al., 2021). Notwithstanding all these, the adoption and practice of CSA in our Nigeria face crippling challenges and impeding the attainment of food security in the region (

Akinsemolu, et al, 2023). Climate-smart agriculture (CSA) however can enhance positive outcomes in food security by integrating climate change mitigating practices into sustainable agricultural strategies. It identifies trade-offs between food security and mitigation as a basis for reorienting policies in response to climate change and calls for a set of actions by decision-makers to enhance the resilience of agricultural systems to reduce the risk of food insecurity (Lipper et al, 2014)

The FAO in 2020 reported that almost 8.9 percent of global populations (690 million people) are hungry. Rehman (2023) noted the figure has increased by about 60 million in the last five years and Prospects and events suggest it may not get better as globally. A 70 percent raise in food production is needed by 2050 to accommodate the growing population estimated to reach 9 billion soon. Efforts to enhance crop productivity, reduce hunger and mitigate the effects of climate change on food production will require the adoption of Climate- smart agriculture which will include strategies that aid the agricultural systems in restoring and maintaining food security among other measures even when the changes in the climate are unfavorable (Westermann et al., 2018). Though hinged on existing knowledge and principles of sustainable agriculture, CSA is distinct in some ways. It addresses largely climate change while considering compromises between productivity, adaptation and mitigation (Rehman, 2023). CSA stresses the relevance of showcasing evidences that identify viable options and necessary enabling activities. It provides tools that can be used in assessing different technologies and practices and how they affect food security objectives under the site-specific effects of climate change. CSA aligns with agricultural systems that use ecosystem services that enhance productivity, adaptation and mitigation (Lipper et al, 2014).

According to Ayinde et al. (2010), variation in climate has substantial effects on agricultural productivity in Nigeria. Nigeria is presumed vulnerable to climate change effects because of her 800km coastline which makes it susceptible to risks of sea level rise and flood. Storms and drought are also concerns to contend with because of Nigeria's closeness to the desert (Apata, Samuel and Adeola (2009). Climate change already is hindering agricultural growth confirming IPCCs submission that climate change upsets crop production globally with negative effects especially in developing countries. Rising frequency and

intensity in extreme climate events are already been reported and expected to accelerate in some areas (Akinsemolu, et al, 2023). Climate change can upset food markets thereby posing global risks to food security and supply. This threat can be mitigated through enhancing the adaptive capacity of farmers and increasing resilience and resource use efficiency in agricultural production structures (Lipper et al, 2014). Based on the fore goings, the researchers therefore aim to access and assess other scholars works and views on climate smart agricultural practices utilized by rural farmers in parts of Nigeria, discuss climate smart agriculture and food security, deliberate on climate smart agriculture and resource use efficiency and, view the constraining factors hampering the adoption of Climate Smart Agricultural practices in Nigeria.

## Methods and Materials

The study made use of secondary data accessed from bulletins, public deliberations and published researches where necessary whose primary focus was on various aspects of the study objectives. This implies that the data on the various tables were not based on empirical analysis by the authors. The deliberations also showcase the authors' positions and views on the subject matter and open to constructive criticisms.

## Result and Discussions

### Climate Smart Agricultural Practices Utilized by rural Farmers in parts of Nigeria

. Agriculture has the potential to mitigate poverty effects and improve food security for about 80% of the world's poor, who live in rural areas and into farming. There are a range of proven climate smart and innovative practices that can increase productivity, strengthen climate resilience and reduce greenhouse gas emissions from agricultural practices (Mutengwa, 2023). Some of these practices locally adopted by rural farmers are shown in the works of Opeyemi et al (2023) and displayed in the table below. Many scholars' works were assessed under this caption, that of Opeyemi et al (2023) was chosen because it was very recent and very inclusive of topical and prevailing practices and therefore adopted

**Table 1: Climate Smart Agricultural Practices Utilized by the Farmers in Nigeria**

| CSA Practices | Frequency | Percentage | Rank |
|---|---|---|---|
| **Awareness of CSA Practices** | | | |
| Aware of CSA | 139 | 99.29 | |
| Not aware | 1 | 0.71 | |
| **CSA Practices in use** | | | |
| Agro-forestry | 38 | 27.34 | 10 |
| Crop rotation | 74 | 52.86 | 9 |
| Mixed cropping | 140 | 100 | 1 |
| Improved crop varieties | 138 | 98.57 | 3 |
| Intercropping | 128 | 87.86 | 6 |
| Compost making | 81 | 58,27 | 8 |
| Improved fallowing | 26 | 18.57 | 12 |
| Organic manure | 115 | 82.14 | 7 |
| Mulching | 133 | 95.00 | 5 |
| Cover crops | 135 | 96.43 | 4 |
| Mixed farming | I40 | 100 | 1 |

**Source:** Opeyemi et al, 2021

Most of these approaches have always been there however; the extent of innovations and advances in some assessed research works is commendable. Nevertheless, in their work, many aspects of climate-smart agriculture were not mentioned such as use of biochar**,** plastic mulching, the use of emerging technologies like drones and precision agriculture amongst others. There non-application however may be tied to economic and literacy factors which calls for further researches. Opeyemi et al (2021) among other works identified, significantly discussed aspects of these applications in climate-smart agricultural practices adopted by some rural farmers in Nigeria. The table indicates about 99.29% are aware of climate smart agriculture. In reference to the works of Teklewold et al. (2013) the authors opined farmers will access more benefits if they leverage multiple strategies as some of them can be complementary, enabling them exploit relevant synergies. The adoption of multiple CSA practices is important in building sustainable agriculture that may be resilient to climate change and other challenges to agricultural production. The implication of this is that the rural farmers are becoming climate smart compliant, the issue of concern is the scale of compliance as most agricultural practices in the region are subsistent and inadequate in tackling food insufficiency hence cannot mitigate food insecurity. Large scale agriculture is suggested.

Mutengwa (2023) agrees with this result noting that Agroforestry, crop rotation, residue management, water management, and land use amongst others are examples of excellent agricultural and water-management methods that contribute to climate-change mitigation which evidently the local and rural farmers are practicing as revealed by the table 1. These methods the researchers noted can increase agricultural productivity in addition to reducing GHG emissions. Mutengwa (2023) also suggests implementing zero- or minimum tillage, conservation agriculture can to a large extent reduce $CO_2$ emissions through less fossil-fuel use. Minimal soil disturbance he pointed out is also linked to lower atmospheric $CO_2$ emissions because of less exposure of soil organic matter to oxidation. Retention of agricultural residues was reported to increases soil carbon in the surface layers and this aids the sequestration of $CO_2$. Low fertilization rates under CSA technology will reduce atmospheric $N_2O$ emissions an enhance fertilizer-use efficiency. Going by this report, the cultural practices of some rural farmers could be said to be climate smart. In another consideration, manure management as a mitigation strategy will lower the $CH_4$ emissions in manure. Ruminants fed on high-protein concentrates produce manure high in methane-production capacity and may be ideal for anaerobic digesters (Mutengwa, 2023)

**Climate smart agriculture and food security**

Mutengwa (2023) opines that the agriculture industry in Africa is very vulnerable to climatic extremes impacting aspects of food security (availability, accessibility, utilization and stability) and believes the comparative economic cost of climatic extremes may reach 8% of the GDP of developing nations. Food availability, accessibility and stability may be affected due to decreased agricultural production. Food prices are expected to rise because of unpredictable food production caused by climate change. The evident increase in food demand due to population growth, urbanization and rising wealth profile in developing nations will likely aggravate this situation due to increasing food prices.

Mekyassi1 and Kızıldeniz (2024) noted that the global food system is facing numerous challenges that can hinder food security aspirations and sustainability. The duo observed that the globalization of food

systems has produced mixed results; there is significant vulnerability to supply chain instabilities. This is in addition to equitable food distribution and food insecurity issues in some regions. Rising food prices have become a burden to low-income countries that may affect food security and access. Climate-Smart Agriculture as a farming strategy can solve problems emanating from the interconnected concerns of climate change, food security and sustainable agriculture since it can be employed in managing landscapes, cropland, forests, fisheries, and livestock having been acknowledged as a veritable tool in adaptive agricultural initiatives that is critical for farmers and agricultural communities in crafting a more climate resilient and sustainable future. The implementation of Climate Smart Agriculture will enable global food system become more resilient, sustainable, assisting in dealing with food security and climate change related challenges.

Farmers have always faced weather variability and uncertainty patterns, the increasing pace of these uncertainties that climate change imposes may execrate food insecurity and hunger incidences and will require some degree of flexibility and rapid response capacity. Building resilience in agricultural and farming practices will reduce the risk of becoming food-insecure outside increasing the adaptive capacity and coping capabilities (Lipper et al., 2014)

Some of these challenges caused by climate change to food security can be tackled through climate-smart agriculture (CSA) practices, adopted and recognized as a sustainable solution to the effects of climate change on agriculture. In response to climate variability issues in South Africa for example, Munkeni and Mutengwa ( ) report of CSA programmes that have led to the development of crop cultivars that are resistant to heat and water stresses in South Africa in response to periodic droughts and heat waves. The development of stress-tolerant crop varieties in Africa under various project codenames is on-going in some areas in the sub-region initiated by various International Research Centers. The cultivars by some of these projects are positively impacting food security (Mutengwa, 2023).

An anticipated consequence of climate change is the emergence and spread of new diseases, weeds, and insect pests that may be more virulent than existing ones. Mafongoya et al. (2019) reported aphids, whiteflies, red spider mites, and trips were becoming more prevalent in South Africa and Zimbabwe. Novel Tomato torrado virus (ToTV) in Africa has also been reported. Effective techniques such as continuous surveillance, integrated pest management (IPM) etc have been proposed in handling the pressure resulting from these pests that are climate-change related. Plant breeders have adopted conventional and modern breeding techniques to raise crop resilience to specific pests and diseases.

Reducing climate change effects will require cutting-edge indigenous farming methods that have been proven successful over the years, such as integrated soil fertility management (ISFM) and water management strategies and procedures. These are climate-smart approaches that can enhance soil carbon and boosts crop outputs while scientifically integrating chemical fertilizers, organic inputs, and improved germplasm. Moreover, it been suggested that Zero- and minimum tillage techniques, can raise soil organic matter levels and, water storage and retention. Furthermore, agroforestry that involves shallow-rooted plants with deep-rooted trees can be adopted for better utilization of the moisture in the soil. Reverse-slope terraces and water-harvesting technologies in hilly terrains have advocated as aspects of integrated water management answer to rain fed systems.

**Climate smart agriculture and resource use efficiency**

The conventional agriculture-food systems have diminished in their contribution to sustainable growth and food security because of inefficient and wasteful water use, unsustainable environmental agronomic practices and inadequately developed value chains (Rehman, 2023). Climate smart agricultural approaches embody resource use efficiency. It leverages tools that facilitate the assessment different technologies and practices in relation to their effects on the development and food security objectives. As a veritable solution to climate change-driven food security problem, CSA has the potential to restore lost soil fertility, enhance water usage and boost crop yield (Branca et al., 2021). There is the anticipation that increased investment and stakeholders' inclusion in decision-making in partnerships with the governments can overcome the challenges of limited knowledge among farmers (Akinsemolu et al, 2023). Efficient resource use in agricultural production systems will birth considerable potential for enhanced

agricultural incomes and resilience of rural livelihoods while reducing the intensity of agricultural emissions. Channeling climate finance to support institutional investments that accelerate the adoption of practices that enhance resource-use efficiency will be an important step towards climate-resilient development in agriculture (Lipper et al., 2014)

An objective of CSA is to complement efforts aimed at sustainably using agricultural systems to achieve food security and integrating essential adaptation and taking up potential mitigation. Three objectives are necessary in actualizing this aspiration. They include sustainably increasing agricultural productivity to support food security and development, adapting and building resilience to climate change and developing opportunities to reduce GHG emissions from agriculture. Mitigation may be an important co-benefit of actions to improve food security and adaptation however; achieving this benefit may attract additional costs. Costs of low-emission growth strategies to conventional high-emission growth paths can link agricultural development efforts that generate mitigation co-benefits to sources of climate finance (Lipper et al., 2014)

Management practices such as minimal tillage, use of varieties of breeds; integrating trees into agricultural systems; restoration of degraded lands; enhancing the efficiency of water and nitrogen fertilizer use and organic manure management are veritable tools in enhancing efficiency. Enhancing soil quality can result in raised production, adaptation and mitigation benefits through the regulation of carbon, oxygen and other plant nutrient cycles, leading to increased resilience to limiting climate factors and carbon sequestration. These changes however must be complemented by changes in consumption patterns, reduction in resource wastages and creation of positive incentives along the production chain (Lipper et al, 2014)

**Constraints to the adoption of Climate Smart Agricultural practices**

Agriculture is susceptible to constraints and stressors and Mapfumo et al. (2014) thinks high reliance on crop production systems that are sensitive to climate change and dwindling capital resource base amongst others may be exacerbating these constraints and stressors. Here in Nigeria, some constraining factors were studied by Opeyemi et al (2023) and presented in table 2 below.

**Table 2: Constraints to the adoption of Climate Smart Agricultural practices**

| Constraints | Not serious | Serious | Very serious | Mean score |
|---|---|---|---|---|
| Limited awareness of CSA practices | 102 | 33 | 5 | 1.31 |
| Inadequate extension services | 51 | 74 | 15 | 1.74 |
| Inadequate information on CSA options | 54 | 71 | 15 | 1.72 |
| Inadequate equipment | 80 | 47 | 15 | 1.54 |
| Illiteracy of farmers | 70 | 66 | 4 | 1.53 |
| Inadequate inputs supply | 76 | 47 | 17 | 1.58 |
| limited technical capacity of farmers | 67 | 50 | 23 | 1.69 |
| inadequate access to agricultural credit | 2 | 25 | 113 | 2.79 |
| Expensive improve crop variety | 8 | 20 | 112 | 2.74 |
| Inadequate farm labor | 129 | 8 | 3 | 1.1 |
| Inadequate government policy | 75 | 54 | 11 | 1.54 |
| High production cost | 6 | 33 | 101 | 2.69 |
| Pest and disease infestation | 90 | 34 | 16 | 1.47 |
| High cost of farm inputs | 0 | 24 | 116 | 2.83 |

**Source**: Opeyemi et al, 2023

According to Opeyemi et al, (2023), high cost of input (mean score = 2.83) suggests a prevalent constraint. Inadequate access to agricultural credit with a mean score of 2.79 also suggests one. Outside bank credits, inadequate financial resources (mean score = 2.47) was rated to be a very serious constraint from their studies. This suggests adequate finance and credit facilitate the adoption of CSA practices and agrees with Oyekale (2009) that asserts small-scale farmers have low resource base and thus vulnerable and limited in coping with the consequences of climate change. Other constraints with mean values of less than 2.0 seem not to be weighty from their study. This corroborates the findings of several other studies that suggest CSA practices may require farmers access to certain inputs like seedlings, fertilizers etc. Absence or inadequacy of these may constrain extensive adoption. Timely access to inputs may be a critical element in efficient resource use which often is absent. It has been considered by some scholars that financial investment in agriculture is insufficient to guarantee access to these needs and often poorly

targeted. Though climate finance may increase in the near future; it likely may not meet a relatively adequate share of total agricultural investment needs (Lipper et al., 2014)

**Conclusion**

Climate change alters agricultural production and food systems, impacting approaches to transforming agricultural systems that would have aided global food security and poverty reduction. An evidence-based approach to addressing these will therefore require coordinated actions from all and sundry. With the right policies and investments, the agriculture sector can leverage CSA pathways to scale up food security while mitigating climate change as a threat to food security. This is because Climate Smart Agriculture presents a holistic response to the negative impacts of climate change on food security. It features comprehensive approaches that tend to reinforce the adaptability of the food system against climate change through myriads of approaches such as development of resilient crop varieties, the adoption of farming methods that will not compromise the integrity of the soil and resource conservation. If implemented, CSA will effectively mitigate to a great extent the effects of climate change on agriculture and enhance food security in Nigeria with the participation of all stakeholders.

**Disclaimer (Artificial intelligence)**

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model,

and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

REFERENCES


Akinsemolu, A. A., Onyeaka, H. N and Tamasiga, P. (2023). Climate-smart agriculture as a possible solution to mitigate climate change impact on food security in Sub-Saharan Africa. Food and Energy Security. John Wiley & Sons Ltd

Apata T.G., Samuel, K.D. and A.O. Adeola (2009). Analysis of Climate Change Perception and Adaptation among Arable Food Crop Farmers in South Western Nigeria. Contributed Paper Prepared for Presentation at the International Association of Agricultural Economists' 2009 Conference, Beijing, China, pp. 1-5.

Ashalatha, K.V., Munisamy, G. and Bhat, A.R.S (2012). Impact of Climate Change on Rainfed Agriculture in India: A Case Study of Dwarwad. International Journal of Environmental Science And Development, 3(4):368-371

Ayinde O.E (2010). Empirical Analysis of Agricultural Production and Climate Change: A Case Study of Nigeria. Journal of Sustainable Development in Africa, 12(6): 345-253.

Branca, G., Arslan, A., Paolantonio, A., Grewer, U., Cattaneo, A., Cavatassi, R., & Vetter, S. (2021). Assessing the economic and mitigation benefits of climate-smart agriculture and its impli cations for political economy: A case study in southern Africa. Journal of Cleaner Production, 285, 125161.

Bazzana, D., Foltz, J. and Zhang, Y. (2022). Impact of climate smart agriculture on food security: An agent-based analysis. Elsevier B.V. 111, August 2022, 102304

FAO (2013). Food Security Indicators. Food and Agriculture Organization of the United Nations. Rome, Italy

Lipper, L, Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A.,

Garrity,D., Henry, K., Hottle, R., Jackson,L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., Thi Sen, P., Sessa, R., Shula, R., Tibu, A. & Torquebiau, E. F. (2014). Climate-smart agriculture for food security. Nature Climate Change 4, 1068–1072 (2014) doi:10.1038/nclimate2437

Mafongoya, P.; Gubba, A.; Moodley, V.; Chapoto, D.; Kisten, L.; Phophi, M.(2019). Climate Change and Rapidly Evolving Pests and Diseases in Southern Africa. In New Frontiers in Natural Resources Management in Africa; Ayuk, E.T., Unuigbe, N.F., Eds.; Springer International Publishing: Cham, Switzerland, 2019; pp. 41–57.

Mapfumo, P.; Jalloh, A.; Hachigonta, S. (2014). Review of research and policies for climate change adaptation in the agriculture sector in Southern Africa. Future Agric. Work. Pap. 2014, 100, 59.

Mekyassi, H and Kızıldeniz, T (2024). The role of nutrition-sensitive climate-smart agriculture in ensuring global food security. BIO Web of Conferences , 01055 (2024)

Masipa, T. (2017). The impact of climate change on food security in South Africa: Current realities and challenges ahead. Jàmbá: Journal of Disaster Risk Studies, 9(1), 1–7.

Müller, C., Cramer, W., Hare, W.L., Lotze- Campen, H. Climate Change Risks for African Agriculture (2011). Proceeding of the National Academy of Science of the United States of America, 108(11), 4313–4315.

Mutengwa, C. S., Mnkeni, P and Kondwakwenda, A (2023). Climate-Smart Agriculture and Food Security in Southern Africa: A Review of the Vulnerability of Smallholder Agriculture and Food Security to Climate Change. MDPI, Basel, Switzerland. Sustainability. 2023; 15(4):2882.

Opeyemi, G., Opaluwa, H.I., Adeleke, A.O. and Ugbaje, B. (2021). Effect of climate smart agricultural practices on farming households′ food security status In Ika North East Local Government Area, Delta State, Nigeria. Journal of Agriculture and Food Sciences. 19 (2) pp . 30 – 32

Oyekale, A.S (2009). Climatic Variability and its Impact on Agricultural Income and Households' Welfare
in Southern and Northern Nigeria. Electronic Journal of Environmental, Agricultural and Food Chemistry, 8(1), 13-34.

Rehman, U. R (2023). Climate Smart Agriculture and Food Security, Challenges & Way Forward for Pakistan. Special report by Rehman, 2023. Ex Young Parliamentary Associate (YPA) - Senate of Pakistan Policy Research Financial Analyst.

Teklewold, H., Kassie, M., Shiferaw, B and Köhlin, G (2013). Cropping System Diversification, Conservation Tillage and Modern Seed Adoption in Ethiopia: Impacts on Household Income, Agrochemical Use and Demand for Labor. Ecological. Economics. 93, 85–93.

Westermann, O., Förch, W., Thornton, P., Körner, J., Cramer, L., & Campbell, B. (2018). Scaling up agricultural interventions: Case studies of climate-smart agriculture. Agricultural Systems, 165, 283–293.