Chapter 16
Climate Change Impact on Nigerian Ecology, Vegetation/Forest, Carbon and Biomass Management

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Abstract Nigeria is currently facing diverse environmental glitches from climate change which are detrimental to the vegetation ecology and ecosystem functioning. Hence, exploring the responses of vegetation to climate change is a necessity to promote management techniques towards their protection and sustenance. This study assessed the impacts of climate change on Nigerian ecology, vegetation as well as carbon and biomass management. Climate change in different Nigerian zones results in variabilities in temperature and rainfall, thereby affecting Nigerian ecology/vegetation. High rainfall in the southern parts of Nigeria causes flooding of vegetation and forests, while high temperature and heat in the Northern parts of Nigeria result in wildfires, especially in savanna vegetation. Flooding issues from sea level rise in the south-south regions, lead to poor regeneration of vegetation, decline in vegetation cover, extinction of plant species and low forest productivity. Fire outbreaks in vegetation due to high temperature, especially in the northern zones, result in land exposure to extreme winds, erosion and nutrient loss. Due to desertification, large area of cropland and vegetation, especially in the Sahel region are lost. Fluctuations in rainfall patterns cause changes in soil moisture regimes which directly hamper vegetation growth. In northern regions of Nigeria, extreme temperature limits soil moisture thereby reducing carbon fixation and inputs in biomass. Drought in northern states of Nigeria causes a decline in vegetation and soil carbon stocks. From the foregoing, there is a need for the adoption of appropriate management techniques towards the management, protection and sustenance of vegetation amidst this environmental crisis.

Keywords Climate change · Vegetation · Biomass · Carbon storage · Flooding · Fire outbreaks · Drought · Desertification

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Introduction

Irrefutable scientific justifications exist concerning the continuous warming of the earth and changing of the climate as a result of diverse anthropogenic activities. These two scenarios have been reported to be associated with devastating consequences on humans, animals, plants and environment as a whole (IPCC 2014). These consequences are felt globally, particularly in the tropical regions (Williams et al. 2018) where several biological and physical changes in the environment have been elicited (IPCC 2014). It is worth noting that, even though countries with low and middle income, especially Africa, are facing higher vulnerability to climate change, their inclination to enhance resilience in these countries is low (ND-GAIN 2021).

Nigeria is one such country in Africa plagued with a high prevalence of climate change. As reported by World Bank (2019), Nigeria ranks amongst the first ten countries in Africa with high susceptibility to climate change effects, with approximately 6% of total land mass exposed to extremities in weather conditions. Various incidences stemming from climate change have been documented in Nigeria ranging from flooding, drought, deforestation, irregularity in patterns of rainfall and encroachment by desert (Audu et al. 2013; Onyekuru and Marchant 2016; Olaniyi et al. 2019). As reported by Jibrillah et al. (2019), Olaniyi et al. (2019) and Giri et al. (2021), these have impacted negatively on the health of humans, land cover and use, as well as the livelihood of the country.

The effects of climate change on Nigerian ecology, vegetation, carbon and biomass is one topical issue that cannot be overlooked and underestimated. The climate of Nigeria over the years has faced variabilities in rainfall and temperature patterns and these have posed impacts that are detrimental to the vegetation ecology and ecosystem functioning. For instance, the increased intensities and durations of rainfall have resulted in runoff and consistent flooding in various places (Enete 2014). In the southern parts of Nigeria, sea level rise is expected due to increased precipitation which further exacerbates issues relating to coastal land submersion and flooding (Ebele and Emodi 2016; Akande et al. 2017). The drought in the northern parts of Nigeria has continued to be a constant scenario due to low or absence of rainfall and temperature rise (Amanchukwu et al. 2015). This causes water bodies to dry up and be at risk of disappearing (Elisha et al. 2017; Dioha and Emodi 2018).

These impacts posed by fluctuations in temperature and rainfall patterns also affect the vegetation ecology since biomass management, cycling and availability of nutrients, microbial and physiological activities are dependent on them. For instance, slight changes in rainfall pattern may be consequential on moisture availability and can trigger erosion as well as increased acidity and salinity levels in the soil. Fluctuation in temperature and rainfall may also cause disturbances such as high winds, floods, wildfires, landslides, avalanches, etc. Since these factors are connected to the growth and productivity of vegetation, they can cause modifications in the composition and structure of vegetation in the long run. Within this purview, this review aims at examining the impacts of climate change on Nigerian ecology, vegetation/forest, carbon and biomass management so as to understand the dynamism of vegetation in response to changes in climate as this will help in better and future management of the ecosystems.

Impacts of Climate Change

Impacts on Nigerian Ecology

Nigeria as a country has a land mass of 923, 768 km^2 and lies between longitudes 2° 2′ and 14° 30′ E and latitudes 4° 1′ and 13° 9′ N. Nigeria consists of six ecological regions namely; rainforest, mangrove swamp, Guinea savanna, Derived savanna, Sahel savanna and Sudan savannah (Fig. 16.1). In the rainforest, mangrove swamps and some areas of the derived savanna, the rainfall pattern is bimodal, while in the Sahel, Sudan and Guinea savannas, rainfall distribution is unimodal. Rainfall ranges from 500 mm (Sahel savanna) to approximately 3000 mm (mangrove swamp) annually. In the past years, the ecology of Nigeria has faced several alterations due to changes in climate as a function of anthropogenic upheavals. This is evidenced in the form of temperature and rainfall variabilities.

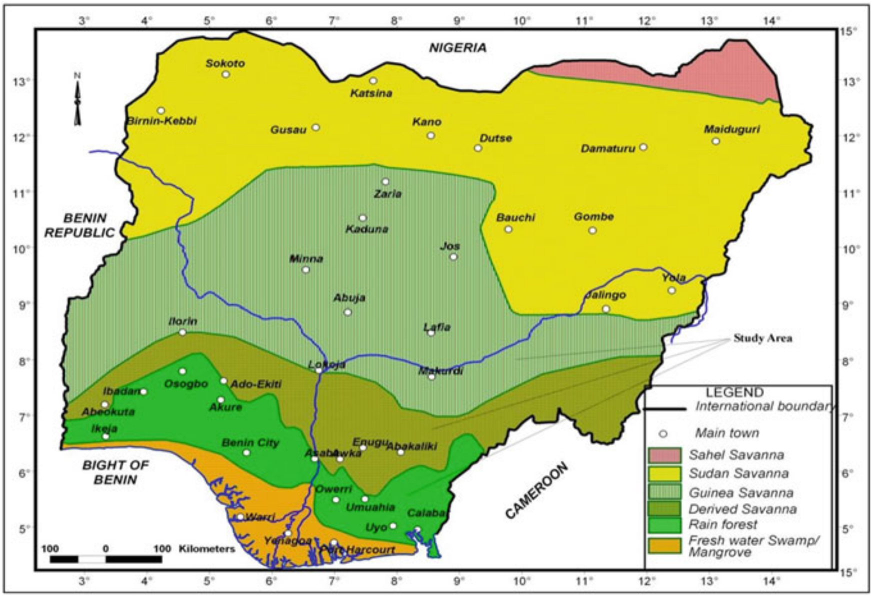

Fig. 16.1 Map of Nigeria showing the ecological zones. *Source* Odebode and Eniola (2019)

An increase in temperature and a decrease in rainfall across the globe are the highest impacts posed by climate change (Hengeveld et al. 2002). Temperature elevation has resulted in the melting of glaciers and ice caps. Melting of the ice caps and glaciers in temperate regions, rainfall increase in some regions of the world and ocean expansion resulting from the warming of water have led to a rise in sea level, erosion and coastal flooding (Hengeveld et al. 2002). Globally, the current rise in sea level is estimated at 0.2 m. This value according to Hengeveld and Whitewood (2005), is predicted to upsurge by 1 m in 2100. This implies that the current estimate of rise in sea level (0.2 m) has flooded about 3400 km^2 of Nigerian coastal areas, and if the projected 1 m rise in sea level is attained in 2100, about 18, 400 km^2 of Nigerian coastal areas will be faced with flooding issues (NEST 2003).

Coastal regions in Nigeria with <10 m above sea level such as Lagos, Calabar, Forcados, Warri, Bonny and Port Harcourt, would face threats arising from sea level rise (Ibrahim et al. 2018). The intrusion of the sea as a result of rise in sea level enhances the infiltration of salt water into freshwater which destroys coastal wetlands, beaches and mangroves. The flooding and erosion of Nigerian coastal areas pose serious environmental glitches in areas like Akwa Ibom, Delta, Lagos, Cross River, Bayelsa and Rivers States. Abu (2007) reported that as a result of rise in sea level, nearly 14 million inhabitants were displaced in Nigerian coastal regions. In Sokoto and Jigawa States 2 million and 40, 000 inhabitants were displaced resulting from flood incidence that took place in the year 2010, respectively, (Elisha et al. 2017). The flood incidence also led to the closure of Usman Dan Fodio University in Sokoto for a period of time due to the collapse of their bridge (Elisha et al. 2017). In Lagos, approximately 689 inhabitants were displaced in Ajegunle due to flood issues (Yekken 2011). BNRCC (2011) also reported that heavy rains which took place in Ikot Ibom Itam, Akwa Ibom State, caused the disappearance of approximately 4 streams and subjected many houses and landscapes to flooding and erosion, respectively.

Several transitions from Sudan to Sahel savanna and Guinea to Sudan savanna are noticeable at high intensities in the Northern parts of Nigeria (Gadzama and Ayuba 2016). A large expansion of the Sahara desert is observed trying to take over and displace the Sahel region. This expansion is estimated at 1–10 km annually (Yaqub 2007). Arising from this, the Northern part of the Nigerian States such as Katsina, Borno, Yobe, Jigawa and Sokoto are threatened severely by sand dunes (Fig. 16.2) typifying encroachment of desert (Odjugo and Ikhuoria 2003). These sand dunes in Northern Nigeria have displaced many agricultural lands leading to low production of crops. This has elicited a mass exodus of people to settlements that are not under the susceptibility of desertification. This emigration of people has often culminated in clashes between the emigrants and the inhabitants (Yaqub 2007). It also results in intense urbanization issues (Akonga 2001). These sand dunes have also threatened the main road leading to Damasak town of Mobbar Local Government Area of Borno State, Nigeria (BNRCC 2012).

Changes in climate also cause an alteration in the water cycle (Mcquire et al. 2002). Irregular rainfall patterns, rainfall decrease and temperature increase, particularly in Africa, will recharge groundwater sources (lakes, wells, rivers and springs) minimally

Fig. 16.2 Encroachment of sand dunes in Yusufari Local Government Area, Yobe State, Nigeria. *Source* Abdullahi (2022)

and this will bring forth scarcity of water and other related problems. In Nigeria, water resources like rivers have been lost due to drying up (Yugunda 2002). The southern region of Lake Chad which occupies some part of Northeastern region of Nigeria (Yobe and Borno States), also dried up due to climate change (Beyioku 2016). In the last 60 years, about 90% of Lake Chad has undergone shrinking after the long-lasting drought incidence in the early 1970s (Beyioku 2016). In 1963, the total surface area of the Chad was over 40, 000 km^2, but presently, it has <1300 km^2 (Beyioku 2016). This puts the Chad together with other northern rivers in Nigeria at the risk of disappearing. The scarcity of water arising from drought issues poses severe tension and threat to the left-over limited water resources, as everybody is dependent on them. This condition triggers the contamination and pollution of such water bodies culminating in the transmission of waterborne related diseases such as typhoid fever, cholera, river blindness and infection by guinea worm (BNRCC 2011).

Climate change also brings about a high spread of pathogenic insects in areas susceptible to this environmental menace. For instance, high rainfall in coastal and southern regions of Nigeria will bring about a high prevalence of mosquito and malaria sickness in the region. Also, increasing temperature will result in massive mosquito migration from the northern regions of Nigeria to a favourable clime.

Impacts on Forestry and Vegetation

Vegetation and forests play pivotal roles in our ecosystems such as modification of climate, protection of soil, primary productivity, and regulation of flood (Adegboyega et al. 2016). In Nigeria, these resources provide numerous benefits to man ranging from being sources of food, fuel wood, raw materials and shelter (Adegboyega et al. 2016). However, in the wake of climate change, forests and vegetation are constantly pressurized and threatened in Nigeria. As a result of high winds and erosion, produce from forests such as timber, cane and wood are on the decline in many forest ecosystems across the country, especially in the southern regions (Ogbuabor and Egwuchukwu 2017). This not only leads to a reduction in the nation's income, but also results in a high cost of furniture and materials for building (Ogbuabor and Egwuchukwu 2017).

Change in climate has caused many native tropical forests housing diverse flora and fauna species to be lost in Nigeria (Federal Ministry of Environment 2014). For example, Beyioku (2016) reported that forests surrounding Oyo have been totally decimated to grassland due to climate change issues. Constant water logging and flooding incidences have led to tree species mortality, making planting trees and regeneration of forests an uphill task (Ammer 2019). The persistent rise in sea level especially in the south-south region sharing proximity with the ocean, has resulted in land cover deterioration, degradation of mangroves, biodiversity loss, destruction of aquifers and catchment making water availability a serious problem in the region. The rise in sea level around coastal regions like in the Niger Delta, leads to the intrusion of salt water into plant communities growing in low-lying niches which can damage plants or vegetation with low tolerance to salinity, causing a wide-scale destruction of wetlands (Sayne 2011). This introduction of saline water in vegetation that is low lying, affects and alters the chemical and physical properties of the soil which, in turn, inhibit vegetation growth by preventing the root of plants from absorbing soil water and lowering the amount of available water to plants (Audu et al. 2013). This enhances moisture stress in vegetation.

Flooding events can be very detrimental to terrestrial and aquatic plants (Fig. 16.3). Anoxic conditions in soil caused by flooding around coastal areas in Nigeria can destroy the roots of plants and other important soil microorganisms. Flooding and runoff of storm due to the rise in sea level water can introduce several impurities into aquatic ecosystems. This makes the water to lose its clarity, making it prejudicial to aquatic plants as decreased availability of sunlight hinders their ability to photosynthesize.

In the northern parts of Nigeria dominated by the savanna biome, a slight change or rainfall reduction can affect the ecosystem through habitat degradation. According to the Federal Ministry of Environment (2014), desertification together with excessive exploitation of marginal lands in the northern regions has resulted in severe environmental degradation. Trees are facing damages arising from the wildfires which are pronounced in the northern and arid parts of Nigeria (Federal Ministry of Environment 2014). Low precipitation and high temperature culminating in issues of drought in the north, negatively affect vegetation cover and its productivity (Ammer 2019; Jibrilah et al. 2019). High temperature in northern states has turned surviving plants/vegetation into scrubs due to its negative influence on vegetation physiology, transpiration, translocation of nutrients, tropism and respiration (Audu

Fig. 16.3 Destruction of farmlands and crops due to flooding incidences. *Source* Hansen (2020)

et al. 2013). For example, under high temperature, there is a rapid loss of water from plants/vegetation by transpiration resulting in high water demand by plants. This causes imbalances in vegetation with regard to water requirements.

Odjugo and Ikhuoria (2003) had reported that high temperature and delayed rainfall in Northern areas like Katsina, Kano and Sokoto, led to high evapotranspiration rates in vegetation which culminated in wilting and subsequent death of plant species. High temperatures wither and weaken vegetation, exacerbating poor photosynthetic and productivity rates. For instance, Edem et al. (2016) reported a low yield of maize due to early cessation and delay in rainfall in the Gassol Local Government Area of Taraba State, Nigeria. The production of rice in Niger State, Nigeria, was reported to have reduced by 17% due to an increase in relative humidity by 1%, while an increase in temperature by 1%, resulted in an increase in 52.3% production of rice (Ayinde et al. 2013). A one percent temperature increase significantly reduced the yield of groundnut in Nigeria.

In the south-south regions of Nigeria, especially the Niger Delta where high rainfall is predominant, vegetation is struggling due to variabilities in rainfall patterns (Okon et al. 2018). In the northern parts of Nigeria dominated by grasslands, intense heat and high temperature are seriously affecting the vegetation of the place due to frequent wildfires (Fig. 16.4). Okon et al. (2018). Also, constant drought and high temperature in the Northern states (Bauchi, Gombe, Adamawa, Borno, Katsina, Jigawa, Yobe, Kebbi, Kano, Zamfara and Sokoto) have led to desertification, whereas encroachment by deserts (Fig. 16.5) has led to the loss of agricultural and grazing terrains to sand dunes which hamper vegetation growth greatly. As reported by Federal Ministry of Environment (2012), areas in these regions that were formerly occupied by bushes, grasses and scattered trees have undergone a transition to sand-like terrains. For example, in Tosha town of Yobe State, Nigeria, the yields of farmlands in uplands have been on a gradual decrease in the past years due to the emergence and formation of sand dunes (Gadzama and Ayuba 2016). Farmlands with proximity to Sansan local Government Area are also being threatened by these sand dunes (Gadzama and Ayuba 2016). Onah et al. (2016) also asserted that the loss of grazing terrains due to desertification in northern parts of Nigeria has forced pastoral nomads to migrate and encroach the southern regions for pasture, causing the destruction of farmlands. The desert which formerly occupied around 35% of the land mass of Nigeria, is progressing to about 0.6 km annually with deforestation rates being placed at 3.5% yearly (Yugunda 2002). This has caused an advancement in the desert belt from Kano, Kebbi and Maiduguri to regions like Jos, New Bussa, Sheleng and Kaduna, with savannas interfacing between the deserts and forest ecosystems along Kogi, Oyo, Benue and Osun States (Ibrahim et al. 2018). Aliyu (2013) reported that about 50% of lands used for agricultural activities in Gudu Local Government Area of Sokoto State was lost as a result of desertification and intrusion by sand dunes. Ragatoa et al. (2019) also reported that around 30 ha of land used for cropping were lost annually as a result of desertification in the Sahel areas of Nigeria. This low productivity of plants, on the other hand, affects wildlife sustainability since they are dependent on plants for food. Hence, this brings about displacement and a decline in wildlife populations.

Alteration of vegetation physiognomy is also prominent in Nigeria emerging from climate change. For instance, the persistence of temperature increases in the northern regions, causes changes in moisture availability in the soil, hence making vegetation shift as a response mechanism. Trees are compelled to move to altitudes that are higher for suitable and convivial climates or habitats for their existence and survival.

Fig. 16.4 Wildfire outbreak in Gulani Local Government, Yobe State, Nigeria destroying vegetation. *Source* Usman (2021)

Fig. 16.5 Degradation of farmlands and vegetation in Northern Nigeria due to desertification. *Source* The New Humanitarian (2017)

In Nigeria, Odujugo (2010) reported a shift in crops (guinea corn) that were predominant and grown in the extreme north of Nigeria to the guinea savanna as a result of delay or low rainfall and early rain cessation. Likewise, in southern regions of Zamfara, millet steadily replaced guinea corn (Odujugo 2010). Climate change has caused so many crops which preferred the Sahelo–Sudan niches for their growth to migrate to the guinea savanna, with those of the guinea savanna moving to occupy the northern forest zones (Odujugo 2010).

Impacts on Biomass and Carbon Management

The biomass of forests serves as important reservoirs for carbon by constantly exchanging CO_2 with the atmosphere, resulting from anthropogenic and natural processes. They have high carbon sequestration and storage in comparison to other ecosystems (Popo-Ola et al. 2012). They serve as a "braking mechanism", especially in the era of climate change. This is because, they act as sinks for carbon, sequestering atmospheric carbon and storing them in various pools like litter (leaves, roots, stems) soil and plants. However, the sequestration and storage of carbon by forests differ depending on the age of the forest. According to Binyam (2012), a young growing forest can sequester tonnes of carbon which is proportional to its biomass growth. An old forest, even when it is devoid of net growth, can serve as a pool by storing a large amount of carbon in its biomass (Binyam 2012). Hence, less amount of carbon is held in young growing forests having high carbon sequestration ability, while more carbon is stored in old forests with low carbon sequestration abilities

(Binyam 2012). Globally, IPCC (2000) reported that plants and soil store 19 and 81% of carbon in the biosphere. In all tropical, boreal and temperate forests, about 31.3 and 69% of carbon is stored in biomass and soils, respectively (IPCC 2000). About 50% of carbon is stored in soils and biomass of tropical forests (IPCC 2000). One of the principal greenhouse gases contributing to global warming and climate change is CO_2. During photosynthesis, vegetation helps greatly in the removal of this gas from the atmosphere and stores them in their various biomass. Resulting climate change, many forested areas have been lost permanently culminating in a decline in the earth's ability to store carbon.

The cycling of carbon in forests is greatly influenced by sets of climatic variables and CO_2 concentrations in the atmosphere. A slight change in these variables will certainly pose severe impacts on forests, especially in the area of carbon storage and management. Deforestation, natural perturbations and changes in rainfall and temperature patterns can be very critical in the development of forest stands (Keeton et al. 2007). This, according to McNulty (2002) and Zuidema et al. (2013), also affects the accumulation and storage of carbon. The impacts of climate change on vegetation or forest carbon storage and biomass may be positive and negative, although the negatives outweigh the positives. Positively, changes in climate have been reported to enhance water use efficiency, Net Primary Productivity and growth of forests under high CO_2 concentrations (Peters et al. 2013). Negatively, under high CO_2 concentrations or global warming, the rates of putrefaction of organic matter and heterotrophic respiration are bound to increase causing a decrease in the effectiveness of this sink to store carbon, thereby making forest ecosystem or vegetation generally, a CO_2 source. In the northern regions of Nigeria with dryness orchestrated by extreme temperature, soil moisture is limited, which, in turn, reduces carbon fixation and inputs in biomass of plants through a reduction in Net Primary Productivity. Drought resulting in the mortality of trees in northern states of Nigeria causes a decline in the carbon stock of above-ground biomass. Drought also contributes to increased loss of soil carbon to the atmosphere from the litter pools (Cleveland et al. 2010). Aside from CO_2, an elevation in the ozone concentration can result in a decrease in the production of biomass in forest ecosystems. Wildfires, especially in the extreme north due to high temperature, expedite the loss of stored organic carbon in soil and vegetation. Loss of vegetation cover and wildfires due to variabilities in rainfall and temperature, exposes the soil to prolonged erosion and leaching incidences leading to organic carbon losses from forest ecosystems. Under high temperature, the root biomass of vegetation is likely to decrease.

Conclusion and Recommendations

It is evidenced from this study that changes in climate pose several impacts on the ecology, forestry, vegetation, carbon and biomass management in Nigeria. These impacts manifest as a result of incidences such as increased temperature, variabilities in rainfall patterns, droughts, flooding and wildfires across various zones of the country. In the northern states, characterized by dryness and drought (due to increased temperature and low rainfall), vegetation cover and forests are disappearing at geometric rates giving room to encroachment by deserts and sand dunes. In the south-south region, with high rainfall, vegetation and forests are lost due to sea level rise and flooding scenarios. The net primary productivity, biomass and carbon stock in various pools of forests are also affected by these extremities in climate across the different Nigerian zones. From the foregoing, it is, therefore, imperative for actions to be taken by environmental stakeholders in Nigeria towards controlling and regulating anthropogenic activities that will lead to the release of greenhouse gases responsible for climate change. Since vegetation plays vital roles in ecosystem productivity and sustainability, there is a need for appropriate management techniques to be adopted for the management, protection and sustenance of vegetation amidst this environmental crisis.

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