

REVIEW ARTICLE

Climate change, wildlife and fisheries: A review of impact on Nigeria's food security

^{1,2}Munir K. A. Wahab & ^{*3}Adams O. Iyiola

Affiliation

¹Department of Wildlife and Ecotourism Management, College of Agriculture, Osun State University, Ejigbo, Osun State, Nigeria.

²Department of Forest Resources Management, College of Agriculture, Osun State University, Ejigbo, Osun State, Nigeria.

³Department of Fisheries and Aquatic Resources Management, College of Agriculture, Ejigbo campus, Osun State University, Ejigbo, Osun State, Nigeria.

*For Correspondence

Email: adams.iyiola@uniosun.edu.ng; **Tel:** (+234) 805 511 2448

Abstract

Climate change is a global phenomenon that affects all facets of life. In Nigeria, the rate of industrialization and urbanization has increased the concentration of greenhouse gases in the last decade. These changes are observable in temperatures and rainfall regimes which have affected food production in both terrestrial and aquatic ecosystems. Agriculture, which used to be the mainstay of the Nigerian economy, has reduced drastically and this may be caused by heat waves, irregular rainfall patterns, encroachment, and government policies leading to food shortage. The terrestrial environment has been faced with human and wildlife conflict issues on land usage and wildfires. Aquatic ecosystems are not left out of these effects as their surface area is shrinking and the water temperature has fluctuated irrationally thereby reducing aquatic biodiversity. The life processes in fish species and wildlife are impaired when the environmental conditions are unfavorable. In view of sustainability, economic, environmental and social strategies can be employed in the terrestrial environments. In the case of aquatic ecosystems, measures such as ecosystem approach to fisheries, forecasting of weather, good governance in fisheries related activities and reduction of conflicts between stakeholders in fisheries are suggested. To this end, this paper reviews the effects of climate change on both terrestrial (agricultural and wildlife) and aquatic ecosystems to eliminate hunger (Goal 2), preserving life underwater (Goal 14) and on land (Goal 15) through climate resilience (Goal 13) as elaborated by the United Nations Sustainable Development Goals.

Keywords: *Environment, climate change, sustainability*

Introduction

The contribution of forests towards sustainable livelihoods of organisms and food production cannot be over-emphasized (DFID, 2014); with more than 500 million people

worldwide depending on various food resources from the environment to supplement their vulnerability. Conversely, climate change is a major threat to the sustenance of ecosystems and biodiversity worldwide. On a good note, climate change has resulted in significant impacts on water, food security, health conditions most especially in African countries in which Nigeria is inclusive (Leddy, 2022). Nigeria had depended on agricultural production as the mainstay of the economy and produced various food and cash crops (Table 1). These crops were exported in the 1960s and early periods of the 1970s to countries like the United States, Canada, France, and Germany. The exploration of oil in the 1970s was given serious attention in respect to agricultural activities and the resultant effect was a decline in food production (Varella, 2021). The alteration in the aquatic ecosystem is not farfetched and the effects of climate change are easily observed in the reduction of water surface area (Iyiola et al., 2022a). Lake Chad is an example, and it has been reported to have reduced in surface area from 26,000 sq kilometers in 1963 to less than 1,500 sq kilometers in 2018, which is about 90% over the last 6 decades. This great reduction was attributed to prolonged drought and the impacts of climate change (UNEP, 2018).

Unexpectedly, the Sahel region and sub-Saharan region in Africa and Nigeria respectively have been predicted to suffer most from the impacts of climate change. This is so because the ecosystems in these areas are very fragile (Izah et al., 2022; Matemilola and Elegbede, 2017). Life on land and in water is also affected by these effects, they receive these impacts either directly or indirectly and their sustenance is important to the ecosystem and humans who depend on them for livelihood as explained by Sustainable Development Goals (SDG) 14 (Life under water) and 15 (Life on land). Hence, promoting the resilience of the natural ecosystems in coping with and adapting to the adverse effects of climate change is vital (Sixth Assessment Report, 2022).

Table 1: Production values of major food crops in Nigeria in the 1960's

Crops	The production area per thousand hectares	Total production (MT) ^a	Total production (MT)
Cowpea	2860	3,368,000	3,600,000 ^b
Cassava	3482	42,533,000	60,000,000 ^c
Maize	4149	7,677,000	12,000,000 ^d
Cotton	399	602,000	93,000 ^e
Soybeans	291	356,000	680,000 ^f
Groundnut	2785	3,799,000	2,508,000 ^g
Sorghum	4960	7,141,000	7,000,000 ^h
Millet	4364	5,171,000	2,000,000 ⁱ
Rice	2433	4,473,000	5,400,000 ^j

Source: Adapted from ^aSimonyan and Fasina (2013), ^bTridge (2023) ^cIkuemonisan *et al.*, (2020), ^dStatista (2020), ^eOlawumi (2022), ^fStatista (2022a), ^gIndustryARC (2021), ^hStatista (2022b), ⁱOlugbode (2023), ^jStatista (2022c)

Climate Change and Vulnerability of Nigeria

As Nigeria attempts to advance in environmental and socio-economic developments, it is faced with a major challenge of climate change as it poses a threat to the country's sustainable development goals. This is so because the economy of Nigeria is very weak, fragile, and low in resilience and adaptive capacity to the impacts of climate change. The economy is dependent on ecosystems and natural resources that is climate sensitive. For instance, agriculture is rain fed and highly vulnerable to extreme events such as floods and droughts which are climate induced. Nigeria was reported by a UK based company in its 2017 Climate Change Vulnerability Index (CCVI) to have a high risk and one of the very vulnerable countries in the world. It was estimated that by 2020, 2-11% of GDP will be lost and national developmental goals will be seriously affected (DFID, 2009). Beyond year 2067, Nigeria will experience 16% reduction in the GDP when a 3°C rise in global temperature occurs (Kompas *et al.*, 2018). To overcome these issues, adaptive and mitigation measures must be extensively adapted in order to reduce vulnerability (FGoN, 2017).

The emission of greenhouse gases by Nigeria is relatively low, because of the low rate of economic development. About 336 million tons of greenhouse gases was emitted in 2018 from sectors such as electricity, agriculture, industry, oil and gas, forestry, wastes, transport etc (NDC, 2021). Therefore, less than 1% global emissions are emitted and expected to increase at 7% per annum, due to the increased population demands and post COVID periods. More gases are projected to be released in the future and therefore important to intensify mitigation efforts and adaptation finance so as to achieve the 2050 zero emission target.

Achieving SDG's in an Era of Climate Change

There are critical elements that must be put into consideration in face of climate change and attainment of SDGs and Agenda 2030; these are promoting conservation measures and sustainable management and use of natural resources with the aim of reducing the climate extreme risks and resilience buildup. On the long run, the national ability of the economy to sustain human capital is threatened and the advances of Nigeria towards attainment of SDGs and national development are affected. Therefore, measures should be geared at ensuring ecosystem resilience through measures of mitigation and adaptation. To achieve this, Nigeria submitted the Nationally Determined Contributions (NDC) to the United Nations Climate Change Framework Convention on Climate Change (UNFCCC) as part of conscious effort to reduce global warming by 2°C as demanded by the Paris Agreement. The contributions included management of wastes, water resources and other natural solutions to activities, majorly focusing on the development in social and economic areas so the economy grows at 5% in lieu of climate resilience to impacts of climate change. The implementation of the NDC will offer Nigeria several opportunities in achieving SDGs and climate action. The key areas of NDC are:

- Stimulate changes in the economic drivers for a long term, such as industry, power, transport, agriculture and forests;
- Improving at local levels the scope to drive actions targeted at climate change reduction

- To strengthen the legislation on climate change and keep up the momentum at the national level
- Advocate and embed the low-emission climate resilient development plans on a long term and economic development and eradication of poverty in the country;
- Mobilize climate change financing and an enabling environment for investment in climate change and adaptation by the private sector.
- Strengthening efforts towards national adaptation
- Coordination and influencing policies on climate and its effects on major economy sectors.

These efforts will help attainment of SDGs and framework development and strategic plans in implementation of climate change adaptation in the context of sustainability and development.

Food Production in Nigeria

Agro-Information of Nigeria

Nigeria is a country with a vast area of arable land of 34 million hectares and can be categorized as an agricultural country despite its huge dependence on the oil industry for revenue generation. About 6.5 million hectares are cultivated for permanent crop production while 30.3 million hectares are for pastures (Table 2). About 70% of its inhabitants engage in subsistence agriculture which is usually carried out in small clusters and scattered around the country (Advameg, 2022). Agriculture contributes over 20% of Nigeria's Gross Domestic Product (GDP) and its contribution has decreased over the years. A huge gap of 24.7% decrease was observed between these years and has continued to decrease because of the poor economic development which has reduced the landmass for agricultural production and changes in climatic factors which is a principal factor for agriculture to thrive. Over the last decade, there has been an increase in GDP based on several government policies on food production (Trading Economics, 2020), and between July and September 2021, it contributed 31% to the total real GDP which has increased by 1% when compared with this period in 2019 (Varella, 2021).

Table 2: The Land use in Nigeria as at 2017

Land size	Percentage (%)	Quantity (Million Ha)
The total area of land	100	92.4
The land area	85.9	79.4
The water bodies	14.1	13.0
Land Use		
*Land for Agriculture	77.8	71.9
**Land for arable crops	30.5	28.2
***Land for permanent crop	2.7	2.5
Land for pasture	30.6	28.3
Forest and woodland	11.6	10.9
Flood plains	2.2	2
Other land	8.1	7.5

*Agricultural land – a land strictly for agriculture

** Arable land – a land capable of being used to grow crops

*** Permanent crop land – it is used for any planting seasons

Source: Adapted from Matemilola and Elegbede (2017)

Climate Change and Food Production Sector of Nigeria

The food sector consists of four sub-sectors namely crop production, livestock, fisheries, and forestry. In the 1980s, cattle herding, fisheries, poultry, and lumbering contributed over 2% to the GDP of the country. The United Nations Food and Agriculture Organization (1987) estimated the abundance of livestock and fish and a drastic reduction of fish to about 120,000 tons/year were reported in 1990 which was partly as a result of the water pollution in Ogoni land by oil companies.

The production of food in Nigeria is dependent on human, technological, and natural causes which may be change in temperature, rainfall, and other elements of weather. Food production processes are mostly altered when there are drastic changes in elements of weather (rainfall and temperature); the production process is affected both in quality and in quantity and if it persists, food shortage is imminent. The current climate change phenomenon has resulted from variability over the years, and it is a major concern in developing countries impacting negatively on their food production and delivery systems. The farmers in the country rely mostly on rain-fed agriculture and this makes them greatly affected when weather pattern becomes unpredictable and extreme weather occurrences like heat waves, flooding, and droughts (Ayanlade *et al.*, 2021).

There have been reports on the effects of climate change on agricultural productivity and its effects on local production (Lobell, 2008; FAO, 2018). The Nigeria Food Security Outlook of Famine Early Warning Systems Network reported that between July and October 2012, the country experienced flooding which resulted from heavy rainfall and lead to the overflowing of dams (Serdeczny *et al.*, 2017). Several farms were destroyed and nearly 2.8 million people were displaced from their native lands. It has been estimated from suggestions that there will be a serious threat of meeting global food needs within the next 50 years (BRNCC, 2008; Sixth Assessment Report, 2021). These predicted changes have been reported to cause a major shift in food production, temperature, and rainfall in some areas and flooding will wipe off various farmlands (Ipinmoroti *et al.*, 2022; Rahman, 2014). By 2100, it is estimated that Nigeria and West African countries are likely to suffer a loss of up to 4% GDP in agricultural production due to the changing climatic system. This is based on the assumption that soil erosion and rain-fed agriculture can decline up to 50% yield in agriculture between 2000 - 2020 due to climatic changes (Sixth Assessment Report, 2021). It was discovered from reports that food production has been negatively affected by climate change and there is a great need to mitigate the effects of climate change (Iyiola *et al.*, 2022bc; Idumah, 2020). The annual trend of food production, mean rainfall, and temperature in Nigeria from 1975 - 2010 is presented in Table 3 (Matemilola and Elegbede, 2017). A sharp rise in 1981 and 2001, a drop in 1984 and 1987 which can be attributed to the change in climate and government policies which improved agricultural production as observed from 2001 to 2010.

Table 3: Mean rainfall, temperature and agricultural production, in Nigeria (1895 - 2010)

Year	Mean rainfall (mm)	Average Temperature (°C)	Production (million tonnes)
1975	1460	22	50000
1977	1260	22.5	50000
1979	1350	23	50000
1981	1200	24	60000
1983	1150	26	63000
1985	1340	27	72000
1987	980	28	60000
1989	1350	27	65000
1991	1600	26	70000
1993	970	26	80000
1995	1100	26.5	90000
1997	1210	25.6	100000
1999	1500	26.3	106000
2001	1210	26	120000
2003	1210	26.1	180000
2005	1450	26	220000
2007	1390	23	270000
2009	1450	26	300000

Source: Adapted from Matemilola and Elegbede (2017).

Importation and Exportation of Agricultural Produce

Presently, Nigeria is the largest producer of cassava in the world and an importer of rice and it is important to boost the production of rice domestically and enhance the competitiveness of cassava in the international market (FAO, 2021). Food importation in Nigeria began when local production couldn't meet up the demand of the increasing population. The population is increasing at a geometric rate and forecasts have been reported to reach over 400 million people by the year 2050, and food demand will also increase significantly. This scenario can lead to severe food insecurity which has been increasing over the years and negates the aim of SDG 2 (Zero Hunger). It was reported that between years 2017 and 2019, about 9% of people went entirely without food which was due to lack of money and other resources and food per unit intake is presently reducing year by year with malnourished people on the increase (Table 4) (Varella, 2021). Nigeria lost its top ranking in terms of cash and food crop exports and the total amount from food and agriculture imports was valued at approximately \$1.6 billion /year. It has been estimated that 10 billion in annual export opportunities have been lost from groundnuts, cocoa, palm oil, and cotton due to a reduction in their production (FAO, 2021). For a facelift, Nigeria has reviewed policies to revitalize the agricultural sector, coupled with the increasing effects of climate change on food production to attain self-sufficiency.

Table 4: Number of malnourished people (millions) around the world (2000 – 2016)

Regions/Year	2000-02	2005-07	2010-12	2014-16
The World	929.6	942.3	820.7	794.6
The developed regions of the world	21.2	15.4	15.7	14.7
The developing regions of the world	908.4	926.9	805.0	779.9
African Continent	210.2	213.0	218.5	232.5
Asian Continent	636.5	665.5	546.9	511.7
Latin American regions and the Caribbean Islands	60.4	47.1	38.3	34.3
The Oceania region	1.3	1.3	1.3	1.4

Source: Adapted from Matemilola and Elegbede (2017)

Consequences of Climate Change on Terrestrial Ecosystems

Human-wildlife-livestock conflicts in land use

Conflict situations have increased from encroachment by human settlements and their activities over the last decade and this has been more prominent in the conflict resolution between the area sharing between humans and wildlife (Karimullah *et al.*, 2022). In developing communities, there is intense competition over wildlife resources and inhabitants in these communities are vulnerable to economic losses. Drought can reduce resource productivity with human-wildlife conflicts and it can be observed that these conflicts will continue shortly based on human population growth, climate change, and increasing trends in demand. To reduce human-wildlife conflicts, interventions are required at various levels from personal to institutional. Animals raised at home must be protected by building fences and other safety measures around them. The capacity of communities to coexist with wildlife species has significantly decreased as a result of increasing pressure on resources that are limited. Wildlife species in areas with warmer temperatures compete for limited food and water because the plant vegetation and productivity are reduced (Williamson *et al.*, 2021).

Wildfires

Wildfires are influenced basically by temperature, atmospheric moisture, lightning, winds, and drought and it has increased in frequency and intensity due to climate change (Williamson *et al.*, 2021). It has been reported that fires can consume millions of hectares of forests in the world annually thereby leading to losses in biodiversity, both in humans and animals (FAO, 2005). It was reported that an average of 380 million ha/year of areas burnt by wildfires between 1960 – 2000 were due to lightning, human ignition through burning of lands for agriculture, and accidental fires. Fires can affect the hydrological cycle and the dynamics of circulation (Pooley *et al.*, 2021). Biodiversity is also affected and can be severe in some cases; sessile animals are more prone to mortality from flames. Wildfires may be beneficial, harmful, or have no effect on individuals and can be seen as a key driver of ecosystems. Therefore, there is a need to improve our knowledge of fire regimes and land use economics.

Climate Change in Nigerian Aquatic Ecosystems

The activities around the Niger Delta coastline of Nigeria have made this area susceptible to the effects of climate change. Industrialization and various gas flaring activities which release various toxic fumes into the atmosphere increase the concentration of greenhouse gases by the addition of carbon. Nigeria has a coastline of 800 km and most of the states around the coastline are involved in gas flaring (Mustapha, 2013). This shows the extent and vulnerability of the country to which gas flaring operations can affect the climatic condition and it is evident in the frequency of rainfall, flooding, temperature rise, and drying off of rivers which are observed in the country today (NiMET, 2019). The northern parts of the country also experience these effects such as shrinking and in extreme cases drying of water bodies and low rainfall. The effects of increased temperature are more pronounced in the Northern regions while increased rainfall is prominent in the Southern regions due to its location in the coastal areas (Leddy, 2020).

Effects of climate change on artisanal fisheries in Nigeria

The artisanal fisheries sector which occurs within the coastline of Nigeria have been reported to contribute 85% of the total fish production in the country (FAO, 2018). Climate change affects the assemblage, abundance, and distribution of fisheries in this sector thereby leading to low productivity, the abundance of juvenile fish, reduction in adult fish, and low catch per unit effort by fisherman. In cases where the fisherman cannot adapt to the current changes resulting from climate change, halt and abandonment of fishing operations are most likely to occur. This will in the long run reduce the diversity of livelihood and increase the level of poverty in the artisanal fishing communities. Climate change can affect the productivity of a lake, making a eutrophic lake turn mesotrophic or oligotrophic or vice versa. In Nigeria, the alteration in productivity of a system can affect the fisheries to an extent of losing about 50% of fish populations and over 20% of fish species can become extinct if the temperature of aquatic ecosystems warms up from its current state of 0.5 – 2°C to about 5°C.

Effects of climate change on fish

Fish are cold-blooded and are very sensitive to any slight change in the temperature of the aquatic ecosystem. The increased gas emission in Africa has been reported to warm the surface water temperatures by 0.2 to 2°C and any increase in temperature above the limit tolerable by fish has negative implications on fish (Awuchi *et al.*, 2022). The major effect is on oxygen concentration which decreases with an increase in temperature thereby inhibiting oxygen supply to the fish tissues (Figure 1). Other effects are:

- a. The time and frequency of spawning activities in fish are also affected by climate change because this activity is a major function of temperature and food availability.
- b. The food, feeding habits, and primary production can also be affected and prolonged effects can lead to a shift in the food web relationship of fish species in aquatic systems.
- c. Fishes may tend to migrate from their endemic environments due to the effects of global warming. This is so because the increased temperature can disrupt the life

processes of fish species and plankton abundance which is a principal source of food in aquatic ecosystems (Harvell *et al.*, 2002).

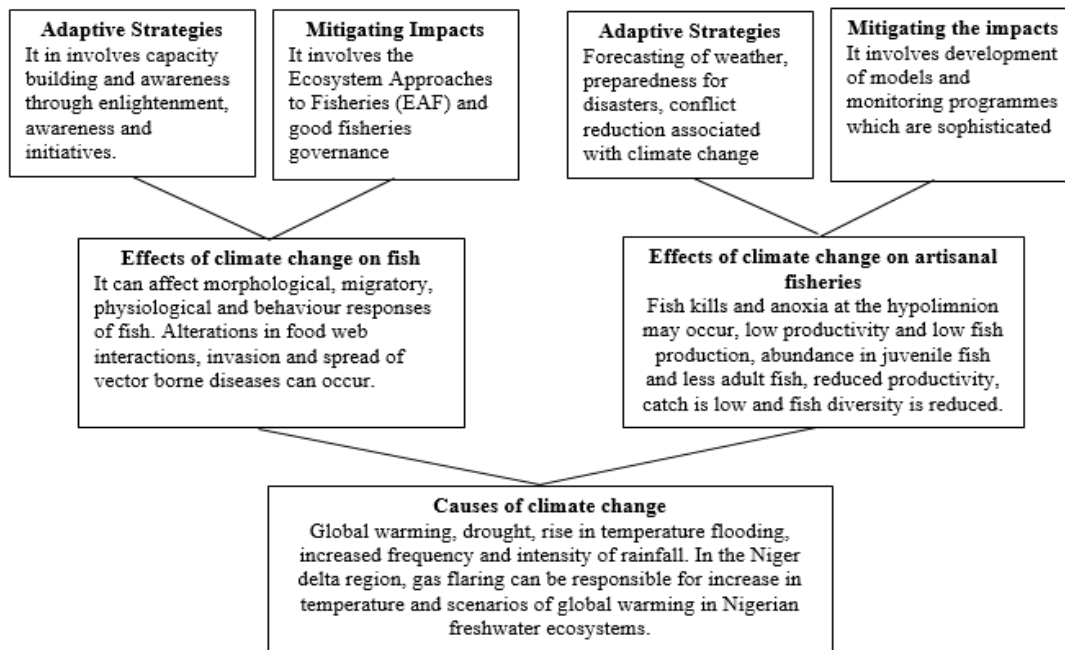


Figure 1: Impacts of climate change on fish and artisanal fisheries

Source: Adapted from Mustapha (2013)

Strategies towards Sustainability in Terrestrial and Aquatic Ecosystems

Climate mitigation and adaptation are the two measures employed towards building climate resilience in food production as explained by SDG- 13 (Climate Action) (Figure 2). Mitigation involves efforts to reduce greenhouse gases through new technologies, renewable energies, or changing management practices while adaptation involves adjusting to the current change in climatic effects (UNEP, 2021).

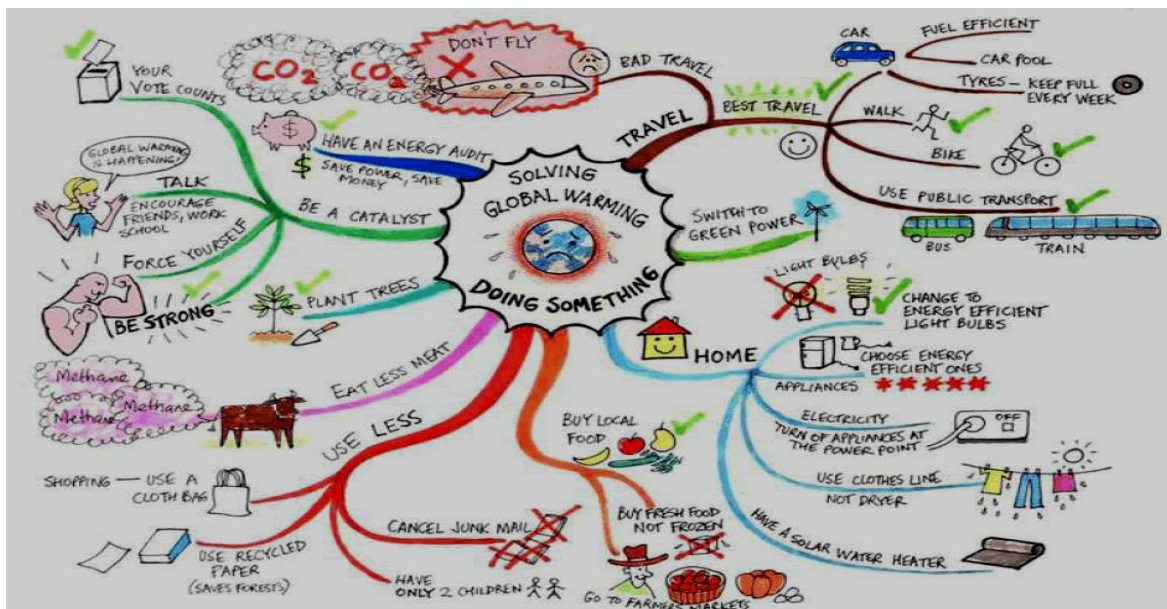


Figure 2: Adaptive strategies and mitigation of climate change on the environment

Source: Mustapha (2013)

Sustainability in agricultural production

The components of accessibility, availability, stability and utilization must be put into consideration for sustainable agricultural production. All these components will ensure that the food is available and affordable for consumers. With the abundant fertile land and favorable climate, Nigeria can attain sufficiency by improving agricultural productivity, building the capacity of farmers, good governance, and accessibility to market, science and technology improvement, etc. (Ilaboya *et al.*, 2018). The following strategies can be employed for increased agricultural production:

- Economic strategies: It involves the increased production by promoting decent employment in the sector, promoting the non-farming economy, and promotion of credit facilities and incentives for agricultural production in the rural areas (Oni *et al.*, 2009; Reddy *et al.*, 2010).
- Environmental Strategies: It involves increased production by regulating the use of agrochemicals and fertilizers, management of industrial effluents (Engel, 2018; Elliott, 2022).
- Social strategies: It involves the increased production through networking and farmers' cooperation, provision of infrastructure, and education (Oni *et al.* 2009; Reddy *et al.*, 2010).
- Technological strategies: it involves the increased production through crop rotation, crop diversification, increased mechanized farming, and biotechnology (Ojo and Adebayo, 2012; Engel, 2018).

Agriculture, forests and other land use (AFOLU)

In Nigeria, the AFLOU sector contributes majorly to climate change and its impacts significantly. In terms of GDP, Agriculture contributes 24% and reduction of emissions from this sector is important in the long-term aim of reducing green-house gases and low carbon development in Nigeria. Human activities such as poor management of livestock, indiscriminate fertilizer use and deforestation contribute a significant amount of greenhouse gases, most especially methane, nitrous oxide and carbon-dioxide. Emissions from AFLOU are about 60% of net emissions in Nigeria and activities such as agro-forestry can increase the sink of carbon of the sector. Therefore, this sector can go a long way in greenhouse gases reduction, agricultural sequestration enhancement and the use of climate smart technologies. The Agenda 2020 focuses in improved productivity in agriculture though enhancement of yield per hectare, post harvest loss reduction, increased processing and integration of processes to feed the geometric population growth. When green house gases are reduced, Nigeria can meaningfully and practically contribute to globally, nationally and locally while supporting farmers to adapt to the impacts of climate change and human-environment relationship.

Deforestation is a major challenge, and it is increasing at a fast rate as a result of rapid population growth which has increased the demand of products, to the extent that only less than 10% of the forest cover is left presently. In this sector, it is expected that the

country will create practices and technologies for agricultural adaptation, water management, fodders that are low in methane for livestock, farming with low-inputs, develop methodologies in soil carbon storage and management. It is essential that the government scale-up the labeling and certification of agricultural produce that are low-carbon, or dairy products that are produced with minimal inputs.

Sustainability of aquatic ecosystems

Fisheries are affected by climate change both in the short-run (increased happenings of events) and long-run (reduced production of fish) and the responses of the aquatic ecosystems can vary based on the depth, size, and trophic status. Effective strategies of mitigation and adaptation must rely on conditions that are associated with human socio-economic needs and pressure on fisheries. The following are measures of climate resilience to be encouraged and advocated:

1. Ecosystem Approach to Fisheries (EAF)
2. Good governance in fisheries-related activities
3. Forecasting of weather
4. The reduction of conflict between stakeholders in fisheries activities.
5. Greenhouse gases should be reduced, stored, or absorbed by carbon sinks.

Freshwater and coastal wetlands

The entire water resources are estimated at 215 billion m³ surface water and 87 billion m³ of groundwater, which differ spatially across the country. The coastline is about 853 km which extends about 15km inland, 150km in Niger Delta and 25km east of Niger Delta. The country is faced with issues regarding sustainable management of aquatic resources for industrial, agricultural and domestic purposes. The annual total water demand is expected to increase in 2030 to 16.58 billion m³/year from the current value of 5.93 billion m³. The projected increase in air temperature induced from global warming can reduce the total rainfall in the country by 20%, ground water recharge by 20% and reduction in ground water level by 5-20m as reported by Nigeria's Water Master Plan (2014). The supply of water for fisheries will be affected, and other health impacts and threats to biodiversity will be eminent. There is therefore need for a holistic and coordinated approach to the predicted water crisis; as there is need for a global effort to reduce the global temperature below 2°C by 2030 as recommended by the Paris Agreement and for policies for national implementation.

The provision and treatment of water requires abundant energy in which several emissions are released into the atmosphere. It is therefore suggested that renewable energy powered sources be used so as to reduce emissions and contribute to the goal of climate change mitigation. Similarly, water extraction, reticulation and treatment can reduce carbon emissions. For instance, the biogeochemical cycle and reduction in hydrostatic pressure during drawdown can stimulate ebullition, which can decrease the methane levels that may be oxidized to carbon dioxide by microbes. The incidental oil spills which cause burning rivers and indiscriminate waste disposals can elevate the carbon pollutants in water bodies.

Conclusion

Climate change has a great impact on the Nigerian ecosystem and long-term solutions to this phenomenon must address building a climate-resilient society. Rainfall and temperature were observed as the two principal interplaying factors in Nigeria governing the condition of the environment. Agricultural production had reduced drastically as a result of limited rainfall which affects plant sprouting and dries off resulting from extreme waves. The natural ecosystem of wildlife species has also been destroyed as a result of wildfires and drought and the shrinking of aquatic habitats thereby reducing fish abundance. To alleviate these effects, the government should provide an enabling environment for agriculture to thrive and capacity building for the farmers. Adoption of modern technologies for improvement in agricultural productivity will help farmers in Nigeria increase their domestic production. Adequate funding is also required for the National Adaptation and Mitigation Programme of Action on Climate Change (NAMPACC) which was established to coordinate research and climate resilience.

Conflict of Interests

The authors declare no conflict of interest exists.

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