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THE ROLE OF INDIGENOUS SOIL WATER CONSERVATION TECHNIQUES IN REDUCING AGRICULTURAL LAND DEGRADATION AND MITIGATING CLIMATE CHANGE IN SEMI-ARID REGION OF NORTHERN ADAMAWA STATE, NIGERIA".

M.G. Bunu

The Federal Polytechnic Mubi
School of Agricultural Technology
Department of Agricultural Tech
Adamawa State Nigeria.
bunugajimartins@gmail.com
07068385494

Abstract

This research focused on the role of indigenous soil water conservation techniques in reducing agricultural land degradation and mitigating climate change in Semi- Arid region of Northern Adamawa State, Nigeria. Agricultural land degradation remains a major environmental and socio-economic challenge in the semi-arid regions of northern Adamawa state of Nigeria, where erratic rainfall, increasing temperature. And unsustainable farming practices intensity, soil erosion, nutrients depletion and declining crop productivity. Indigenous soil and conservation (ISWC) techniques developed and refined by the local communities over generations represent context specific low cost adaptation and mitigation strategies. This study examined the role of indigenous conservation practices such as ridging, zai pits, mulching, agroforestry stone bunds and traditional fallowing systems in reducing agricultural land degradation and contributing to climate change mitigation in selected communities in northern Adamawa State 'Using a mixed method approach that integrate households surveys, field observation, soil analysis and focus group discussions. The research evaluated the effectiveness of these practices in improving soil structure, enhancing moisture retention, increasing soil carbon and reducing surface runoff and erosion. Comparative analysis between plots adopting indigenous techniques and non adopting plots quantified the differences in soil fertility indicators, crop yield stability and carbon sequestration potential.it was suggested that land degradation can effectively be controlled using afforestation, crop rotation for sustainable agricultural production can be adopted to control climate change in the study area.

Keywords: Indigenous, Conservation, Degradation, climate change, Semi-Arid Region, Environment, Northern Adamawa

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INTODUCTION

The role of indigenous measures on soil and water conservation techniques has over decade been used to control climate overtime, whether due to natural variability or as a result of human activity (Vermeulen et al.,2023 and Arslan at al 2024). Due to poverty and excessive reliance on rain-fed agriculture, and lack of resources to lessen the consequences. Africa is vulnerable to climate change. Climate change can also be seen as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (Malachi and Martins, 2023). In an attempt to sustain the environment, communities device her means locally to maintain and sustain her environment to conserve soil and water retention to maintain climate change. Traditionally these has long over time has been achieved through contouring and land terracing, crop rotation and conservation amongst others Climate change has become a global issue in recent times manifesting in variations of different climate parameters including cloud cover, precipitation, temperature ranges, sea levels and vapour pressure (Kang'ee,2026;Zakaria et al.,2020).

Climate change poses a major and growing threat to global food security. Population growth and rising incomes in much of the developing world have pushed demand for food and other agricultural products to unprecedented levels. Food and Agriculture Organization of the United Nations (FAO, 2018) has estimated that, in order to meet food demand in 2050, annual world production of crops and livestock will need to be 60% higher than it was in 2006. In developing countries, about 80% of the required increase will need to come from higher yields and increased cropping intensity and only 20% from expansion of arable land (FAO, 2018).

In recent years, climate change and its variability are emerging as major challenges to Nigerian Agriculture. The projections of global climate change include altered average temperatures, rainfall, and increased extreme events (e.g., heat and cold waves, flooding), enhanced

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atmospheric carbon dioxide and ground-level ozone concentrations and rise in sea level leading to inundation of coastal areas etc. In recent past, it is more evident, as one or the other climatic events. Determining how people will react to and implement adaptation measures requires an understanding of their views of environment and climent change. (Vedwan and Rhoaders, 2001).

Climate change will have negative effects on rain fed and irrigated crops yield across regions in Northeastern Nigeria, due to temperature rise and changes in water availability. While rain fed agriculture primarily impacted due to rainfall, shifts in seasons, increase in temperatures and change in rainfall pattern are already being observed. In view of these, the crops may encounter extreme weather events like drought, flood, heat and cold during its life cycle, resulting in substantial yield losses (FAO, 2017). The impacts of these may vary with region, crops and cropping systems, soils and management practices.

The development and identification of climate resilient crop varieties, with enhanced tolerance to heat, drought, flooding, chilling and salinity stresses are essential in order to sustain and improve crop yields to cope with the challenges of climate change. It is essential to bridge the yield gaps, enhance the productivity and profitability, minimize risk and improve the livelihoods of millions of people dependent on agriculture. While, abiotic stresses such as drought, heat or cold may trigger a series of responses in plants that include changes in gene expression, signal transduction pathways, metabolic and molecular mechanism as well as cumulative manifestations of these in terms of source and sink relations for adaptation (FAO, 2017).

Crop farming in the Adamawa State is mostly practiced on traditional method, with more than 80% of the population dependent on crop production or livestock farming. The *Boko haram* insurgency has led to massive displacement and high levels of food insecurity in the area. Already poor vulnerable communities have observed large number of people, placing considerable pressure on fragile agriculture and pastoral

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livelihood, while the insecurity and malnutrition has pushed large majority of the population to abject poverty in the region (FAO, 2023).

Climate smart agriculture is an approach for transforming and reorienting agricultural development under the realities of soil and water degradation and climate change. Its goal is to achieve sustainable agricultural development for food security through sustainably increasing agricultural productivity from crops, livestock and fish, to contribute to achieving food and nutritional security as well as higher incomes, but not at the expense of the environment and adapting to climate change, with a focus on reducing exposure to short-term risks, enhancing capacity to adapt and develop in the face of shocks and longer-term stresses, and maintaining healthy ecosystems that provide environmental services to farmers, such as soil management practices, crop rotation, good range land management and the use of climate resilient crop varieties to mitigating climate change for climate smart agriculture (Onwachukwa, 2016).

Sub-Saharan African region is at high risk of the climatic variation risk, characterized by strong wind storm at the beginning of raining season, prolonged dry season and very short rain across the years.

Report has revealed that, in Mozambique and Tanzania, the increase in their capacity to adopt to climatic variability through the application of sustainable intensification practices, through working with farmers to help them apply conservation practices such as crop resilient increase the yield of cereal crops. Such mission with minimum soil disturbance and inter- cropping simultaneously boost yields and protect their environments (Spore, 2018). Not only this practice reduces soil degradation, and improving soil moisture level, carbon capture, they are increasing the yields of cereals such as Maize, Sorghum and legumes (FAO, 2007).

The climate-smart agriculture (CSA) concept reflects an ambition to improve the integration of agriculture development and climate responsiveness. It aims to achieve food security and broader development goals under a changing climate and increasing food demand. Climatic Smart Agriculture initiatives sustainably increase productivity, enhance resilience, and reduce/remove greenhouse gases (GHGs), and require planning to address tradeoffs and synergies between these three pillars: productivity, adaptation, and mitigation.

The priorities of different countries and stakeholders are reflected to achieve more efficient, effective and equitable food systems that address challenges in environmental, social, and economic dimensions across productive landscapes (FAO, 2019). While the concept is new, and still evolving, many of the practices that make up climate smart agriculture already exist worldwide and are used by farmers to cope with various production risks. Mainstreaming climatic smart agriculture requires critical stock taking of ongoing and promising practices for the future and of institutional and financial enablers for climatic smart agriculture adoption. This gap necessitated for the study in reducing agricultural land degradation and climate mitigation in the area under study.

Statement of the Problems

1. Increasing land Degradation
2. Impact of climate variability and change
3. Declining use of indigenous conservation Techniques
4. Ineffective integration into modern agricultural systems

Statement of Objective

1. To control Agricultural land degradation in the study area.
2. Examine the impact of climate change on soil and water in the study area.
3. To determine the declining use of indigenous conservation technics among the communities in the study area.
4. Examine effective integration into modern agricultural production system in the area

DISCUSSION

Climate change refers to any change in climate overtime, whether due to natural variability or as a result of human activity (McCarthy 2001).

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It can also be seen as: “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (Parry 2007). Climate change has become a global issue in recent times manifesting in variations of different climate parameters including cloud cover, precipitation, temperature ranges, sea levels and vapour pressure (Ministry of Environment of the Federal Republic of Nigeria (MOEFRN 2003). With reference to sub-Saharan Africa, there is growing interest on the likely impacts of climate change on agriculture, economic growth and sustainable development. Incidences of climate change include changes in soil moisture, soil quality, crop resilience, timing/length of growing seasons, yield of crops and animals, atmospheric temperatures, weed insurgence, flooding, unprecedented droughts, sea level rises and many more.

There are projections of increases in rainfall in the humid regions of southern Nigeria, which are accompanied by increases in cloudiness and rainfall intensity particularly during severe storms. Similarly, the savannah areas of northern Nigeria were projected to experience less rainfall, which coupled with temperature increases, reduces soil moisture availability. Increased temperatures and accompanying decrease in water availability reduce the length of growing seasons and yield potential and hence the areas suitable for agriculture, further adversely affecting food security over the continent It is now clear that most adverse climatic and environmental impacts that occur today are manifestations of man’s inadvertent modifications to climate on local and to a limited extent, regional scale in some activities of the distant past. Natural and human induced global environmental change belongs to the class of risk with high probability of occurrence and damage potential but in such a remote future that for the time being no one is willing to perceive the threat.

Although the probability of occurrence and the damage potential are well known and clear, there is always a time lag between trigger and consequence which create a fallacious impression of security. Most disasters (including flood, droughts, desertification, land degradation, subsidence, etc.) are not random events without underlying causes; they are sudden manifestations of slow but continuous degradation processes (UNEP-GRID-Arendal 2005). Broad scientific agreement now exists that continued accumulation of heat-trapping "greenhouse" gases in the atmosphere is contributing to changes in the global climate, and in the climates of regions around the world (Crosson, 1997). An analysis of temperature records shows that the earth has warmed an average of 0.6 ^{0}C over the past 100 years (Environment Canada 2008). The warming is real and significant though its intensity has varied from decade to decade, from region to region and from season to season, and been mainly caused by greenhouse gases (Crosson 1997).

There is a growing consensus in the scientific literature that over the coming decades, higher temperatures and changing precipitation levels caused by climate change will be unfavourable for crop growth and yield in many regions and countries (Yesuf *et al*. 2008). To what extent this will be the case in Nigeria particularly in the southeast rainforest zone where both temperature and precipitation approach extremes has not received much research interest? Disaster risk and climate change are two threats to human well-being that reinforce each other. Hence, they represent some of the greatest challenges to humankind in this century. Disaster risk is an intrinsic characteristic of human society, arising from the combination of natural and human factors and subject to exacerbation or reduction by human agency. While the adverse impacts of climate change on society may increase disaster risk, disasters themselves erode environmental and social resilience, and thus increase vulnerability to climate change (O'Brien *et al*. 2008). Climate change, and the likely increase in disasters, threatens to block pathways out of poverty in developing countries especially those in Africa. Any increase in disasters, whether large or small, will threaten development gains and hinder the implementation of the Millennium Development Goals (ISDR 2008: 55).

In the coming decades, climate change is expected to exacerbate the risks of disasters, not only from more frequent and intense hazard events but also through greater vulnerability to the existing hazards (ISDR 2008).

Approaches toward the management of climate change impacts have to consider the reduction of human vulnerability under changing levels of risk. A key challenge and opportunity therefore lies in building a bridge between current disaster risk management efforts aimed at reducing vulnerabilities to extreme events and efforts to promote climate change adaptation (Olorunfemi 2008; Few *et al*. 2006). The long term horizon of climate change and current scientific uncertainties pose special challenges. Strategies that address challenges recognize that there is no best solution. In this sense, climate change provides new incentives for the need to plan ahead and to anticipate extreme events and trends (Zevenbergen *et al*. 2008). Within the context of extreme weather events especially flooding, this means that management strategies must meet the present needs while providing a path of adjustment for the future. Nigeria, like many other countries, is exposed to climate change-induced dangers of desertification, erosion, flooding and other ecological problems. Considering the strong nexus between climate change and development, Nigeria is highly at risk in the area of food and nutrition, poverty and hunger reduction, and most importantly, economic development. Consequently, Nigeria's efforts and actions must be informed by these realities.

Climate change is a global problem that requires global solutions and is also one of the most important issues on the global political agenda, with a series of efforts to find solutions through international negotiations. Climate change has become a global issue in recent times manifesting in variations of different climate parameters including cloud cover, precipitation, temperature ranges, sea levels and vapour pressure (Ministry of Environment of the Federal Republic of Nigeria (MoEFRN) 2003: 43). The variations in climate parameters affect different sectors of the economy such as agriculture, health, water resources, energy etc. The main cause of climate change has been attributed to anthropogenic (human) activities. For example, the increased industrialization in the developed nations has led to the introduction of large quantities of greenhouse gases (GHGs), including carbon (IV) oxide (CO_2), methane

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(CH_4) and nitrous oxide (N_2O) into the atmosphere. These GHGs are the primary causes of global warming. The global increases in CO_2 concentration are due primarily to fossil fuel use and land use change, while those of CH_4 and N_2O are primarily due to agriculture. There is no doubt there- fore that the earth is getting warmer and human beings are mainly to be blamed (Spore 2008: 4). With reference to sub-Saharan Africa, there is growing interest on the likely impacts of climate change on agriculture, economic growth and sustainable development.

Approaches toward the management of climate change impacts have to consider the reduction of human vulnerability under changing levels of risk. A key challenge and opportunity therefore lies in building a bridge between current disaster risk management efforts aimed at reducing vulnerabilities to extreme events and efforts to promote climate change adaptation (Olorunfemi 2008; Few et al. 2006). The long term horizon of climate change and current scientific uncertainties pose special challenges. Strategies that address challenges recognise that there is no best solution. In this sense, climate change provides new incentives for the need to plan ahead and to anticipate extreme events and trends (Zevenbergen *et al*. 2008: 23). Within the context of extreme weather events especially flooding, this means that management strategies must meet the present needs while providing a path of adjustment for the future. Climate change, which is attributable to the natural climate cycle and human activities, has adversely affected productivity in Nigeria (Ziervogel *et al*. 2006: 8). Available evidence shows that climate change is global, likewise its impacts; but the most adverse effects will be felt mainly by developing countries, especially those in Africa, due to their low level of coping capabilities (Nwafor 2007: 2; Jagtap 2007: 6).

Nigeria is one of these developing countries (Odjugo 2010: 47-55). As the planet warms, rainfall patterns shift, and extreme events such as droughts, floods, and forest fires become more frequent (Zoellick 2009: 7), which results in poor and unpredict- able yields, thereby making farmers more vulnerable, particularly in Africa (UNFCCC 2007) Farmers (who constitute the bulk of the poor in Africa) face prospects of tragic crop failures, reduced agricultural productivity, increased hunger, malnutrition and diseases (Zoellick 2009:). It is projected that crop yield in Nigeria may fall by 10-20% by 2050 or even up to 50% due to climate change (Jones and Thornton 2003: 54), particularly because Nigerian agriculture is pre-dominantly rain-fed and hence fundamentally dependent on the vagaries of weather. As the people of Nigeria strive to overcome poverty and advance economic growth, this phenome- non threatens to deepen vulnerabilities, erode hard-won gains and seriously undermine prospects for development.

RISK MANAGEMENT AND CHALLENGES OF CLIMATE CHANGE

There is a need for concerted efforts toward tackling this menace. The constant reportage of disasters occurring in different parts of the world as always seen or heard in the print and electronic media signals the enormous vulnerability of humans to day-to-day natural and human-induced hazards. Recent events are replete with various accidents and mishaps which reveal the lack of preparedness of the world population to deal with emergencies. Nigeria can be cited as an example of the nations that has inadequate disaster management systems were even more harshly exposed when the nation endured a series of air crashes from 2005 to 2006 and beyond. All the violent conflicts and civil disturbances which ubiquitously flared up in many parts of the country over the past decade were characterised by the slow response of the security, emergency and relief agencies to crisis spots, and the consequent needless prolongation of the suffering of those who had been affected by them. As Nigeria marked the tenth anniversary of the 2002 Ikeja ammunition depot explosion disaster, and as the world continues the mop up activities following the recent massive earth- quake devastation of Haiti, it has become imperative for Africa’s most populous State to radically reorganise its disaster response capability, and to prepare a specific plan to improve the response capacities of the local people, improve their livelihood in everyday life, for example, by strengthening and improving housing quality, gainful employment and access to income.

Integrated climate risk management would need to include elements of anticipatory risk management (ensuring that future development

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reduces rather than increases risk), compensatory risk management (actions to mitigate the losses associated with existing risk) and reactive risk management (ensuring that risk is not reconstructed after disaster events). Moreover, it will have to take into account both potential impacts on socio-economic and environmental systems. Integrated climate risk management could provide a framework to allow the disaster community to move beyond the still dominant focus on preparedness and response and for the adaptation to climate change community to move beyond the design of hypothetical future adaptation strategies. In some regions, such as the Caribbean and the South Pacific, synergy such as this is already being achieved. However, urgent actions must be taken at the international, national and local levels if integrated cli- mate risk management is to move from a concept to practice and serve to reduce risks and protect development. The agricultural extension change agents must be adequately trained and equipped with the skills and knowledge of how to mitigate the menace of global warming. The ministry of environment and disaster management must work hand in hand with the change agents in the ministry of agriculture to ensure that the farmers, both the livestock and crop production sectors are properly informed of the dangers of global warming, how it affects their productivity and lively hood and the sustainability of the agricultural sector of the economy locally and the world at large.

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METHODOLOGY

A systematic literature review approach was used to perform an extensive analysis of the acceptance and difficulties of climate-smart agriculture in Northeast Nigeria. Key words associated with "climate-smart agriculture", "adoption", "challenges", "Northeast Nigeria" and other related phrases were used to search major academic databases, such as Web of Science, Scopus, and Google Scholar, for relevant papers. To make sure the most recent and pertinent material was included, the search was restricted to peer-reviewed journal articles, book chapters, and reports from respectable organisations published within the last 15 years. The initial search results will be screened based on the title and abstract to identify potentially relevant studies. The full texts of the selected studies will then be thoroughly reviewed, and those meeting the inclusion criteria will be included in the final review. The inclusion criteria considered factors such as the study's focus on climate-smart agriculture practices, the geographical context of Northeast Nigeria, and the relevance of the findings to the research objectives. Additionally, a backwards and forward reference search was conducted to identify any relevant studies that may have been missed in the initial database searches. The selected studies were critically appraised, and their findings were synthesised and analysed to address the research questions and objectives of the review.

SOIL EROSION

Decreased Water Retention: Degraded land often loses its ability to retain water due to reduced vegetation cover and soil structure degradation. This exacerbates water scarcity, as both surface and groundwater resources become less available for agricultural and domestic use.

Soil and Water Pollution: Degraded lands may become contaminated with harmful chemicals from agricultural runoff or industrial activities. This pollution poses risks to human health through contaminated water supplies and food sources.

Soil and Water Conservation: Techniques such as terracing, check dams, and contour farming were employed to reduce soil erosion and improve water retention.

Rainwater Harvesting: Implementing rainwater harvesting systems allows communities to capture and store rainwater for agricultural and domestic use. This practice enhances water availability, particularly during dry spells, and reduces reliance on groundwater resources.

Reforestation and Afforestation: Restoring degraded landscapes through reforestation (replanting trees in deforested areas) and afforestation (planting trees in non-forested areas) enhances biodiversity, improves soil stability, and increases carbon sequestration, contributing to climate change mitigation.

CLIMATE CHANGE SCENARIO IN NORTHEAST NIGERIA

Over the past few decades, temperatures in Northeast Nigeria have significantly increased in line with global warming trends. The Nigerian Meteorological Agency (NIMET) reports that between 1961 and 2010, the region's mean annual temperature increased by an average of 0.8°C (NIMET, 2020). Forecasts suggest that by the middle of the twenty-first century, temperatures will have increased by an additional 1.5°C to 3°C, showing that this warming trend will continue (IPCC, 2021). Heat waves are occurring more frequently, intensely, and for longer periods of time in Northeast Nigeria, which is indicative of global warming. There have been a lot more hot days (with temperatures above 35°C), especially from March to May when the dry season is in full swing (Adamu et al., 2018). This prolonged exposure to high temperatures can have severe implications for agricultural production, human health, and the overall well-being of communities in the region.

Equally, Northeast Nigeria exhibits a semi-arid climate, with rainfall patterns heavily influenced by the West African Monsoon system. Historical data from NIMET show a declining trend in annual rainfall over the past few decades, with significant inter-annual and spatial variability (NIMET, 2020). The region experienced a prolonged drought period during the 1970s and 1980s, which had severe consequences for

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agriculture and led to widespread food insecurity (Mortimore, 2000). According to climate forecasts, the region is expected to see more modifications in rainfall patterns, characterised by a reduction in annual precipitation overall and an escalation in the frequency and intensity of extreme downpour events (IPCC, 2021). Rain-fed agriculture, which is the primary farming method used by smallholder farmers in the area, has substantial challenges as a result of this fluctuation in rainfall patterns (Jamilu et al., 2018).

Furthermore, Northeast Nigeria has witnessed an increase in the frequency and intensity of extreme weather events, such as droughts and floods, in recent decades. The region is particularly vulnerable to droughts, which can have devastating impacts on crop yields, livestock production, and water availability (Abaje et al., 2014). Extended dry spells have been connected to the region's increasing desertification and deterioration of land (Bello et al., 2016). On the other hand, flash floods have also become more common in the area, especially in metropolitan areas and along river basins. According to Adeloye and Rustum (2011), these floods are frequently brought on by periods of heavy rainfall and made worse by shoddy urban planning and insufficient drainage systems. Flash floods have the potential to cause crop damage, livestock losses, and community uprooting, which exacerbates the difficulties smallholder farmers in the area already experience.

IMPACTS ON AGRICULTURE AND FOOD SECURITY

Climate change has had a major influence on crop productivity in Northeast Nigeria, which directly affects food security and livelihoods.

Rising temperatures and changing rainfall patterns have led to an increase in crop failures and yields (Adamu et al., 2018). Farmers in the region are finding it increasingly difficult to effectively plan and manage their farming operations because of the region's substantial reliance on rain-fed agriculture. In addition, the frequency and intensity of heat waves and droughts have increased, which has made matters worse for smallholder farmers. Crops that are staple foods in the region, such as sorghum, millet, and cowpea, are especially vulnerable to these climate

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stressors (Jamilu et al., 2018). Prolonged droughts can lead to soil moisture deficits, reducing crop yields and, in severe cases, complete crop failure, threatening food security and livelihoods.

LIVESTOCK PRODUCTION

The output of cattle, a vital part of Northeast Nigeria's agricultural system, is similarly impacted by climate change. The area is home to a large number of pastoralists and agro-pastoralists, whose primary source of income is cattle (Abubakar and Attah, 2013). Rising temperatures and changing precipitation patterns have an impact on the amount and quality of grazing areas, which has reduced cattle production and increased animal mortality rates. Furthermore, the scarcity of water resources brought on by prolonged droughts has exacerbated conflicts between sedentary farmers and pastoralists over access to grazing lands and water (Okoli and Atelhe, 2014). The food security in the area has been further jeopardised by the escalation of these conflicts in recent years, which has resulted in community displacement.

LIVELIHOOD CHALLENGES

The lives of smallholder farmers in Northeast Nigeria have been profoundly impacted by the effects of climate change on agriculture. More than 80% of people in the area depend on agriculture either directly or indirectly, making it the backbone of the economy (Hassan, 2018). Lower animal productivity and agricultural yields have resulted in lower household incomes, higher rates of poverty, and more food insecurity in rural areas. Inadequate extension services, insufficient infrastructure, and restricted access to agricultural inputs are just a few of the problems smallholder farmers already face, all of which have been made worse by climate change (Adesiji et al., 2012). These elements, along with the effects of climate change, have produced a poverty- and vulnerability-based vicious loop that makes it harder and harder for farmers to adapt and become resilient.

In addition to the direct impacts on agriculture, climate change has also contributed to the displacement of communities and the rise of conflicts in the region. The Lake Chad Basin, which spans parts of

Northeast Nigeria, has experienced a significant reduction in water levels due to a combination of climate change, overexploitation of water resources, and poor management (UNEP, 2018). This has led to the displacement of communities that rely on the lake for their livelihoods, further exacerbating food insecurity and social instability. Moreover, the impacts of climate change have been linked to the rise of conflicts in the region, such as the Boko Haram insurgency (Nagarajan et al., 2018). While the root causes of this conflict are complex and multifaceted, environmental factors, including climate change, have played a role in exacerbating existing tensions and grievances, particularly in relation to access to natural resources and livelihood opportunities.

Comprehensive adaptation and mitigation measures that address the multifaceted effects of climate change on agriculture and food security in Northeast Nigeria are desperately needed to solve these issues. The main goals of these initiatives ought to be to advance climate-smart farming methods, increase community resilience to climate shocks and strains, fortify social safety nets, and facilitate better access to agricultural supplies and extension services. Adopting climate-smart agriculture (CSA), which attempts to decrease greenhouse gas emissions, adapt and create resilience to climate change, and sustainably boost agricultural productivity and incomes, is one promising strategy (FAO, 2013). Smallholder farming systems may become more resilient as a result of CSA techniques like integrated crop-livestock systems, agroforestry, and conservation agriculture, which also help to mitigate the effects of climate change.

However, the adoption of CSA practices by smallholder farmers in Northeast Nigeria has been hampered by several barriers, including limited awareness and knowledge, inadequate access to inputs and technologies, lack of institutional support and extension services, and socio-economic factors such as poverty and land tenure insecurity (Adesiji et al., 2012). Overcoming these barriers requires a concerted effort from all stakeholders, including policymakers, researchers, extension services, and local communities. In addition to promoting CSA practices, there is a

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need for comprehensive policies and strategies that address the broader challenges of climate change adaptation and mitigation in the agricultural sector. These may include investments in water resource management, infrastructure development, early warning systems for climate-related disasters, and the promotion of alternative livelihood opportunities for rural communities.

Furthermore, a comprehensive strategy that takes into account the interdependence of environmental, social, and economic aspects is needed to address the effects of climate change on agriculture and food security in Northeast Nigeria. This entails dealing with concerns about the security of land tenure, gender parity, market and financial accessibility, and the general management of natural resources. Ultimately, addressing the issues brought about by climate change in Northeast Nigeria necessitates a coordinated strategy involving a variety of stakeholders, including local communities, governmental and non-governmental organisations.

ADOPTION OF CLIMATE-SMART AGRICULTURAL PRACTICES IN NORTHEAST NIGERIA

Climate-smart agriculture in Northeast Nigeria’s semi-arid regions depends on conservation agricultural practices such as crop rotation, mulching, and low tillage. FAO (2013) states that these techniques improve soil fertility, reduce soil erosion, and retain soil moisture, enhancing the land’s ability to withstand erratic rainfall and soil degradation issues. Furthermore, minimum tillage techniques such as zero- and strip-tillage minimise soil disturbance and erosion risk (FAO, 2013). Herbicide use is decreased when crop residue is mulched because it keeps moisture in the soil and prevents weed development (Nelson et al., 2014). Crop rotation reduces erosion, inhibits the growth of pests and diseases, and boosts fertility (Triomphe, 2015).

In Northeast Nigeria's water-scarce regions, rainwater harvesting systems like surface runoff ponds and underground tanks can store water during rainy seasons for dry periods (Quiroga et al., 2015). This addresses water scarcity challenges. Efficient irrigation techniques like drip and sprinkler systems deliver water directly to crop root zones, reducing evaporation losses and runoff erosion (Botha et al., 2015; Mul et al., 2011). This improves water use efficiency crucial for climate-smart agriculture.

Climate change is projected to increase drought and heat wave frequency and severity in Northeast Nigeria (Campbell et al., 2014a). Adopting drought-tolerant and heat-resistant crop varieties can help farmers adapt and ensure better yields and food security. Examples of suitable varieties include drought-tolerant maize, sorghum, millet, and heat-resistant cowpea and groundnut cultivars (Campbell et al., 2014b). Integrating these into cropping systems or for diversification can build resilience. It should be noted that agroforestry systems that integrate trees and shrubs into agricultural lands provide multiple benefits aligned with climate-smart agriculture goals (FAO, 2013; Lee, 2012). Trees regulate microclimates, improve soil fertility through nitrogen fixation and leaf litter, and provide additional income from products. Suitable agroforestry systems for Northeast Nigeria include alley cropping (crops between tree rows) and parklands (scattered trees on croplands) using tree species like Faidherbia albida, Acacia spp., mango, and cashew, which are already cultivated in the region (Lee, 2012).

Climate change can increase pest and disease outbreak risks, threatening crop productivity (FAO, 2013). Integrated Pest Management (IPM) combines cultural, biological, and judicious chemical control methods in an environmentally sustainable approach. Suitable IPM practices include crop rotation, intercropping, pest-resistant varieties, and biological control agents (FAO, 2013). This reduces reliance on chemical pesticides with adverse health and environmental effects. In Northeast Nigeria’s vital livestock sector, improved feed and fodder management is key for climate-smart production (Henri-Ukoha et al., 2019). Climate change affects feed availability and quality, necessitating strategies to optimise utilisation and reduce emissions. Strategies include cultivating drought-tolerant, high-yielding fodder crops like sorghum and cowpea, preserving crop residues, and establishing fodder banks or silage production (Henri-Ukoha et al., 2019; Ncube et al., 2016). This ensures a reliable, high-quality feed supply during droughts and scarcity.

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Promoting well-adapted, resilient livestock breeds and effective animal health practices is crucial for climate-smart production (FAO, 2013). Heat-tolerant and disease-resistant breeds can help cope with climate impacts on animal health and productivity. Implementing vaccination programs, disease surveillance, and improved housing and management systems provides adequate shelter during extreme weather events and prevents disease spread, reducing livestock mortality (FAO, 2013; Ncube et al., 2016).

Biogas production from agricultural residues like crop residues and animal manure is a climate-smart practice providing renewable energy while contributing to waste management and soil fertility improvement (FAO, 2013). In Northeast Nigeria's livestock and crop production systems, which generate significant residues, small-scale household or community biogas digesters can provide energy, improve waste management, and reduce pollution risks (Rosenstock et al., 2015; Markanday et al., 2015). Equally, solar-powered irrigation systems harness Northeast Nigeria's abundant solar energy to provide reliable, environmentally friendly power for irrigation, reducing fossil fuel reliance and emissions (FAO, 2013; Ncube et al., 2016). These systems are beneficial in remote areas lacking grid electricity access and can be combined with efficient techniques like drip irrigation to maximise water use efficiency for optimal productivity (Ncube et al., 2016).

In order to improve food security, increase resilience, and lessen the effects of climate change on Northeast Nigeria's agricultural systems, it is imperative that these methods be adopted (Movilla-Pateiro et al., 2021; Malhi, 2021). Applying crop and livestock management, land and water management, and renewable energy methods in a comprehensive way that considers local contexts is imperative (FAO, 2013). However, obstacles related to socioeconomics, institutions, and policies need to be removed for adoption to be successful. Enhancing regional institutions and groups, opening up financing sources, offering extension services, and passing laws that are helpful can all help achieve these goals (Deressa et al., 2009; FAO, 2013b; Meinzen-Dick et al., 2013). In order to tailor strategies to specific needs and environments, planning and execution must involve local people and stakeholders, increasing the likelihood of acceptance and sustainability (Meinzen-Dick et al., 2013; FAO, 2013).

For integrated, comprehensive solutions that manage trade-offs and find synergies, cross-sectoral coordination between the agricultural, environmental, energy, and water sectors is essential (FAO, 2013). Research and development initiatives ought to concentrate on climate-smart practices and technologies that are context-specific, such as newly adapted crop varieties, creative approaches to water management, and cutting-edge innovations like digital tools and precision agriculture (FAO, 2013). While there are obstacles in the way, overcoming them with teamwork, legislative backing, and creative solutions can maximise the promise of climate-smart agriculture in Northeast Nigeria for resilient, sustainable food systems, improved food security, and climate change adaptation and mitigation.

CHALLENGES AND BARRIERS TO CSA ADOPTION SOCIO-ECONOMIC FACTORS

One of the biggest obstacles to smallholder farmers using CSA techniques is poverty and restricted resource availability. A large number of African farmers are undercapitalised and do not have access to credit or insurance, two financial services that would enable them to engage in CSA technology (Mapfumo et al., 2015; Henri-Ukoha, 2019). For farmers with limited resources, the high upfront expenses of techniques like agroforestry and conservation agriculture are unaffordable (Giller et al., 2015). Furthermore, the ability of smallholder farmers to shift to climate-smart production methods is limited by the difficulties they frequently have in gaining access to markets, infrastructure, and inputs like better seeds and fertilisers (Williams et al., 2012; FAO, 2014). It is imperative to tackle these socio-economic obstacles by means of enhanced financing and resource accessibility to promote the adoption of CSA.

Insecure land tenure and ownership rights can disincentivise farmers from investing in long-term, sustainable agricultural practices (Nyanga et al., 2016; Antwi-Agyei et al., 2015). In many parts of Africa, customary land tenure systems and rising land acquisitions by investors undermine smallholders' land rights, hampering their adoption of CSA (Williams, 2014). Studies suggest that farmers with secure land tenure are more likely to adopt practices like agroforestry, as they have the assurance of reaping long-term benefits from their investments (Antwi-Agyei et al., 2015). Addressing land tenure issues through policy reforms and strengthening land rights is essential for promoting CSA adoption.

Gender inequality and cultural norms pose barriers to the adoption of CSA practices, particularly for women farmers (Gubbels, 2013). Women in many African societies face constraints like insecure land tenure and limited access to capital, inputs, information, and decision-making power, hindering their ability to adopt climate-smart practices (Williams et al., 2015). Cultural beliefs and traditional gender roles can also limit women's participation in economic activities and adoption of new agricultural practices (Gubbels, 2013). Empowering women through education, access to resources, and challenging gender stereotypes is crucial for promoting CSA adoption and achieving sustainable agricultural development.

TECHNICAL AND INSTITUTIONAL FACTORS

One major obstacle to the adoption of CSAs is limited access to expertise, information, and extension services (FAO, 2014). The willingness and capacity of many smallholder farmers to implement CSA methods is hampered by their ignorance of possible practices and their advantages (Below et al., 2012; Teklewold et al., 2013). Farmers face difficulties in evaluating risks and reaching well-informed decisions due to inadequate extension services and restricted information sharing on climate-smart practices (Williams et al., 2012). To get past this obstacle, extension services must be strengthened, farmer-to-farmer knowledge exchange must be encouraged, and access to climate and agricultural data must be improved.

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Inadequate infrastructure, such as transportation, communication, and market access, can impede the adoption of CSA practices, especially in remote rural areas (Foster and Briceño-Garmendia, 2010; FAO, 2014). Lack of reliable infrastructure and support systems limits farmers' access to inputs, markets, and information, constraining their ability to adopt climate-smart practices. Investments in infrastructure development, including roads, storage facilities, and market linkages, are crucial for creating an enabling environment for CSA adoption. Additionally, strengthening support systems like extension services, credit facilities, and input supply chains can facilitate the transition to climate-smart agriculture.

The absence of supportive policy frameworks and incentives can hinder the adoption of CSA practices (Williams et al., 2015). Many existing agricultural policies and investment plans in Africa fail to mainstream climate change adaptation and mitigation, leading to inconsistencies and a lack of coherence in promoting CSA (Mul et al., 2011). Developing supportive policies, coordinating across different sectors (agriculture, climate change, energy, etc.), and providing incentives such as payments for ecosystem services or carbon credits can encourage farmers to adopt climate-smart practices (Meinzen-Dick et al., 2013; McCarthy et al., 2021). Strong policy and institutional frameworks are essential for creating an enabling environment for CSA adoption.

ENVIRONMENTAL AND CLIMATIC FACTORS

Adopting CSA methods presents a substantial challenge for smallholder farmers due to the growing frequency and intensity of extreme weather events such as heat waves, floods, and droughts (IPCC, 2014). Farmers may get discouraged from investing in climate-smart agriculture as a result of these climatic pressures, which can also cause crop losses and compromise the efficacy of some techniques. Developing and promoting heat- and drought-resistant agricultural varieties is necessary to overcome this obstacle, as is putting risk management techniques like weather-based insurance plans into practice (Conradt et al., 2015; Hess

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and Syroka, 2005). Increasing one's capacity to withstand adverse weather conditions is essential to the effective implementation of CSA practices.

Adoption of CSA practices may be impeded by the deterioration of natural resources, such as nutrient depletion, soil erosion, and water scarcity (Munang et al., 2015). The productivity and resilience of agricultural systems can be weakened by overexploitation and unsustainable resource management, which makes it difficult for farmers to implement climate-smart practices. Implementing ecosystem-based adaptation (EBA) strategies, such as agroforestry, sustainable land management methods, and soil and water conservation techniques, is necessary to overcome this obstacle (Munang et al., 2015). The effective implementation of CSA principles requires the restoration and sustainable management of natural resources.

The adoption of climate-smart agricultural practices faces various socio-economic, technical, institutional, and environmental challenges in Africa, particularly for smallholder farmers (Matteoli et al., 2020). Addressing these multifaceted barriers is essential for promoting the widespread adoption of CSA and achieving sustainable agricultural development. Overcoming socioeconomic barriers requires improving access to resources, strengthening land tenure rights, empowering women, and addressing cultural norms that hinder adoption (Williams et al., 2015; Gubbels, 2013). Providing financial support, capacity building, and inclusive policy frameworks can help address these challenges. Technical and institutional barriers, such as limited access to information, inadequate infrastructure, and lack of supportive policies, can be addressed through investments in extension services, infrastructure development, and policy reforms that mainstream climate change adaptation and mitigation (Foster and Briceño-Garmendia, 2010; Meinzen-Dick et al., 2013).

Environmental and climatic challenges, including the increasing severity of extreme weather events and natural resource degradation, require the development and promotion of resilient agricultural practices, risk management strategies, and ecosystem-based adaptation approaches

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(IPCC, 2014; Munang et al., 2015). Overcoming these barriers necessitates a coordinated and multi-stakeholder approach involving governments, research institutions, civil society organisations, and local communities (FAO, 2013). Collaboration, knowledge sharing, and capacity building are crucial for facilitating the successful adoption of climate-smart agricultural practices and achieving sustainable agricultural development in the face of climate change. It is imperative to tackle these obstacles by implementing interventions that are relevant to the local socio-economic, cultural, and environmental circumstances. A one-size-fits-all strategy is unlikely to work because the difficulties and limitations that farmers encounter can differ between areas, neighbourhoods, and individual households. It is also crucial to continuously monitor and review CSA adoption campaigns in order to spot new obstacles, deal with them, determine the efficacy of interventions, and make any required corrections. To ensure that climate-smart agriculture initiatives are successful in the long run, it is imperative to cultivate a culture of learning and adaptation. Furthermore, it is essential to involve and empower local communities in the planning and execution, especially smallholder farmers.

STRATEGIES AND RECOMMENDATIONS FOR SCALING UP CSA

To enhance the capacity of smallholder farmers and promote the adoption of climate-smart agriculture (CSA) methods, it is imperative to fortify farmer education and extension initiatives. Extension services are crucial for knowledge exchange, providing technical support, and assisting rural people in implementing CSA practices, according to FAO (2014). Training programs should focus on increasing farmers' understanding of CSA concepts, methods, and potential benefits. Field days, interactive displays of various CSA techniques, such as integrated pest management, conservation agriculture, and agroforestry, and hands-on training workshops are some examples of how this might be done (Below et al., 2012; Teklewold et al., 2016).

Extension of Community Supported Agriculture (CSA) operations can be facilitated by fostering farmer-to-farmer learning and utilising

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participatory methods. Involving farmers in the co-development and adaptation of CSA strategies can increase their ownership and increase the likelihood of successful adoption (Chhetri et al., 2012). The sharing of experiences, best practices, and local innovations pertaining to CSAs should be encouraged through platforms that facilitate information acquisition and exchange among farmers. These platforms can leverage pre-existing social networks and community-based organisations to disseminate information and promote the adoption of context-specific CSA practices (Minja et al., 2004).

It is necessary to create incentive programs and supportive policy frameworks to encourage the widespread implementation of CSA approaches. Investment strategies, agricultural development plans, and regulatory frameworks should all include provisions for climate change adaptation and mitigation (Mul et al., 2011; Williams et al., 2015). Farmers may be encouraged to embrace sustainable and climate-smart practices by offering incentives like compensation for ecosystem services, carbon credits, or subsidies for CSA technologies (McCarthy et al., 2021; Meinzen-Dick et al., 2013). The needs and unique obstacles faced by smallholder farmers should be taken into consideration while creating these incentives.

Research and development (R&D) expenditures are essential for producing and distributing context-specific CSA knowledge, technologies, and practices. Climate-resilient crop varieties, creative water management strategies, and sustainable farming methods adapted to regional conditions should be the main goals of R&D initiatives (FAO, 2013). CSA technologies can be co-developed and adapted more easily if research institutions, extension services, and farming communities work together more closely. This will ensure that the technologies are relevant and increase the chances that they will be adopted (Chhetri et al., 2012; CCAFS and CGIAR, 2012a cited in FAO, 2013a).

Accelerating the implementation of CSAs requires promoting multi-stakeholder engagement and public-private partnerships. Including a variety of stakeholders can help to pool resources, expertise, and collective

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action. These stakeholders include government agencies, commercial sector players, civil society organisations, and local communities (Agrawal, 2008; Dethier and Effenberger, 2012). These collaborations can help with capacity building, technology transfer, financing access, and market connections, among other CSA adoption-related issues. In order to provide a coordinated and cohesive strategy for promoting CSA, they can also help link policies, programs, and activities across various sectors and levels (Williams et al., 2015).

It is necessary to increase smallholder farmers' access to financing and funding channels in order to encourage them to engage in CSA technologies and practices. Adoption is severely hampered by a lack of funding, especially for farmers with limited resources (Mapfumo et al., 2015; Henri-Ukoha, 2019). Innovative financing options that can give smallholders the money they need to implement CSA practices include climate finance instruments, agricultural credit programs, and microfinance. In order to ensure affordability and accessibility, these methods must be customised to the unique requirements and limitations of farming communities (World Bank, 2011; Läderach et al., 2021).

Promoting and disseminating climate-smart concepts and innovations is necessary to support the adoption of climate-smart behaviours. This entails developing and distributing drought- and heat-resistant crop varieties, efficient irrigation methods, renewable energy sources, and digital tools for precision farming (FAO, 2013; Ncube et al., 2016). Involving research organisations, the commercial sector, and technology providers can help with the development and commercialisation of suitable CSA technologies. In addition, indigenous knowledge and local ingenuity can help create solutions that fit the particular context and culture (Chhetri et al., 2012; CCAFS and CGIAR, 2012a, cited in FAO, 2013a).

To scale up community-supported agriculture (CSA) methods and solve issues at the ecosystem level, integrated landscape management techniques must be used. This entails putting into practice landscape-level interventions, like farmer-managed natural regeneration, agroforestry

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systems, and methods for conserving soil and water (Ariom et al., 2022; Binam et al., 2017). To guarantee fair and sustainable management of natural resources, these interventions should take stakeholder engagement, land tenure, and grazing rights into account. Effective landscape-level interventions require cooperation across various stakeholders, such as local communities, governmental entities, and environmental groups (Neate, 2013).

Adoption of CSA techniques can be encouraged and supported by creating value chains that are climate resilient and fortifying market ties. To increase the resilience of the overall food system, this entails making improvements to market facilities, transportation infrastructure, post-harvest handling, food processing, and distribution systems (Yadav et al., 2019). Farmers can be financially motivated to adopt sustainable practices by creating trustworthy market connections and guaranteeing fair prices for climate-smart agricultural products. Furthermore, encouraging sustainable value chains can support rural livelihoods, nutrition, and food security (FAO, 2013; Henri-Ukoha et al., 2019).

Expanding the implementation of climate-smart farming methods necessitates a thorough and diverse strategy that tackles the different environmental, institutional, technological, socioeconomic, and technical obstacles smallholder farmers encounter. Stakeholders may provide an enabling environment for the successful and long-lasting adoption of CSA practices by putting methods like integrated landscape and value chain approaches, enabling legislative frameworks, capacity building, and financial and technological support into practice. Collaboration across a range of stakeholders, including local governments, corporations, academic institutions, civil society organisations, and government agencies, is necessary for the effective implementation of these programs. By pooling information, resources, and experience, stakeholders can develop inclusive, context-specific solutions that address the unique needs and difficulties experienced by agricultural communities across different regions.

CONCLUSION

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The adoption of indigenous soil and water conservation techniques alongside climate-smart agriculture (CSA) remains imperative for addressing the multi-dimensional challenges posed by climate change to agricultural productivity and food security in Northern semi-arid region of Adamawa State Nigeria. This review has established that climate change continues to exacerbate vulnerabilities across environment, crop and livestock systems, with implications for livelihoods, nutrition, and rural stability. Despite the demonstrable benefits of CSA, such as improved soil fertility, water efficiency, and resilience to climate variability, uptake among smallholder farmers in the region remains uneven. Barriers such as insecure land tenure, limited access to inputs and finance, poor extension services, and gender-based inequalities persist. Overcoming these challenges requires a coordinated response that integrates technical, institutional, and socio-economic dimensions of agricultural adaptation and resilience.

It is necessary to put into place special policies and programmes to solve these difficulties. It is important to give legal land ownership and permanent land use rights to women and youth by implementing reforms in land tenure. Also, with drought insurance and other climate schemes, smallholders can use drought-resistant seed types, better irrigation and improve the quality of their soil. Also, more attention should be paid to training climate-smart agriculture extension agents, who have mobile technology, ready to counsel farmers in real time and warn them about potential risks. Finally, all CSA activities should include women-oriented sessions on agroforestry, managing pests and ways to protect livestock from climate risks. Lastly, state governments ought to make sure that every level of government has a CSA innovation hub for managing farmer training, sharing agricultural products and bringing together different partners. Importantly, these hubs can be used to set up partnerships with the private sector that aid with financing, green energy for watering and connecting market players. When these steps are carried out, CSA will strongly support climate resilience, poverty reduction in rural

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communities and changes that make agriculture more sustainable in Northeast Nigeria

RECOMMENDATION

Indigenous soil and water conservation techniques is an ancient method used by local communities to control the menace soil degradation and moisture retention to sustain and maintain agricultural lands.

It is recommended that while local communities in northern Adamawa State embark on their indigenous knowledge of soil and water conservation through the use of contouring , terracing and local afforestation etc, there is need for the State and the national government of Nigeria to integrate the modern measures with the indigenous techniques through construction of dams, drainages and water catchments, afforestation campaign projects etc, to reduce or combat the menace of climate change for agricultural and environmental sustainability. This will reduce the high rate of desert encroachment in Northern Adamawa state as it lies in the front line of desert encroachment.

Furthermore this research serves as a national and international call for the national governments, NGOs and all stakeholder with vested interest in agriculture and environmental sustainability control to seek ways through which they call assist in desert control.

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