K4D | Knowledge, evidence and learning for development

Climate change in Nigeria: impacts and responses

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Question

What is the evidence on climate change effects on Nigeria? Focusing on:

- *What are the historical and projected impacts of climate change in Nigeria?*
- *What mitigation and adaptation efforts have been undertaken in Nigeria?*
- *What is Nigeria's capacity to deal with these impacts and challenges?*

Contents

1. Summary

Nigeria's climate has been changing, evident in: increases in temperature; variable rainfall; rise in sea level and flooding; drought and desertification; land degradation; more frequent extreme weather events; affected fresh water resources and loss of biodiversity (see: Elisha et al., 2017; Ebele and Emodi, 2016; Olaniyi et al., 2013).

The durations and intensities of rainfall have increased, producing large runoffs and flooding in many places in Nigeria (Enete IC, 2014). Rainfall variation is projected to continue to increase. Precipitation in southern areas is expected to rise and rising sea levels are expected to exacerbate flooding and submersion of coastal lands (Akande et al., 2017; Ebele and Emodi, 2016). Droughts have also become a constant in Nigeria, and are expected to continue in Northern Nigeria, arising from a decline in precipitation and rise in temperature (Amanchukwu et al., 2015; Olapido, 2010). Lake Chad and other lakes in the country are drying up and at risk of disappearing (Dioha and Emodi, 2018; Elisha et al., 2017).

Temperature has risen significantly since the 1980s (Enete IC, 2014, 234; Federal Ministry of Environment, 2014). Climate projections for the coming decades reveal a significant increase in temperature over all the ecological zones (Akande et al., 2017).

Geographic impacts

The challenges associated with climate change are not the same across the country. Nigeria has a tropical climate with two precipitation regimes: low precipitation in the North and high precipitation in parts of the Southwest and Southeast. This can lead to aridity, drought and desertification in the north; and flooding and erosion in the South (Akande et al., 2017; Nkechi et al., 2016). Vulnerability analysis demonstrates that **states in the north experience higher degrees of vulnerability to climate change than those in the south** (Madu, 2016; Federal Ministry of Environment, 2014).

The Northeast and the Northwest are the most vulnerable. The combination of rising heat and less rain has hastened desert encroachment, with loss of the wetlands, and fast reduction in the amount of surface water, flora and fauna resources on land (Abdulkadir et al., 2017; Akande et al., 2017; Ebele and Emodi, 2016; Federal Ministry of Environment, 2014).

The Southwest and Southeast are relatively less vulnerable than other parts of the country. Within Southern Nigeria, the South-south (Niger Delta region) is the most vulnerable, due to sea level rise, increased precipitation, coastal erosion and flooding – which has resulted in the displacement of many settlements (Matemilola, 2019; Federal Ministry of Environment, 2014; Sayne, 2011).

The pattern of vulnerability to climate change also corresponds to the dominance of climate-sensitive agricultural activities (Madu, 2016). The Northern regions of Nigeria, which have higher degrees of rurality, are more vulnerable to climate change (Madu, 2016).

Sectoral impacts

Agriculture: Over 70 percent of the country's population is engaged in agriculture as their primary occupation and means of livelihood (Onwutuebe, 2019, 3; Shiru et al., 2018; Nkechi et al., 2016; Federal Ministry of Environment, 2014). Agricultural produce in Nigeria is mostly rain fed. Unpredictable rainfall variation makes it difficult for farmers to plan their operations (Anabaraonye

et al., 2019; BNRCC, 2011). Higher temperatures, lower rainfall, droughts, and desertification reduces farmlands, lowers agricultural productivity and affects crop yields. Increased rainfall intensity in the coastal region, sea level rise, flooding and erosion of farmland will also lower agricultural production (Ogbuabor and Egwuchukwu, 2017).

Fisheries: Climate change affects the nature and characteristics of freshwater resources on which many Nigerians depend. Sea level rise and extreme weather will affect the ability to fish. The viability of inland fisheries is also threatened by increased salinity and shrinking rivers and lakes (Ebele and Emodi, 2016; BNRCC, 2011).

Food security and water: Unpredictable rainfall variation, heat stress and drought can adversely affect food production and result in food shortages (Abdulkadir et al., 2017; Elum et al., 2017; Ebele and Emodi, 2016; Enete IC, 2014). The high vulnerability of states in the north to climate change poses a serious threat to food security throughout the country (Madu, 2012). Drought conditions in parts of Northern Nigeria has also resulted in less drinking water (Sayne, 2011).

Forestry: Erosion and excessive wind reduces the amount of forestry produce, such as wood and cane (Ogbuabor and Egwuchukwu, 2017). Forests are under significant pressure not only from climate change but also from increasing populations and greater demand for forest resources (BRNCC, 2011).

Health: Climate change has serious implications for human health in Nigeria. Direct health impacts stem from extreme weather events such as heat waves (BNRCC, 2011). Indirect effects of climate change can arise from malnutrition due to food shortages; the spread of infectious disease and food- and water-borne illness (e.g. typhoid fever, cholera); increased air pollution; and from higher temperatures correlated with increased cases of meningitis (Abdulkadir et al., 2017; Osuafor and Nnorom, 2014; BNRCC, 2011).

Economy: Given the importance of the agricultural sector to livelihoods and the economy in Nigeria, problems with crop yields and productivity can have an adverse effect on gross domestic product (Anabaraonye et al., 2019; Solomon and Edet, 2018; Ogbuabor and Egwuchukwu, 2017; Ebele and Emodi, 2016). In addition, extreme weather events, such as floods, can undermine economic growth through production and infrastructure losses and the need for extraordinary spending (Federal Government of Nigeria, 2013).

Energy: Climate change is expected to negatively impact the already limited electrical power supply in Nigeria, through impacts on hydroelectric and thermal generation (Ebele and Emodi, 2016). Lower rainfall in the north, for example, reduces the availability of trees and biomass for fuel, which affects hydroelectric output (Ebele and Emodi, 2016; BNRCC, 2011). Increased rainfall intensity in coastal and rainforest zones is also expected to adversely affect power generation, through damage to transmission lines and substation equipment (Ebele and Emodi, 2016; BNRCC, 2011).

Demographic impacts

Climate change will affect income groups, classes, occupation, age and gender in varying ways (Amobi and Onyishi, 2015). The high vulnerability of the agricultural sector to climate change will continue to affect women disproportionately as a larger percentage of women are poor farmers who rely on small-scale and rain-fed agricultural (Onwutuebe, 2019). Women are also more dependent on natural resources as they are primarily responsible for gathering wood for cooking and heating, collecting the household water supply, and ensuring food security for the family

(NEST, 2011). Climate change impacts also affect children. It interferes with schooling as many children are absent during heavy rains, particularly in villages with poor transportation. Food scarcity, and consequent hunger, can also undermine the ability of children to learn (Amanchukwu et al., 2015).

Security impacts

Climate change can pose threats to the security situation in Nigeria through conflict over resources. This is exacerbated by increasing water and food scarcity (Madu, 2016; Madu, 2012; BNRCC, 2011). Desert encroachment and steadily depleting vegetation and grazing resources in the North Sahelian zone has prompted massive emigration and resettlement of people to areas less threatened by desertification. This has exacerbated communal clashes among herdsmen and farmers and inter-ethnic clashes, some of which have turned deadly (Elisha et al., 2017; Nkechi et al., 2016; Amobi and Onyishi, 2015).

Climate Change Mitigation

Renewable/clean energy: The energy sector is the most important sector for climate change mitigation. It is important to control greenhouse gases by moving towards renewable energy development. Despite movement in Nigeria toward the development of policy and legislation in support of renewable energy, there are few existing renewable energy projects (Dioha and Emodi, 2018; Elum and Momodu, 2017). The vast majority of renewable energy consumption that do exist are derived from hydropower (Achike et al., 2019; Dioha and Emodi, 2018; Elum and Momodu, 2017; Yahaya and Nwabuogo, 2016). The development of solar energy is new to the country, with growing interest from investors. The bioenergy industry could receive a boost from a persistent increase in the production of sugarcane, maize and cassava (Elum et al., 2017). It is necessary to develop innovative financing schemes that will reduce the cost of low carbon technologies for consumers in addition to making it a profitable project for investors (Dioha and Emodi, 2018).

Other sectors/lifestyle choices: There is a need to encourage sustainable lifestyle choices among Nigerians. These include less meat consumption, phasing out of inefficient appliances, and greater access to and use of public transportation. Public infrastructure and services for effective waste reduction also need to be encouraged (Dioha and Emodi, 2018; Nkechi et al., 2016; Elias and Omojola, 2015).

Tree planting/reforestation: Reforestation in Nigeria is only about 10 percent of the deforestation rate (Elum and Momodu, 2017, 74). There is an urgent need for a more aggressive tree planting.

Climate Change Adaptation

Vulnerable groups can be more affected by climate change due to limited resources and low adaptive capacity (BNRCC, 2011). Studies demonstrate that rural women in developing countries, for example, are more vulnerable to climate change as they have low adaptive capacity.

Agricultural initiatives: The adoption of existing and new technologies for adapting to climate change and variability is a high priority for many ecological regions in Nigeria. This includes crop diversification, the adoption of drought-tolerant and early maturing varieties of crops; and crop cover (Achike et al., 2019; Amadi and Udo, 2015; Federal Ministry of Environment, 2014). Studies show that Nigerian farmers on their own and with the help of government and other

intervention agencies are already adapting to climate change using these and other methods (Ifeanyi-obi and Nnadi, 2014). In addition, agricultural extension services are essential to improving agricultural productivity by providing farmers with useful farming and weather related information and skills training that can enhance their productivity (Oluwole et al., 2016; Federal Ministry of Environment, 2014). The current irregularity of extension services in Nigeria is a constraint to agricultural adaptation (Oluwole et al., 2016; Federal Ministry of Environment, 2014).

Insurance and other financial tools: Insurance provision has the potential to reduce the impact of climate change on insurance policy holders. Nigerian insurers have not, however, paid sufficient attention to the impact of climate change (Elum and Simonyan, 2016; Federal Ministry of Environment, 2014). The Nigerian government should support private insurance firms through policies that would encourage public-private partnerships (Elum and Simonyan, 2016; Federal Ministry of Environment, 2014). Efforts to scale up agricultural insurance also requires building the capacity of farming communities to understand and effectively demand appropriate insurance products (Hansen et al., 2017). Access to credit, such as through microfinance institutions, is also essential to the ability of farmers to adapt to climate change (Abraham and Fonta, 2018; Abaje et al., 2015).

Infrastructure: Irrigation facilities are increasingly important as rain fed agriculture becomes more unreliable, yet they are extremely lacking in Nigeria (Federal Ministry of Environment, 2014). Good roads are also important for efficient distribution of necessary agricultural inputs to rural farmers (Abaje et al, 2015). Urban areas should consider the effects of climate change in city planning. Residential developments, for example, require the maintenance of adequate spaces to allow for easy infiltration of surface runoffs during rainfall (Akeh and Mshelia, 2016).

Adaptive capacity and capacity development

Adaptive capacity is the ability of individuals and communities to adjust to climate change, to moderate potential changes, to take advantage of opportunities or to cope with the consequences (BNRCC, 2011, xiii). It depends on sufficient education, assets, information and income (Madu, 2016).

Skills and knowledge: In order to integrate climate change adaptation into every aspect of national life, Nigerians must have awareness and knowledge – and access to knowledge – of what climate change is, how it is impacting them and how they can adapt (BNRCC, 2011). They also need to be equipped with specialised skills to enable individuals, communities and the country to address climate change risks and implement adaptation. Information and knowledge sharing must be made accessible to a wide range of people, particularly those most vulnerable (Anabaraonye et al., 2019; BNRCC, 2011).

Information and awareness: The level of public awareness on issues related to climate change in Nigeria is considered to be low (BNRCC, 2011). Studies indicate that the Nigerian media has not given sufficient attention to climate change issues (Ajaero and Anorue, 2018). The degree of information available influences the level of awareness on climate change issues (Duru and Emetumah, 2016). Access to specific weather information, early warning and forecast technologies can also help farmers to develop and readjust coping or adaptation strategies (Otitoju and Enete, 2016).

Agricultural extension services: Farmers need to have access to adaptive technology and innovations. The greater contact farmers have with agricultural extension personnel and

services, the better their production, productivity, efficiency in use of resources and profitability (Otitoju and Enete, 2016). Farmers with better access to information of the changing climate through extension services also have a greater likelihood of adopting adaptation measures (Solomon and Edet, 2018; Otitoju and Enete, 2016). Recognition of the need for agricultural extension services has not, however, been matched with corresponding capacity for extension professionals. They require training to act as educators and information/service providers (Dimelu et al., 2014).

Education and school curricula: Nigeria has yet to recognise and adopt education as an effective counter-strategy (Amanchukwu et al., 2015). Nigerian children and youth are not yet properly educated on these issues and thus do not have sufficient knowledge on how to deal with situations caused by climate change (Duru and Emetumah, 2016; Amanchukwu et al., 2015). The inclusion and integration of climate change in the Nigerian educational curricula and in university courses is essential. Challenges include inadequate teacher qualifications and infrastructure (Amanchukwu et al., 2015). Teacher training and adequate equipment needs to be provided. Alternative methods of teaching and awareness-raising that can be effective include use of climate change poems and interactive blogs (Amanchukwu et al., 2015).

Indigenous knowledge: There is a growing awareness of the importance of indigenous knowledge and its value for environmental management and sustainable development. Various adaptive practices in agriculture, for example, have a strong element of indigenous knowledge (Federal Ministry of Environment, 2014). Indigenous knowledge must be documented, in order to counter its gradual disappearance (Dimelu et al., 2014). It should also be incorporated into agricultural education and extension curriculums, and into policy guidelines to address climate change issues. This would allow for more comprehensive measures (Dimelu et al., 2014; Nkechi et al., 2016).

Institutional capacity: The efforts of the government and different agencies in Nigeria have been inadequate (Ifeanyi-obi and Nnadi, 2014). Institutional capacity building will be necessary for all institutional stakeholders engaged in climate change adaptation in Nigeria (BNRCC, 2011). The Special Climate Change Unit in the Federal Ministry of Environment, for example, needs to be strengthened (Olapido, 2010). There is a need also for new institutions, such as Public-Private-Partnerships that can take research findings into the field and help smallholder farmers adapt to a changing climate (Avanlade et al., 2017).

Strength of the evidence

There are a few comprehensive reports and papers that provide useful evidence and discussion of the various impacts of climate change throughout Nigeria. The vast majority of the literature that provides evidence of climate change impacts and responses, however, focuses on the agricultural sector and on individual farming communities in particular regions of the country. Discussion of other mitigation and adaptation measures in the literature often takes the form of recommendations, rather than examples of what has already been achieved. This is likely due to the need for much greater implementation of mitigation and adaption measures in Nigeria. In addition, while there is some discussion about necessary capacity building at the individual, group and community level to engage in climate change responses, there is much less attention given to higher levels of capacity at the state and national level. The literature features gender issues, particularly given that women comprise a significant proportion of the population engaged in agriculture. However, issues concerning disability are absent.

2. Climate change impacts

Nigeria experiences dry and rainy seasons. Too much heat can damage crops and vegetation and too much rainfall can produce widespread flooding and forced relocation (Amanchukwu et al., 2015). There is evidence of impacts of climate change on Nigeria arising from (see: Elisha et al., 2017; Ebele and Emodi, 2016; Olaniyi et al., 2013):

- increases in temperature;
- variable rainfall (decreasing rainfall amount in the continental interiors, increasing rainfall in the coastal areas);
- sea level rise, flooding and erosion;
- drought and increasing desertification;
- land degradation;
- extreme weather events (thunderstorms, lightning, landslides, floods, droughts, bush fires); and
- affected fresh water resources and loss of biodiversity.

Evidence also shows that changes in weather conditions will continue to have a major impact on human life and ecosystems (Amanchukwu et al., 2015). All sectors of the country's socio-economic development, including agriculture, are vulnerable to climate change. Further, extreme weather events have become a yearly occurrence, for which people have not learned to prepare. (Enete IC, 2014; BNRCC, 2011).

Historical impacts

Precipitation: Between 1941 and 1970, late onsets of rains occurred in only a few areas of Nigeria. However, from 1971 to 2000, late onset and early cessation of rains had spread to most parts of the country, shortening the length of the rainy season. Only a narrow band in the middle of the country remained with normal conditions (BNRCC, 2011, 7). Between 1941 and 2000, annual rainfall decreased by 2-8mm across most of the country, but increased by 2-4mm in a few places (BNRCC, 2011, 7).

Nigeria has also experienced climate extremes in recent years (Akande et al., 2017; Amanchukwu et al., 2015). Floods are the most common, recurring disaster in the country (Federal Government of Nigeria, 2013, xix). The durations and intensities of rainfall have increased in the last three decades, producing large runoffs and flooding in many places (Enete IC, 2014). Rising sea level and ocean surge in Southern Nigeria has submerged villages in Lagos and some places in the Niger Delta (Anabaraonye et al., 2019). In Northern Nigeria, a flood in 2010 affected 2 million people in Jigawa State (Elisha et al., 2017). Severe nationwide floods in 2012 resulted in unprecedented damage and losses to human settlements located downstream (Akande et al., 2017; Federal Government of Nigeria, 2013).

Droughts have also been a constant in Nigeria. In the Nigerian Sahelian region, there has been a 25 percent decrease in precipitation on average in the last 30 years (Amanchukwu et al., 2015; Olapido, 2010, 76). The drying up of Lake Chad from around 4000 sq.km to around 3000 sq.km between 1960 and 2007, respectively, is attributable to the effects of climate change in that part of the country (Dioha and Emodi, 2018, 29; Elisha et al., 2017). Other lakes, particularly in Northern Nigeria, are also in danger of disappearing (Elisha et al., 2017).

Temperature: Temperatures have risen significantly above normal since the 1980s, with relatively higher figures in 1973, 1987 and 1998 (Enete IC, 2014, 234; Federal Ministry of Environment, 2014). Temperature increases of approximately 0.2 to 0.3°C per decade have been observed in the various ecological zones of the country (Enete IC, 2014, 234; Federal Ministry of Environment, 2014; BNRCC, 2011; Olapido, 2010).

Minimum temperature in the country has increased slightly faster than the maximum temperature, resulting in smaller temperature range. This warming of the environment is most significant between June and November each year (Amanchukwu et al., 2015; Federal Ministry of Environment, 2014).

Projected impacts

Precipitation: Climate change is expected to continue to increase rainfall variability, with an increase in precipitation by approximately 5-20 percent, and subsequent flooding, in some humid areas of the forest regions and savanna areas in southern Nigeria (Olapido, 2010, 7). Floods near the coast in southern Nigeria will be exacerbated by rising sea level (Akande et al., 2017). Low prediction estimates are for a rise in average sea levels of 0.1m and 0.2m by 2020 and 2050 respectively, due to climate change. Higher estimates are 0.3m by 2020 and 1m by 2050 (see Federal Ministry of Environment, 2014, 14).

In Nigeria, inundation is the primary threat for at least 96 percent of the land at risk (Ebele and Emodi, 2016, 7). A sea level rise of 1m could result in loss of about three-quarters of the land area of the Niger Delta (Federal Ministry of Environment, 2014, 31; Olapido, 2010, 38). It has also been estimated that a rise in sea level by up to 59cm by 2100 will result in the submersion of several Nigerian coastal states. This includes parts of Lagos and other smaller towns along the coast (Ebele and Emodi, 2016, 7). This will disrupt the life and activities of residents and wreak immense havoc on the ecological balance (Ebele and Emodi, 2016).

Flooding is expected to occur alongside droughts in northern Nigeria, arising from a decline in precipitation and rise in temperature (Olapido, 2010).

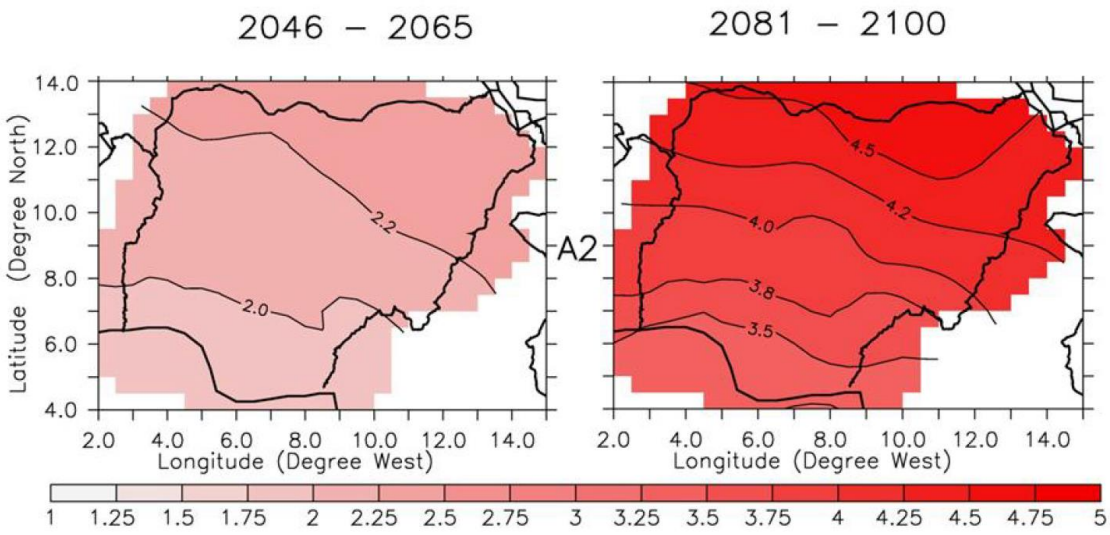
Temperature: Climate projections for the coming decades reveal a significant increase in temperature over all the ecological zones (Akande et al., 2017). It is predicted that there will be a temperature increase of 0.4 to 1°C over the time period 2020-2050 due to climate change, and an increase of up to 3.2°C by 2050 under a high climate change scenario (Olapido, 2010, 38; Federal Ministry of Environment, 2014). Regional variations are expected, with the highest increase (4.5°C by 2081-2100) projected in the Northeast (BNRCC, 2011, ii). See Table 1 and Figure 1 for projected maximum daily temperatures by location. Such heightened temperatures will have negative impacts on agriculture and food security (Akande et al., 2017).

Table 1: Current and Projected Maximum Daily Temperature by Location

Location	Current Mean Annual Maximum (°C)	Projected Increase by 2046-2065 (°C)
Ikeja	31.6	1.4 - 2.3
Warri	32.0	1.4 - 2.3
Ibadan	32.0	1.4 - 2.5
Owerri	32.5	1.5 - 2.3
Makurdi	33.6	1.5 - 2.6
Ilorin	32.6	1.4 - 2.6
Abuja	33.1	1.4 - 2.7
Zaria	32.0	1.4 - 3.0
Kano	33.7	1.5 - 3.2
Sokoto	35.5	1.5 - 3.2
Maiduguri	35.5	1.5 - 3.2

Source: BNRCC, 2011, p.10

Figure 1: Projected Increases in Maximum Daily Temperature across Nigeria, presented in °C relative to the Present Day Climate



Source: BNRCC, 2011, p.10

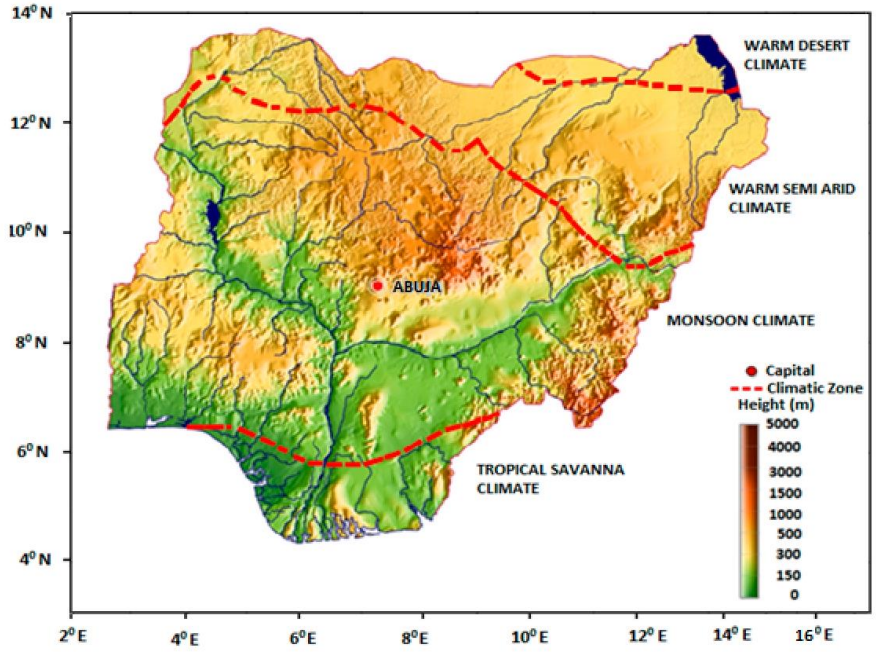
Ongoing increases in carbon dioxide emissions, a major greenhouse gas, is a key contributor to climate change - responsible for the warming of the earth's surface. Figure 2 illustrates the trend of CO2 emissions in Nigeria if nothing drastic is done in the coming years to reverse the causes (Akuru et al., 2017).

See: Figure 2: Population and CO2 emission trends in Nigeria (1990–2050), *Source: Akuru et al., 2017, p.952,* https://reader.elsevier.com/reader/sd/pii/S1364032116311716?token=40B77FCCC963301FC5AA3673B640B66E8D0DCE47DF01CB15B93373E608992451DDECFE18CC0D663DB8A6BF0C9EB643E2

Geographic impacts

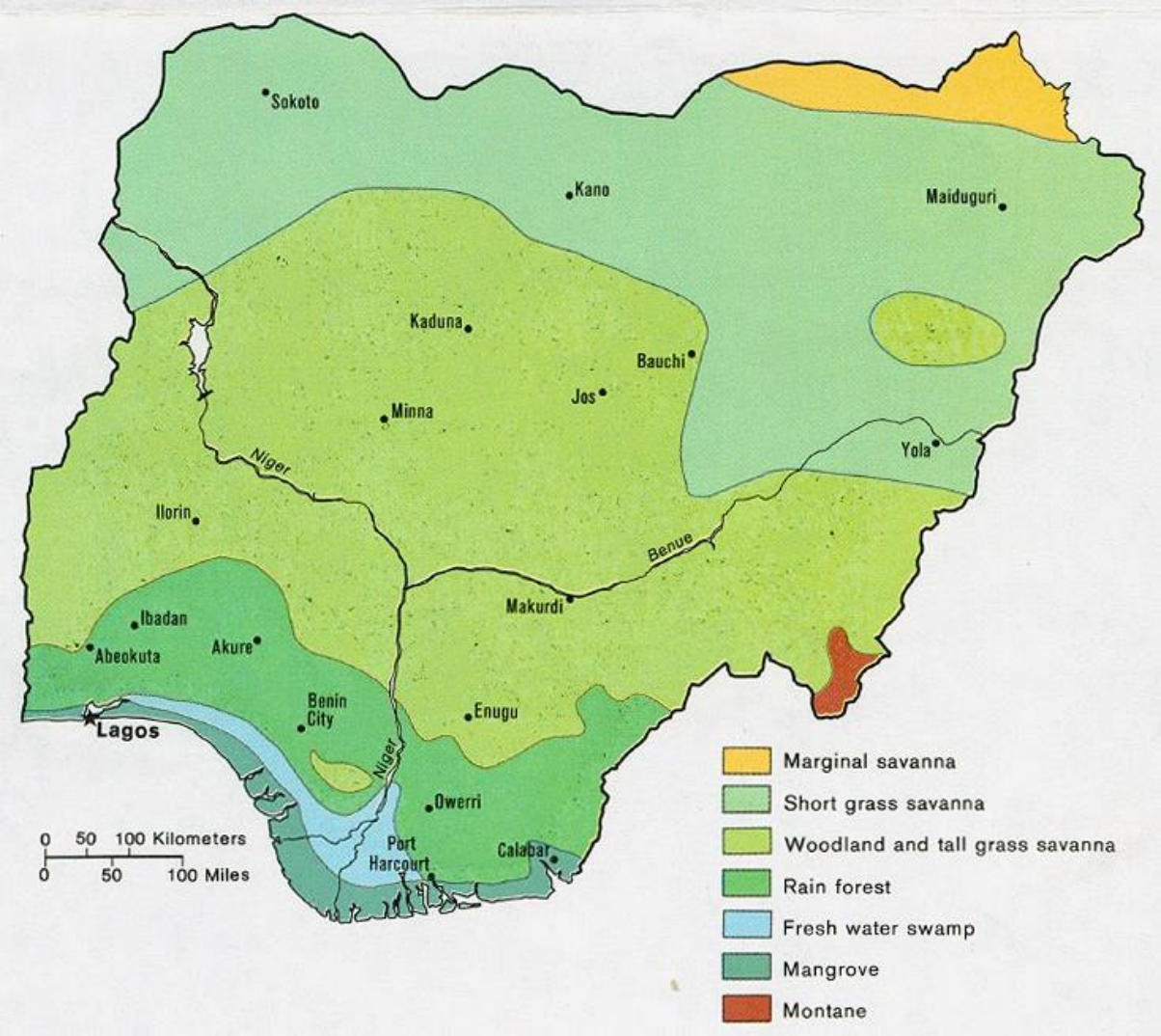
Nigeria has a tropical climate with two precipitation regimes: low precipitation in the North (shortgrass and marginal savanna) and high precipitation in parts of the Southwest and Southeast (rainforest and mangrove). This can lead to aridity, persistent drought and desertification in the north; and erosion and large scale flooding in the south (Akande et al., 2017; Nkechi et al., 2016). As such, while climate change is a national phenomenon, **the challenges associated with the climate change vary across the country** (Federal Ministry of Environment, 2014). See Figures 3 and 4 for the topography and climatic zones; and agro-ecological zones of Nigeria.

Figure 3: The Topography and Climatic Zones of Nigeria



Source: Shiru et al., 2018, p. 873, licensed under Open Access

Figure 4: Agro-ecological Zones in Nigeria[1]



A summary of the projected trends in the key climate change parameters for Nigeria is presented in the Table 2, by ecological zone.

[1] See: https://agriculturenigeria.com/research/introduction/agro-ecological-zone, licensed under Public Domain

Table 2: Summary of Projected Trends by Ecological Zone

Climate variables	Mangrove zone	Rain forest	Tall grass (savanna)	Short grass (Sahel)
Temperature	↑	↑	↑	↑
Rainfall amount	↑	↑	↓	↓
Rainfall variability	↑	↑	↑	↑
Extreme rainfall events - droughts	Likely	Likely	↑	↑
Extreme rainfall events – storms and floods	↑	↑	Likely	Likely
Sea level rise	↑	NA	NA	NA

Legend: ↑ likely increase or increase; ↓ likely decrease or decrease; NA not applicable

Source: BNRCC, 2011, p.14

Vulnerability analysis, based on sensitivity and exposure to climate change; and degree of adaptive capacity, reveals variations across Nigeria (Madu, 2016). Sensitivity to climate change relates to how readily a particular system, such as agriculture, would react to changes related to climate (Federal Ministry of Environment, 2014). Exposure refers to the extent of climate stress to which a particular unit or system is exposed (Federal Ministry of Environment, 2014). Adaptive capacity depends on sufficient education, assets, information and income (Madu, 2016). Regions with the least adaptive capacity are more vulnerable to climate change (Madu, 2016). An understanding of geographic variation and impacts is essential to efficient deployment of adaptation actors (Federal Ministry of Environment, 2014).

Vulnerability analysis demonstrates that **states in the North experience higher degrees of vulnerability than those in the South** (Madu, 2016; Federal Ministry of Environment, 2014). Figures 5, 6 and 7 illustrate the geographic variation in levels of vulnerability, segmented by states and by the six geopolitical zones of Nigeria.

See: Figure 5: Patterns of Climate Change Vulnerability in Nigeria, by State, *Source: Madu,, 2016, p.13,*
https://pdfs.semanticscholar.org/508b/94cab07b84a703b44eca1089326cc98d7495.pdf?_ga=2.154518008.112403230.1572433568-162569160.1557482164

See: Figure 6: Climate Change Vulnerability by Geo-political Zones in Nigeria, *Source: Madu, 2016, p.14,*
https://pdfs.semanticscholar.org/508b/94cab07b84a703b44eca1089326cc98d7495.pdf?_ga=2.154518008.112403230.1572433568-162569160.1557482164

NB: Lower value indicates more vulnerability

See: Figure 7: Spatial Variation in Relative Vulnerability to Climate Change over Nigeria, by Geopolitical Zone, *Source: Federal Ministry of Environment, 2014, p.89,*
https://unfccc.int/sites/default/files/resource/nganc2.pdf

Northern Nigeria: Climate change is exacerbating drought and aridity, affecting the entire savanna landscape of Northern Nigeria and resulting in a decline of socio-economic activities around Lake Chad. The Northeast and the Northwest are the most vulnerable. The combination of **rising heat and less rain has hastened desert encroachment**, with loss of the wetlands, and fast reduction in the amount of surface water, flora and fauna resources on land (Abdulkadir et al., 2017; Akande et al., 2017; Ebele and Emodi, 2016; Federal Ministry of Environment, 2014).

According to some estimates, two-thirds of Bauchi, Borno, Gombe, Jigawa, Kano, Kaduna, Katsina, Kebbi, Sokoto, Yobe, and Zamfara states could turn desert or semi-desert in the twenty-first century (Sayne, 2011, 4). The Sahel already creeps south by approximately 1,400 square miles a year, encroaching on whole villages. Government geological data show a 400 percent increase in sand dunes over twenty years (Sayne, 2011, 4). Migrating sand dunes have buried large areas of arable lands, reducing viable agricultural lands and crop yields (Elisha et al., 2017).

Of the six zones, the North-central has the lowest sensitivity, likely associated with its relatively stable seasonal rains and the presence of a large distribution of lakes that allow for year round irrigation. This can compensate for lower than expected rainfall (Federal Ministry of Environment, 2014). There is growing concern though that the North-central region might be undergoing climatic shift towards aridity, which alongside variable, declining rainfall, adversely affects water resources, agricultural output and economic performance. A downward trend in rainfall was observed in Plateau, Benue Nassarawa and Abuja, the FCT (Ideki and Weli, 2019).

The most exposed region is the Northeast. Exposure factors vary across the country. Declining precipitation that affects water supply in rain fed agriculture is an exposure issue of priority in the north, while water loss due to high soil porosity is a key concern in the Southeast, which also experiences high exposure (Federal Ministry of Environment, 2014).

Southern Nigeria: The southern ecological zone is largely known for high rainfall and an irregular rainfall pattern, with Guinea savannah experiencing gradually increasing temperatures (Ebele and Emodi, 2016). Large proportions of the population in the Southwest rainforest zone and Southeast region live in rural areas and engage in agricultural activities for their livelihood (Nnadi et al., 2019; Avanlade et al., 2018). Crop production is the dominant agricultural enterprise that farmers in Southwest Nigeria engage in (Otitoju and Enete, 2016). Farmers have to contend with variations in climate and the risk of flooding (Nnadi et al., 2019; Avanlade et al., 2018).

The South-south and Southeast zones have high sensitivity due to the porosity of its soils. Even a short dry period can have severe effects on soil moisture (Federal Ministry of Environment, 2014). In terms of exposure, the Southeast is highly exposed while the Southwest is least exposed (Federal Ministry of Environment, 2014). In terms of overall vulnerability, the Southwest and Southeast are relatively less vulnerable than other parts of the country, with the South-south (Niger Delta region) as the most vulnerable in the south (Federal Ministry of Environment, 2014).

Coastal region: Much of Nigeria's densely populated, increasingly urbanized southern coast is less than twenty feet above sea level (Sayne, 2011). Lagos and the Niger Delta region, with its easily flooded network of estuaries, rivers, creeks, and streams, sits particularly low (Sayne, 2011). **Rising sea levels, attributable to climate change, and precipitation are expected to be higher in coastal areas**. Coastal areas have already experienced sea level increment of almost one foot in the past five decades, with forecasts indicating that the increment could be as high as three feet within the next nine decades (Duru and Emetumah, 2016, 2). This will increase the frequency and intensity of flooding by incoming rivers and/or the sea; and lead to widespread erosion and disarticulation of coastal wetlands (Agumagu and Agumagu, 2018; Abdulkadir et al., 2017; Akeh and Mshelia, 2016; Federal Ministry of Environment, 2014). Hydrological modeling indicates that a 1.5-foot sea level rise would submerge more than 11,000 square miles of coastal land (Sayne, 2011, 4).

Many studies have identified the Niger Delta region as highly vulnerable to impacts from climate change, stemming from sea level rise, increased precipitation, and intensive industrial activities from oil exploration (Matemilola, 2019). Coastal erosion and flooding are the most pervasive problems, which have caused the displacement of many settlements in some regions of the Niger Delta (Matemilola, 2019; Matemilola, 2019).

Urban areas: More surface runoffs are expected in urban areas since buildings, roads infrastructure and other paved areas within the built environment prevents rainfall from infiltration into the soil. Heavy rain and/or prolonged rainfall will thus produce significantly large volumes of surface water, which could overwhelm drainage systems and exacerbate the risk of flooding (Akeh and Mshelia, 2016).

Lagos State, in southwestern Nigeria, is the largest urban agglomeration – and Lagos the most populous city - in Sub-Saharan Africa (Elias and Omojola, 2015). The Lagos coastal lowlands are already at risk and will become more at risk with sea level rises (Fashae and Onafeso, 2011). Coastal inundation is expected to increase problems with flooding and intrusion of sea water into fresh-water sources and ecosystems, heightening the social conflict already prevalent in this area (Fashae and Onafeso, 2011).

Other urban environments, such as Warri, are also at risk from the combination of climate change impacts and rapid urban expansion into floodwater storage zones. In recent years, the

frequency and magnitude of floodwater retention pools on urban streets has increased with greater urban development into low-lying swamplands within the city (Odemerho, 2014).

Rural areas: The pattern of vulnerability stems primarily from the dominance of climate-sensitive agricultural activities, poor infrastructural development and other socio-economic conditions in rural areas of the country (Madu, 2016). The **Northern regions of Nigeria, which have higher degrees of rurality, are more vulnerable to climate change** (Madu, 2016). See figures 8 and 9 for patterns of rurality in Nigeria, by states and geo-political zones.

See: Figure 8: Patterns of Rurality by States in Nigeria, *Source: Madu, 2016, p.15,* https://pdfs.semanticscholar.org/508b/94cab07b84a703b44eca1089326cc98d7495.pdf?_ga=2.154518008.112403230.1572433568-162569160.1557482164

Figure 9: Degree of Rurality by Geo-political Zones in Nigeria, *Source: Madu 2016, p.18,* https://pdfs.semanticscholar.org/508b/94cab07b84a703b44eca1089326cc98d7495.pdf?_ga=2.154518008.112403230.1572433568-162569160.1557482164

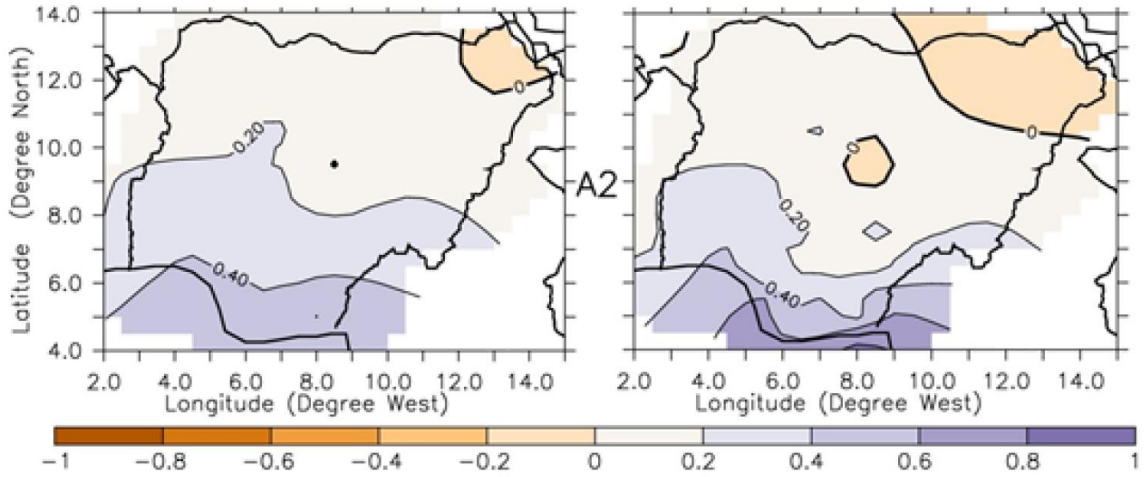
Precipitation forecasts: Projected changes in rainfall vary across the country, with forecasts of wetter climate in the south, but a drier climate in the northeast. For the 2046-2065 period, forecasts indicate an average increase of 0.4mm per day in the south (15 cm annually), and a longer rainfall season by up to two weeks in the mangrove, rainforest and tall grass (Guinea/Sudan) savanna. In the same period, forecasts indicate an average decrease of 0.2 mm per day (7.5 cm annually) in the north, and a shorter rainfall season over short grass (Sahel) savanna, with a potential decrease of more than one week (BNRCC, 2011, ii, 10). Although projected annual rainfall increases in some parts of Nigeria and decreases in others, all areas demonstrate increases in rainfall during at least some part of the year (BNRCC, 2011).

In the mangrove, rain forest and tall grass savanna (Southern Nigeria), the scenarios project earlier rainfall season onset and later rainfall season cessation, resulting in a longer rainfall season by up to two weeks by the 2046-2065 period (BNRCC, 2011). In contrast, the scenarios project a shorter rainfall season over short grass savanna (Northern Nigeria), with a potential decrease greater than one week (BNRCC, 2011, 11). Figure 10 shows these projected changes to the rainfall season.

Higher coastal temperatures are also likely to increase evaporation from the ocean and produce more rainfall over the coastal region. In contrast, a warmer climate in the semi-arid Northeast region would decrease the atmospheric humidity and reduce the chance of cloud formation and rainfall (BRNCC, 2011, 10).

Figure 10: Projected Changes in Average Daily Rainfall over Nigeria

(mm/day relative to the present day climate)



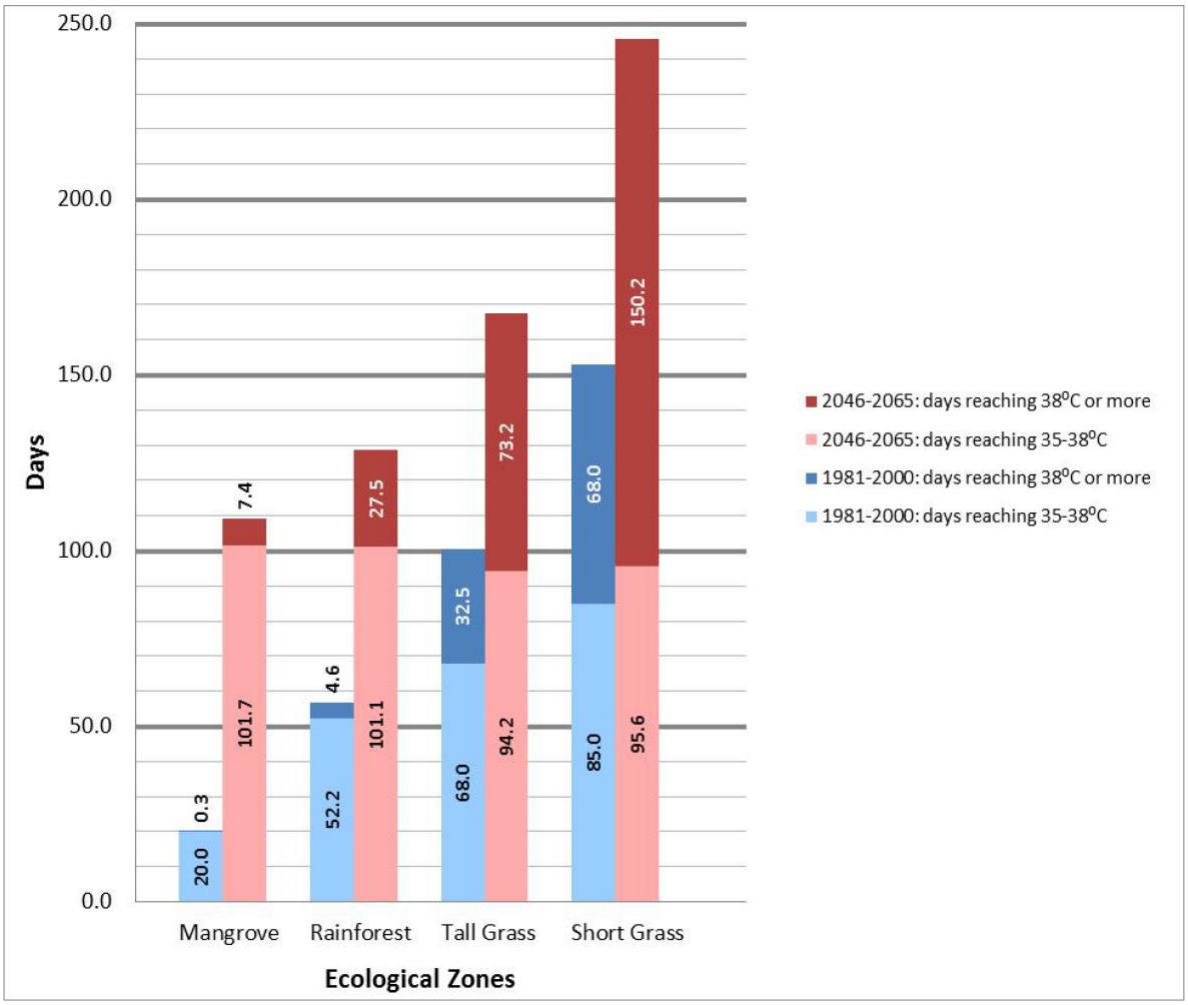
Source: BNRCC, 2011, p.11

Temperature forecasts: Temperature rises have been stronger in the Southern part of the country than in the north (Federal Ministry of Environment, 2014). The most significant increases were recorded in the extreme Northeast, extreme Northwest and extreme Southwest (BNRCC, 2011).

Projected changes in temperature-based extreme events are pronounced over the entire country. Scenarios indicate that by the 2046-2065 period the number of extreme heat days with the temperature reaching 38°C or more could increase by 7 days per year in the mangrove (Southern Nigeria), 23 days per year in the rain forest (Southern Nigeria), 41 days per year in tall grass savanna, and 88 days per year in the short grass savanna (Northern Nigeria). The number of heat wave days (number of days when the maximum temperature is greater than 35°C for three or more consecutive days) are also projected to increase over the entire country (BRNCC, 2011, 12). Figure 11 shows these projected changes.

Figure 11: Actual (1981-2000) and Projected (2046-2065)

Annual Extreme Heat Days by Zone



Source: BRNCC, 2011, p.12

Sectoral impacts

Climate change has an adverse impact on the Nigerian society and economy in many ways, notably agriculture, food production, water resources, health, energy, human settlement and societal relations (Amadi and Udo, 2015; Amobi and Onyishi, 2015).

Agriculture: Nigeria produces a range of food crops including rice, corn (maize), yam, cocoyam, beans, sorghum (guinea corn), melon, and soya beans (Shiru et al., 2018). Over 70 percent of the country's population is engaged in agriculture as their primary occupation and means of livelihood (Onwutuebe, 2019, 3; Shiru et al., 2018; Nkechi et al., 2016; Federal Ministry of Environment, 2014). Reduction in the production of crops would have a significant impact on the population's livelihoods, food security, and the economy of the country (Onwutuebe, 2019; Shiru et al., 2018; BNRCC, 2011).

Agricultural produce in Nigeria is **mostly rain fed**. Unpredictable rainfall variation makes it difficult for farmers to plan their operations and reduces the cropping season and length of growing days (Anabaraonye et al., 2019; BNRCC, 2011). **Many crops are sensitive to even tiny shifts in rainfall and temperature** (Sayne, 2011). Experts have already linked higher temperatures and drought in the northeast to increasing crop failures and declining crop yields (Sayne, 2011). Along the Southern coast, rising sea level is flooding farmland, rendering soils too salinized for planting and eroding soils in the Southeast, again resulting in lower yields (Sayne, 2011).

Higher temperatures, lower rainfall, drought and desertification also reduces farmlands, lowers agricultural productivity and affects crop yields, particularly crops cultivated under rain-fed conditions (Ogbuabor and Egwuchukwu, 2017). Studies conducted in Yobe state, for example, finds that sand dunes and desert encroachment has covered from approximately 25,000 to more than 30,000 hectares, undermining food and livestock production (Ebele and Emodi, 2016).

Prolonged dry spells, from climate change, affects livestock production, making it difficult for livestock farmers to find water and green pastures due to reductions in surface water resources and available pasture land. The loss of weight for animals can reduce meat and dairy production (Avanlade et al., 2017; Ogbuabor and Egwuchukwu, 2017; Nkechi et al., 2016; Idowu et al., 2011). Warming trends also make the storage of root crops and vegetables challenging for farmers without access to refrigerators (Ebele and Emodi, 2016).

Increased rainfall intensity in the coastal region, sea level rise, flooding and erosion of farmland will also lower agricultural production (Anabaraonye et al., 2019; Amobi and Onyishi, 2015; BNRCC, 2011). Flooding of the River Niger, for example, has washed away significant amounts of farmlands (Nkechi et al., 2016).

Fisheries: Livelihoods in coastal areas largely involve the fisheries (Idowu et al., 2011). Climate change affects the nature and characteristics of freshwater resources. The impacts will vary between ecological zones, exacerbating existing problems with flooding or droughts (BNRCC, 2011). These impacts on water resources will affect fisheries, a key source of livelihoods and protein for riverside and coastal rural communities (BRNCC, 2011).

Sea level rise and extreme weather will also affect Nigeria's coastal and marine areas (BNRCC, 2011). Severe storms will threaten fishing vessels and crew, affecting fish farmers on board (Ebele and Emodi, 2016). The viability of inland fisheries is also threatened by increased salinity and shrinking rivers and lakes (Ebele and Emodi, 2016).

Food security and water: About 80 percent of Nigeria's population depends on rain-fed agriculture and fishing as their primary occupation (Abdulkadir et al., 2017; Ebele and Emodi, 2016). Unpredictable rainfall variation, heat stress and drought, stemming from climate change, can adversely affect the food production system and result in food shortages (Abdulkadir et al., 2017; Elum et al., 2017; Ebele and Emodi, 2016; Enete IC, 2014). Poor responses to resource shortages could result in more hunger (Sayne, 2011).

A large proportion of grain crops are grown in states in northern Nigeria (Madu, 2011). The high vulnerability of states in the north to climate change poses a serious threat to food security throughout the country (Madu, 2012). The shrinking of Lake Chad, the north's biggest irrigation resource, contributes to this threat (Sayne, 2011).

Heat stress associated with climate change is also a challenge to poultry farmers due to its adverse effect on chicken growth and productivity (Liverpool-Tasie et al., 2018). A survey conducted in Kaduna and Oyo states in 2017 finds that 10 percent of all farmers have experienced losses of product (chicken, eggs) due to heat waves (Liverpool-Tasie et al., 2018).

Drought conditions in parts of northern Nigeria has resulted in less drinking water. Government data demonstrates that rural households harvest rain for more than half their total water consumption and northern groundwater tables have dropped sharply over the last half century, owing in part to less rain (Sayne, 2011).

Forestry: Climate change also affects the forestry sector in Nigeria. Erosion and excessive wind reduces the amount of forestry produce, such as wood and cane, consequently reducing income and increasing the costs of building and furniture materials (Ogbuabor and Egwuchukwu, 2017).

Forests are under significant pressure not only from climate change but also from increasing populations and greater demand for forest resources (BRNCC, 2011). Native forests have already been lost and climate change is creating more challenges, including difficulty in tree planting, death of trees and decline in species diversity. Desertification in the arid and semi-arid areas, alongside over-exploitation of marginal lands, are also aggravating environmental degradation (Federal Ministry of Environment, 2014).

Health: Climate change has serious implications for human health in Nigeria. Direct health impacts stem from extreme events such as heat waves, floods, droughts, windstorms, and wildfires (BNRCC, 2011). Indirect effects of climate change can arise from **malnutrition** due to food shortages; from the spread of **infectious disease and food- and water-borne illness**; and from increased air pollution (Abdulkadir et al., 2017; BNRCC, 2011). Rising temperatures, rising sea levels, floods and changes in rainfall pattern affect fresh water supply, which can predispose people to infection and other health challenges (Nkechi et al., 2016).

High temperatures can trigger incidences of tropical diseases, such as heat cramps, heat strokes, cerebrospinal meningitis, and malaria (Amadi and Udo, 2015; Osuafor and Nnorom, 2014). In the savanna and Sahelian region, drought and high temperatures, reducing fresh water quantity, has increased heat stress, compromised hygiene and raised the risk of diarrhea and other water-borne diseases such as typhoid fever, cholera and river blindness (Nkechi et al., 2016; BNRCC, 2011).

Cases of cerebrospinal meningitis have been found to correlate positively with the highest maximum temperature of the northern winter season (Osuafor and Nnorom, 2014). Studies find that meningitis cases in Northwest Nigeria may increase in the future due primarily to warmer temperatures. During the peak of the season, cases could potentially increase because of climate change by 32–38 percent for 2020–35 and by 43–91 percent for 2060–75 (Abdussalam et al., 2014, 379).

In coastal eco-zones, windstorms and extreme rainfall, rising sea levels and floods can cause injuries, drowning, death, severe physical and mental trauma, particularly for citizens who live along major river deltas, on islands and in low-lying coastal areas (Abdulkadir et al., 2017; Amanchukwu et al., 2015). Increased rainfall intensity, flooding, stagnated water and polluted ground water increases outbreaks of water-borne diseases and other diseases like hepatitis and malaria commonly experienced in Southern Nigeria (Ebele and Emodi, 2016; Osuafor and Nnorom, 2014; BNRCC, 2011). Heavy rainfall events can also lead to contaminated drinking water from sewage, industrial and chemical waste, which can lead to the outbreak of infections

(Ebele and Emodi, 2016; BNRCC, 2011). In parts of Southern Nigeria, for example, flooding from sea level rise has contaminated freshwater aquifers, rivers, and stock-watering points. This has increased salinity in these bodies of water and polluted them with sediment and sewage (Sayne, 2011).

Economy: It is estimated that, in the absence of adaptation, climate change could result in a loss of between 2 to 11 percent of Nigeria's GDP by 2020, rising to between 6 to 30 percent by the year 2050. This large projected cost is the result of a wide range of climate change impacts that affect all sectors in Nigeria (BRNCC, 2011, iii).

Agriculture: The impacts of climate change are greatly felt on Nigeria's agricultural sector. This in turn undermines the country's economy through loss of gross domestic output, and reduction in the income/consumption of the most vulnerable population (Anabaraonye et al., 2019; Solomon and Edet, 2018; Ogbuabor and Egwuchukwu, 2017; Ebele and Emodi, 2016).

Forestry: Forest depletion adversely impacts economic growth in the short-run (Ogbuabor and Egwuchukwu, 2017). The cost of deforestation and losses in non-timber forest products in Nigeria has been estimated at approximately 1.7 percent of gross domestic product in 2003 (Ogbuabor and Egwuchukwu, 2017, 218; Abdulkadir et al., 2017).

Transportation: Much of Nigeria's transportation infrastructure is inadequate and vulnerable to the impacts of climate change. Under-maintained road networks, for example, will be further degraded by extreme weather (BRNCC, 2011). Higher sea level rise may require costly changes to other ports and rising sea water may damage railway infrastructure (Ebele and Emodi, 2016). Such negative impacts on the transportation system are likely to have negative impacts on the overall Nigerian economy (BRNCC, 2011).

Other sectors: Other sectors affected by climate change include tourism and manufacturing. Tourism, especially the beach based tourism, will be negatively affected by sea level rises that wash out beaches, as in the case of Lagos bar beach and Lekki Island (Ebele and Emodi, 2016). Sea level rise may also lead to flooding that can destroy plants and industrial layouts. This can in turn hamper productivity and efficiency in the manufacturing sector (Ebele and Emodi, 2016).

Extreme weather events can greatly undermine economic growth. The 2012 floods in Nigeria affected several sectors of the economy. The overall impact of the flood on real GDP growth in 2012 is estimated at 1.4 percent, stemming from production losses and from extraordinary spending in most sectors of the economy as a result of the floods (Federal Government of Nigeria, 2013, xx).

Energy: Climate change is expected to negatively impact the already limited electrical power supply in Nigeria, through impacts on hydroelectric and thermal generation (Ebele and Emodi, 2016). This type of power generation is sensitive to the amount of, timing and geographical pattern of precipitation; and to temperature. Lower rainfall in the north reduces the availability of trees and biomass for fuel, which affects hydroelectric output (Ebele and Emodi, 2016; BNRCC, 2011). Reduced river flow and higher temperature also reduces the capability of thermal electric generation as higher temperature reduces transmission capacity. Drought also leads to higher evapotranspiration that adversely affects water volume, thus reducing hydroelectric capacity (Ebele and Emodi, 2016; Amadi and Udo, 2015; BNRCC, 2011). The effectiveness of the Kainji dam hydropower project in central Nigeria has, for example, been undermined by extended drought, resulting in much lower power supply than expected (Ebele and Emodi, 2016).

Increased rainfall intensity in coastal and rainforest zones in the south of Nigeria, stemming from climate change, is also expected to adversely affect power generation. Damage or destruction of transmission lines and substation equipment, due to sea level rise, erosion, flash floods and other extreme weather events, can disrupt service (Ebele and Emodi, 2016; BNRCC, 2011). These same effects of climate change, in addition to high winds and heavy storms, can create risk for oil and gas investment in Nigeria's coastal and offshore areas (BRNCC, 2011).

The use of energy is also affected by climate change. Temperature increases are likely to increase the demand for electric fans and air conditioners, which use a lot of electrical energy (Amadi and Udo, 2015).

Demographic impacts

Climate change will have differential impacts not only among different regions but among different demographic groups. It will affect income groups, classes, occupation, age and gender in varying ways (Amobi and Onyishi, 2015). There is a need for better mapping of these varying impacts (Sayne, 2011). Particularly vulnerable communities include farmers and fishers (particularly those living in more vulnerable areas), the elderly, women, children and poor people living in urban areas (Madu, 2016; Olapido, 2010). These individuals and groups may also have fewer resources to cope with the changes and low adaptive capacity, which exacerbates their vulnerability to climate change (Madu, 2016; BNRCC, 2011).

Gender: Among all sectors of the economy, agriculture is highly vulnerable to the adverse impacts of climate change (Onwutuebe, 2019). It is a key source of livelihoods in Nigeria. These negative impacts have affected and will continue to affect women more because of the cultural division of roles between men and women. A **large percentage of women are poor farmers who rely primarily on small-scale and rain-fed agricultural** (Onwutuebe, 2019). Disruptions in agricultural activities will undermine their livelihoods, which could increase the need for dependency on men working in less vulnerable occupations (Onwutuebe, 2019).

In Anambra in Southeast Nigeria, for example, women farmers are more vulnerable to the changes in climate than men as they supply most of the labour required on farms, in addition to managing their own farms (Nnadi et al., 2019). Women also felt more impact of food and water shortage, resulting from changes in rainfall in the area (Nnadi et al., 2019).

Other livelihoods engaged in by women are also vulnerable to climate change. The majority of women involved in fish processing in Nigeria, for example, use firewood or wood products in their activities. The majority of food sellers in Nigeria are also women and fuel wood is used extensively in food processing and in domestic activities that are dominated by women (NEST, 2011). Erosion and extreme weather events can undermine wood production and the ability to engage in such livelihoods.

Women are also **more dependent on natural resources** for their household roles. They are primarily responsible for collecting the wood for cooking and heating, the household water supply, in addition to ensuring food security for the family (NEST, 2011). Increased rainfall and flooding can also have a greater negative effect on women, if it destroys roads and increases the distances they have to walk to get water and firewood. Decreased rainfall could also create more burden for women in finding water (Nnadi et al., 2019; BNRCC, 2011; NEST, 2011).

Children: Climate change can interfere with schooling. In Nigeria, particularly in the Rivers state, many children are absent from school during heavy rains. This is more prevalent in villages

where there are no means of transportation (Amanchukwu et al., 2015). Difficulties with fetching water during times of drought may also result in households keeping girls home from school to fulfil this task, as it is primarily women and girls who are responsible for collecting water (Amanchukwu et al., 2015).

Food scarcity, and consequent hunger, can undermine the ability of children to learn. Children are also more vulnerable to dehydration from heat stress (BNRCC, 20110). Displacement from climate events and/or damages to school buildings and other infrastructures such as roads and bridges can further interrupt studies (Amanchukwu et al., 2015).

It is **important to understand how climate change impacts vulnerable groups and how the impacts are different among various demographic groups** (BNRCC, 2011). Government policies need to factor in the particular concerns of and issues experienced by different groups with regard to climate related problems and how they should be addressed (Onwutuebe, 2019).

Security impacts

Climate change can pose threats to the security situation in Nigeria through **conflict over resources**. This is exacerbated by increasing water and food scarcity; growing land scarcity stemming from desertification; increasing climate-induced migration; and rising poverty (Madu, 2016; Madu, 2012; BNRCC, 2011).

Desert encroachment and steadily depleting vegetation and grazing resources in the North Sahelian zone has prompted massive emigration and resettlement of people to areas less threatened by desertification (Elisha et al., 2017; Amobi and Onyishi, 2015). There are incidences of cattle rearers from the north encroaching on lands in southern parts, destroying farmlands (Nkechi et al., 2016). This has exacerbated communal clashes among herdsmen and farmers and inter-ethnic clashes, some of which have turned deadly (Elisha et al., 2017; Nkechi et al., 2016; Amobi and Onyishi, 2015).

Efforts to address the impacts of climate change through adaptation must consider the potential for climate change to fuel violence in Nigeria. Although experts are currently divided about the precise causal links between climatic shifts and violence, there is strong agreement that responses **must consider the potential for climate change to increase the risk of conflict** (Sayne, 2011).

3. Climate change responses

Mitigation and adaptation are the two main responses to climate change. Mitigation refers to “measures that may either reduce the increase in greenhouse emissions (abatement) or increase terrestrial storage of carbon (sequestration)”, while adaptation refers to “all the responses to climate change that may be used to reduce vulnerability” (Ifeanyi-obi and Nnadi, 2014, 2). Climate change mitigation and adaptation initiatives should be integrated in development projects and programmes in order to reduce the vulnerability of people to the impact of climate change (Akeh and Mshelia, 2016).

Mitigation

Renewable/clean energy: In Nigeria, as elsewhere in the world, the energy sector is the most important sector for climate change mitigation (Federal Ministry of Environment, 2014). In

Nigeria, conventional energy (oil and gas) with gas flaring has the highest percentage of carbon dioxide (Yahaya and Nwabuogo, 2016). It is important to control CO2 emission and other associated greenhouse gases by moving towards renewable energy development and an energy efficiency mechanism (Yahaya and Nwabuogo, 2016).

Nigeria has abundant sources of renewable energy but **lacks the adequate government banking** to harness these resources for electricity power (Akuru et al., 2017; Yahaya and Nwabuogo, 2016). Despite movement toward the development of policy and legislation in support of renewable energy, in particular the Renewable Energy Master Plan (REMP), developed in 2006 and updated in 2011, there has been **limited progress in implementation** (Elum and Momodu, 2017). In addition, fossil fuels in Nigeria have benefitted more from subsidies and incentives than the renewable energy industry (Elum and Momodu, 2017).

There are few existing renewable energy projects. In order for Nigeria to provide energy for its entire population while limiting greenhouse gas emissions, all forms of renewable energies needs to be exploited (Dioha and Emodi, 2018). These include solar power, tidal, ocean energy, geothermal power, and wind power; nuclear power, the use of carbon sinks, and carbon capture and storage (Yahaya and Nwabuogo, 2016). Currently, the vast majority of renewable energy consumption is derived from hydropower (Achike et al., 2019; Dioha and Emodi, 2018; Elum and Momodu, 2017; Yahaya and Nwabuogo, 2016). The development of solar energy, which is the most available form of renewable energy in Nigeria, is very new to the country, with growing interest from investors (Dioha and Emodi, 2018; Yahaya and Nwabuogo, 2016). Nigera also has some margin of wind energy (Dioha and Emodi, 2018).

The bioenergy industry could receive a boost from a persistent increase in the production of sugarcane, maize and cassava (Elum et al, 2017). The conversion of agricultural and municipal wastes into bioenergy can alongside contribute to climate change mitigation, in addition to job creation (Elum et al., 2017).

It is recommended that the government **provide incentives for investment in renewable energy** resources and put in place policies that will tax businesses emitting greenhouse gases. Tax proceeds could in turn be used for research and building the capacities of farmers to engage in climate change adaptation (Achike et al., 2019; Elum and Momodu, 2017).

Evaluating carbon footprint by gender can contribute to more targeted mitigation strategies aimed at behaviour change (Federal Ministry of Environment, 2014). Men in Nigeria tend to account for a larger proportion of CO2 emissions and air pollution through their energy use. Women generally adopt less emission-intensive modes of transport than men, with lower levels of car-ownership and car usage, less travel by air, and greater use of public transport facilities (Federal Ministry of Environment, 2014). Women, however, engage in many activities that contribute to deforestation and emit greenhouse gases, such as charcoal production, firewood gathering, waste management, agro-processing and electricity usage at home. This is in large part because they spend more time at home and thus use more electrical appliances there than men (Federal Ministry of Environment, 2014). Programmes thus designed to achieve energy efficiency at the household level should recognise the demographic differential in energy use (Federal Ministry of Environment, 2014).

There are **various barriers to renewable energy production in Nigeria**. These include inadequate legal backing of the REMP; insufficient manpower and requisite skills to develop and deploy appropriate clean energy technology; lack of funding for renewable energy projects and

poor incentives for investors (Elum and Momodu, 2017). Studies demonstrate that renewable energy is associated with high start-up costs for installation (Dioha and Emodi, 2018; Akuru et al., 2017; Elum and Momodu, 2017). In Nigeria, the cost of setting up biogas plants, in term so capital and land space requirement can be prohibitive (Elum et al., 2017).

It is necessary to **develop innovative financing schemes** that will reduce the cost of low carbon technologies for consumers in addition to making it a profitable project for investors (Dioha and Emodi, 2018). Alongside opening up the energy sector for investment, government should apportion a sufficient proportion of the national budget to the energy sector and levy taxes on industries that cause a significant amount of greenhouse gas emissions (Dioha and Emodi, 2018).

Timely, accurate and accessible data on renewable energy is crucial for effective policy making. There have been challenges with properly documenting and collecting data for traditional biomass used for heating and cooking, which has resulted in estimations. If faulty, these could produce inaccurate national energy statistics (Akuru et al., 2017).

Other sectors/lifestyle choices: While the energy sector has been identified as the largest contributor to Nigeria's national greenhouse gas inventory, efforts toward climate change mitigation should be distributed across various sectors, such as agriculture (Dioha and Emodi, 2018). There is also a need to encourage sustainable lifestyle choices among Nigerians. These include less meat consumption, phasing out of inefficient appliances, such as incandescent bulbs, greater access to and use of public transportation and greater use of non-motorised modes of transport (Dioha and Emodi, 2018; Nkechi et al., 2016; Elias and Omojola, 2015). Public infrastructure and services for effective waste reduction also need to be encouraged. This includes private sector partnerships for the purpose of collection and disposal of domestic and industrial wastes and for waste reduction strategies (Elias and Omojola, 2015).

Tree planting/reforestation: More than 70 percent of the people living in rural areas in Nigeria use fuel wood, which has been a key contributor to deforestation. However, reforestation is only about 10 percent of the deforestation rate (Elum and Momodu, 2017, 74). There is an urgent need for a more aggressive tree planting.

Adaptation

Mitigation efforts take time and may only occur to a limited extent. Adaptation efforts are thus essential (Otitoju and Enete, 2016; Olaniyi et al., 2013). Adaptation focuses on actions that would help to lessen the sensitivity of systems in different ecological zones in Nigeria (Federal Ministry of Environment, 2014). Planned adaptation strategies include government intervention and public policy, such as investment in infrastructure, subsidies, research, innovation and tax regimes (Jellason et al., 2019). Autonomous adaptation involves coping strategies by farmers and others affected in rural settings. These include diversification, irrigation, changes in planting date, crop and livestock insurance and using tolerant varieties of crops (Jellason et al., 2019).

Studies find that the **socio-economic characteristics of farmers determine their level of use of climate change adaptation strategies**. Education level, degree of farming experience, use of extension services, access to weather information, access to agricultural inputs, level of household income and availability of credit are positively and significantly related to uptake of adaptation to climate change (see Solomon and Edet, 2018; Oluwole et al., 2016). A study conducted in Osun state in Southwest Nigeria finds that length of farming experiences determine

the level of awareness that farmers have about climate change, which in turn increase the likelihood of adopting climate change adaptation measures (Avanlade et al., 2018).

Vulnerable groups can be more affected by climate change due to limited resources and low adaptive capacity (BNRCC, 2011). Studies demonstrate that rural women in developing countries, for example, are more vulnerable to climate change as they have low adaptive capacity (Akimbami et al., 2019).

Agricultural initiatives: The patterns and linkages between rurality and climate change vulnerability make agriculture a key sector for climate change adaptation measures to foster sustainable agricultural production. Adaptation strategies include: rural infrastructure development, including irrigation; skills training and assistance to adopt climate resilient technologies; education and weather information services; and agricultural insurance (Achike et al., 2019; Madu, 2016; Federal Ministry of Environment, 2014).

The **adoption of existing and new technologies** for adapting to climate change and variability is a high priority for many ecological regions in Nigeria, requiring medium level financial commitment. This includes **crop diversification** and the **adoption of climate-adapted crops** (e.g. drought-tolerant and early maturing varieties of crops) that would allow for profitable crop harvest with less rain and prolonged dry periods (Achike et al., 2019; Amadi and Udo, 2015; Enete IC, 2014; Federal Ministry of Environment, 2014). Improved soil management practices and **crop cover**, such as the use of potatoes, melon and groundnut, can also be used to protect topsoil from the effects of soil erosion (Amadi and Udo, 2015; Federal Ministry of Environment, 2014).

A study of farming practices in Southeast Nigeria finds that **farmers on their own** and with the help of government and other intervention agencies **are already adapting** to climate change, particularly farmers in the South-south zone (Ifeanyi-obi and Nnadi, 2014). It recommends that adaptation measures, such as improvement in farm input and movement toward more disease resistant crop varieties, are further supported (Ifeanyi-obi and Nnadi, 2014). A study of adaptation measures in Imo state in Southeast Nigeria also reveals that farmers have devised various ways to reduce the effects of climate change (Okoroh et al., 2016). These include: crop rotation, mixed cropping practices and the use of water channels as draining systems, mulching, regular weeding and conservation of soil moisture through appropriate tillage operation – all of which have been undertaken by more than half of the farmers studied (Okoroh et al., 2016).

A study, focused on Oyo and Ekiti States in Southwest Nigeria finds that farmers use various climate change adaptation strategies, including (in order of popularity) fertiliser application; mixed cropping; cultivation of improved varieties; mulching; altering of crop planting date and planting of crop cover (Oluwole et al., 2016). The variation in the type of strategies adopted among farmers can be attributed to differences in access to capital, information on the use of different climate change adaptation strategies and type of arable crop grown by the individual farmers (Oluwole et al., 2016). Another study conducted in Southwest Nigeria finds that crop cover is proving to be effective in conserving soil and protecting against climatic factors, such as excessive heat/dry spell, heavy and erratic rainfall and erosion (Enete et al., 2015).

Varying strategies for climate change adaptation have also already been adopted by farmers in the Niger Delta, including (in order of popularity) planting with early rainfall; adopting mixed farming; using proper preservation of seeds as an adaptive strategy; and crop cover (Nzeadibe et al., 2011).

In the Northwestern Nigerian drylands, studies find that good practices, such as mulching and soil sealing, were poorly adopted. There is variation across the region in the uptake of improved crop varieties and crop rotation (Jellason et al., 2019).

Agricultural extension services are essential to improving agricultural productivity by providing farmers with **useful farming and weather related information and skills training** that can enhance their productivity (Oluwole et al., 2016; Federal Ministry of Environment, 2014). A study of farming practices in Southeast Nigeria finds, for example, that it is important to educate farmers to cultivate away from flood prone areas in order to reduce the impacts of flooding in the farms (Nnadi et al., 2019). Another study also conducted in Southeast Nigeria, recommends that farmers should be taught through extension services the benefits of pooling resources together through co-operative societies to more effectively counter the impacts of climate change (Ifeanyi-obi and Nnadi, 2014).

Agricultural extension professionals need to be more engaged to improve local agricultural practices. Their cost is relatively low; however the **current irregularity of extension services in Nigeria is a constraint to agricultural adaptation** (Oluwole et al., 2016; Federal Ministry of Environment, 2014). For further discussion, see the section on capacity.

Building environmental consciousness among Nigerians, particularly those connected to the agricultural sector, is another key priority. This can be fostered through curriculum restructuring (see the section on capacity) and provision of **weather information services** by the Nigerian governments and their agencies to enable farmers to plan against weather uncertainty and risk (Achike et al., 2019). The Nigerian Meteorological Agency (NIMET) produces weather information, but its facilities are in need of upgrading in order to create more robust and reliable forecasts, and to improve the agency's ability to disseminate weather information to farmers at the grassroots (Federal Ministry of Environment, 2014). Farmers with better access to information of the changing climate are more likely to adopt adaptation measures (Solomon and Edet, 2018).

Given the prominence of women in the agricultural sector in Nigeria, women are particularly affected by climate-related impacts. While the need to build rural adaptive capacity and to **empower rural women** is well documented, there needs to be greater recognition of women's agency and attention to how women's entrepreneurship development can improve adaptation responses (Akinbami et al., 2019). A study on women's empowerment in farming communities in Southeast Nigeria recommends, for example, that women's participation in the construction, maintenance and management of sustainable water and irrigation systems should be encouraged to counter the impacts of water shortage (Nnadi et al., 2019).

Insurance and other financial tools: Insurance can be an effective adaptation strategy, with the potential to reduce the impact of climate change on insurance policy holders (Elum and Simonyan, 2016; Federal Ministry of Environment, 2014). Nigerian insurers have not, however, paid sufficient attention to the impact of climate change as there is no evidence to demonstrate that they have investigated the potential effects on the industry of incorporating climate change and weather-related losses (Elum and Simonyan, 2016). There has been a general reluctance to take up risks in climate-related ventures (Federal Ministry of Environment, 2014).

The Nigerian government should support private insurance firms through policies that would encourage public-private partnerships, in order to encourage firms to be more willing to provide insurance to agricultural businesses for climate-related affects (Elum and Simonyan, 2016). The

insurance sector needs to be strengthened to assist farmers particularly at the group level to cope with crop failures, damages to buildings and loss of life (Federal Ministry of Environment, 2014). Efforts to scale up agricultural insurance also require attention to the demand side, building the capacity of farming communities to understand and effectively demand appropriate insurance products (Hansen et al., 2017). Partnering with organisations that already interact with farming communities and have built trust with them has proven to be effective in various successful agricultural index insurance initiatives (Hansen et al., 2017).

Capital unavailability is a considerable constraint to climate change adaptation (Oluwole et al., 2016). Access to credit is essential to the ability of farmers to adapt to climate change. A study of rural areas in the savannah region of Northern Nigeria finds that when farmers' perceive greater exposure to climate change, they also demonstrate a greater need for credit (Abraham and Fonta, 2018). Efforts should be made to promote financial inclusiveness through, for example, the provision by **microfinance institutions** of products and services to farmers in need, such that they can build resilience that will maximise agricultural production (Abraham and Fonta, 2018). Microfinance institutions often support rural communities by providing credits for technology packages (Abaje et al., 2015).

Infrastructure: The quality and availability of infrastructure and institutions is an important measure of adaptive capacity of a given community. The low infrastructural capacity of farmers in Nigeria contributes to their high dependency on rain fed agriculture (Ifeanyi-obi and Nnadi, 2014). Government and non-government organisations in Nigeria should seek to understand infrastructural and technological constraints experienced by farmers; and intensify efforts with regard to land tenure and information systems (Otitoju and Enete, 2016).

Rural areas also require attention to irrigation infrastructure in rural settings. **Irrigation facilities are increasingly important as rain fed agriculture becomes increasingly unreliable**. They are currently limited in Nigeria as only approximately 1 percent of irrigable land is irrigated (Federal Ministry of Environment, 2014, 97). Nigeria's National Policy on Irrigation provides a foundation for the expansion of irrigation facilities. Greater resources are needed, however, as such facilities are costly (Federal Ministry of Environment, 2014). The introduction of good irrigation systems that use low amounts of water can help to boost farmers' adaptive capacity (Amadi and Udo, 2015; Ifeanyi-obi and Nnadi, 2014).

Good roads are also important for efficient distribution of necessary agricultural inputs to rural farmers. In addition, the availability of health facilities can assist in the provision of preventive treatments for diseases associated with climate change, such as malaria and cholera (Abaje et al, 2015).

Urban areas should also **consider the effects of climate change in city planning**. Residential developments, for example, require the maintenance of adequate spaces to allow for easy infiltration of surface runoffs during rainfall (Akeh and Mshelia, 2016). In Lagos, various activities are being undertaken as strategies for adaption. These include primary and secondary drainage channel construction and rehabilitation; cleaning of open drains and concrete lining of canals to improve water flows; regular flood warning and disaster relief planning for vulnerable communities (Elias and Omojola, 2015).

4. Capacity to engage in climate change responses

Adaptive capacity is the ability of individuals and communities to adjust to climate change, to moderate potential changes, to take advantage of opportunities or to cope with the consequences (BNRCC, 2011, xiii). It depends on sufficient education, assets, information and income (Madu, 2016).

Climate change capacity can be assessed at three levels: the individual level, the organisational or institutional level and the systemic level:

- The **individual level** concerns all relevant actual and potential actors (for example, policymakers, the private sector, and local population) who carry out tasks or functions related to climate change management. Individual climate capacity depends in large part on the degree of knowledge and skills, and quality of information, available to individuals and communities and how easily they can access the information (BNRCC, 2011; Olapido, 2010). The **adaptive capacity of individuals or social groups varies, and is dependent upon their access to and control over resources**. The poor have particularly limited access to such resources, and as such are particularly vulnerable to climate change and least able to develop viable adaptation strategies (Avanlade et al., 2017; BNRCC, 2011).

- The **organisational/institutional level** focuses on **overall organisational performance and management capacitie**s (for example, the existence of an organisation with a specific mandate on climate change or a specific climate unit). In Nigeria, agencies under the national government charged with managing environmental issues such as climate change include the National Emergency Management Agency (NEMA) (Olapido, 2010). The implementation of effective adaptation response strategies requires strengthening of the Special Climate Change Unit, within the Federal Ministry of Environment (Olapido, 2010).

- The **systemic level** focuses on the creation of an enabling environment for climate action (for example, policy, economic, regulatory, and accountability frameworks within which organizations and individuals operate). It relates to **the long-term framework conditions** for climate action and therefore the opportunity structure of climate actors (Olapido, 2010). Nigeria has various frameworks in place, such as the REMP. However, as noted, lack of adequate legal backing and insufficient resources and skills have resulted in limited progress toward the adoption and use of renewable energy.

Skills and knowledge

In order to integrate climate change adaptation into every aspect of national life, Nigerians must have awareness and knowledge – and access to knowledge – of what climate change is, how it is impacting them and how they can adapt (BNRCC, 2011). They also need to be equipped with specialised skills to enable individuals, communities and the country to address climate change risks and implement adaptation (Nkechi et al., 2016).

It is necessary to **strengthen climate change knowledge architecture** in Nigeria to reach policy-makers, community-based organisations, students and researchers, who are in the frontline of delivering adaptation projects (Amanchukwu et al., 2015). Ideally, it would include an organisation, special unit and platform for coordinating and facilitating the regular generation,

management, exchange and dissemination of climate-related knowledge and capacity-building services (Amanchukwu et al., 2015).

Information and knowledge sharing must be made accessible to a wide range of people, particularly those most vulnerable (Anabaraonye et al., 2019; BNRCC, 2011). Indigenous people should also be incorporated within climate change oriented organisations to enable local fishermen and farmers to have a sense of belonging (Anabaraonye et al., 2019).

Information and awareness: The level of public awareness on issues related to climate change in Nigeria is **considered to be low** (BNRCC, 2011). In the Niger Delta, for example, results of a household survey indicate that the level of awareness of local communities of climate change impacts is low, with close to 60 percent of respondents knowing little or nothing about climate change and its impacts (Nzeadibe et al., 2011, 5). Studies indicate that the Nigerian media did not give sufficient attention to climate change issues. This could be attributed to inadequate funding and the perception of climate change stories as “hard sell” (Ajaero and Anorue, 2018). There is a need for news editors to look for ways to make climate change reports more interesting, perhaps by framing stories more to reflect the human angle (Ajaero and Anorue, 2018). In contrast, a study conducted in Southwest Nigeria finds that the high level of awareness among farmers of climate change (84 percent of those surveyed were aware of it) can be attributed to extensive awareness creation made through the print and electronic media and through other social and religious networks (Ozor et al., 2012, 243).

The **degree of information available influences the level of awareness** on climate change issues (Duru and Emetumah, 2016). Lack of adequate information is considered to be one of the key constraints encountered by farmers in adapting to climate change in Africa (Otitoju and Enete, 2016). There is a pressing need to improve information dissemination and access, and public awareness and understanding of the impacts of climate change. This includes access to information regarding historical climate, projections of future climate change, potential impacts, causes of vulnerability, technologies and measures for managing climate risks, and the know-how for implementing these technologies (BNRCC, 2011).

A study on knowledge of climate change in Nigeria finds that mass media (radio, television and newspapers) was the largest source of information, followed by contacts with friends. Other sources include the internet, researchers, extension workers and farmers’ co-operative (Nzeadibe et al., 2011). National agencies charged with managing environmental issues, for example the National Emergency Management Agency, have had some success at sensitizing people and raising awareness through radio, newspapers and television in addition to on the ground contacts with vulnerable people (Ozor et al., 2012). Among Nigerian students, radio was the most accessible information source, followed by mobile phone, television and newspapers (Duru and Emetumah, 2016).

Another study of Nigeria finds that while the internet is considered to be accessible by more than half of the respondents, and to be important in sourcing information on climate change issues, the quality and the ability of the respondents to understand that information is subjective (Duru and Emetumah, 2016, 2). The study recommends greater awareness creation on climate change issues through public participation and technological tools (Duru and Emetumah, 2016).

Policies and programmes should be aimed at increasing access to information for and raising awareness among public policy makers, the organised private sector, civil society organisations,

users of natural resources and those working in agriculture, and managers of infrastructure (BNRCC, 2011).

Alongside information provision and awareness-raising of climate change impacts and responses, more generally, **access to specific weather information**, early warning and forecast technologies can help farmers to develop and readjust coping or adaptation strategies (Otitoju and Enete, 2016; Amadi and Udo, 2015). Poor climate change information and lack of access to weather forecasts can be a significant barrier to informed decision making, useful farming plans and adaptation, rendering farmers increasingly vulnerable to the impacts of changes in the climate and weather. This has been the case among farming households in Southern Nigeria (Otitoju and Enete, 2016).

Socio-economic factors also affect access to information and level of awareness in relation to climate change. A study on Southern Nigeria finds that income is positively and significantly related with institutional adaptation since only farmers with the resources to buy radios and television will be able to listen to weather forecasts. Further, men generally listen to the radio and television, where weather forecasts are usually broadcast, more than women (Ozor et al., 2012).

Information and knowledge on the causes of climate change, its impacts, and mitigation and adaptation strategies need to be available in simplified forms and translated into and conducted in local languages. This includes all mediums, whether through radio, television, newspapers, magazines, seminars, workshops and manuals (Anabaraonye et al., 2019; BNRCC, 2011).

Agricultural extension services: There is an urgent need to educate farmers and fishermen in rural areas in Nigeria on climate change issues and to build their technical capacity to engage in mitigation and adaptation. Currently, many of them have little or inadequate understanding or knowledge of climate change and possible responses (Anabaraonye et al., 2019). A study conducted in Southwest Nigeria finds that there is a need for capacity building of farmers to cope with changing climate. It suggests that agricultural extension workers develop climate smart agriculture training (Avanlade et al., 2017).

Agricultural extension services involve the application of scientific research and knowledge to agricultural practices and delivery of information and skills training to farmers. Education and training to impart specialized climate change knowledge and skills is necessary to equip farmers with the ability to understand and address climate change risks and opportunities; and to engage in possible adaptive and mitigation measures feasible in their locality (Nkechi et al., 2016; Dimelu et al., 2014). Farmers also need to have access to adaptive technology and innovations—through extension and information systems (Dimelu et al., 2014). In addition, farmers need to learn about and understand the consequences of some of their farming practices that can exacerbate ecological problems (for example, mono cropping, bush burning, indiscriminate use of synthetic agrochemicals and felling of trees) (Dimelu et al., 2014).

It is established in the literature that the greater contact farmers have with agricultural extension personnel and services, the better their production, productivity, efficiency in use of resources and profitability (Otitoju and Enete, 2016). Farmers with better access to information and knowledge of the changing climate through extension services have a greater likelihood of adopting agricultural technologies and other adaptation measures (Solomon and Edet, 2018; Otitoju and Enete, 2016; Ozor et al., 2012).

The absence of adequate agricultural extension programmes directed to meet climate change adaptation strategies in food crop production and/or poor agricultural extension delivery have

been key constraints in the adoption of adaptation measures, such as among cocoa agroforestry households in Southwest Nigeria (Otitoju and Enete, 2016).

Recognition of the need to educate farmers and rural communities in Nigeria through agricultural extension services has not been matched with corresponding capacity building (improved knowledge/skill or information and responsive attitude) for extension professionals (Dimelu et al., 2014). **Extension professionals** in such contexts are expected to build awareness, facilitate generation and transfer of knowledge and technologies, and implement actions for effective management of climate change risks. They need to be competent in terms of technical knowledge of climate change issues and responses and information management skills. They **require training to act as educators and information/service providers**. All of this **necessitates comprehensive capacity building of extension professionals** and extension systems in Nigeria and elsewhere (Dimelu et al., 2014). The government has a role to play in building the capacity of agricultural extension systems to achieve these various functions in relation to climate change (Avanlade et al., 2017).

Education and school curricula: Education is a key aspect of the global response to climate change. It helps young people understand and address the impact of climate change, encourages changes in their attitudes and behavior, and helps them adapt to climate change-related trends (Amanchukwu et al., 2015). UNESCO's Climate Change Education for Sustainable Development programme makes climate change education a more central and visible part of the international response to climate change and seeks to strengthen the capacity of member states to provide quality climate change education. It encourages innovative teaching approaches to integrate climate change education in schools (Amanchukwu et al., 2015). In turn, stakeholders in the education system (academics, researchers, teachers, students, school administrators and policy-makers) have a key role to play in national programmes to achieve the goal of public awareness of climate change (Amanchukwu et al., 2015; BNRCC, 2011).

Nigeria has yet to recognise and adopt education as an effective counter-strategy. Nigerian children are not yet properly educated on these issues and thus do not have sufficient knowledge on the risks and impacts of climate change or how to deal with situations caused by climate change (Amanchukwu et al., 2015).

Introducing an effective public education programme requires that curriculum planners address the various deficits in the fields of climate change and education (Amanchukwu et al., 2015). The **inclusion of climate change in the Nigerian educational curricula is essential**. Basic knowledge about climate change, including both the science and its potentials, should be taught in an objective and evidence-based way in schools, either as a separate subject or spread between more than one subject area (Amanchukwu et al., 2015).

Challenges to integrating climate change issues into educational curricula include inadequate teacher qualifications and infrastructure (Amanchukwu et al., 2015). **Teacher training and the provision of adequate equipment** should be provided to give students the necessary knowledge, skills and understanding that they need to be educated citizens and to manage their own local environments (Amanchukwu et al., 2015).

Climate change education should also become an integral part of the university system, as part of the general studies curriculum and through modules on environmental issues. This could contribute to increasing environmental consciousness among students and young Nigerians in general (Duru and Emetumah, 2016). Teaching of climate change impacts should go beyond a

basic understanding of how the climate system works and extend to options for adaption and mitigation (Amanchukwu et al., 2015).

University lecturers should be given incentives to carry out research in various fields of knowledge related to climate change, so that innovative research can contribute to practical solutions (Amanchukwu et al., 2015). Students should also be encouraged to participate in campus campaigns on climate change awareness. This can help to foster consciousness within their immediate environment about the effects of climate change on our daily lives (Duru and Emetumah, 2016).

Other effective methods of teaching and awareness-raising include use of climate change poems, interactive blogs, and leadership summits on climate change (Anabaraonye eta l., 2019). The Project Green Initiative in Nigeria, for example, is an enterprise that has creatively and effectively used poetry focused on climate change to educate farmers and fishermen. Interactive blogs also allow farmers and fishermen to contribute their ideas, suggestions and feedback to climate change educators and bloggers for global sustainability (Anabaraonye et al., 2019).

Other technological tools and social media platforms, such as mobile phone applications, should be utilized in improving information literacy, access to information and awareness creation among students (Avanlade et al., 2017; Duru and Emetumah, 2016). In addition, students in computer science and related disciplines should explore the development of software applications that can be used in understanding everyday environmental transformations (Duru and Emetumah, 2016).

Indigenous knowledge: There is a growing awareness of the importance of indigenous knowledge and its value for environmental management and sustainable development. Various adaptive practices in agriculture, for example, have a strong element of indigenous knowledge. Indigenous knowledge in building houses can also offer valuable options for internal cooling and stability of buildings (Federal Ministry of Environment, 2014). In order to improve outcomes in sustainable rural development and climate change adaptation and mitigation, indigenous knowledge should be documented. This could help to counter the gradual disappearance of valuable indigenous knowledge that remains solely in the memory of elderly people living in remote rural areas (Dimelu et al., 2014).

African indigenous religious values and practices can also serve as a response to climate change. African traditional religion is very close to nature, with structures, practices and sanctions that can effectively protect the environment (Nkechi et al., 2016). Sacred forests, for example, have special place and significance. Often, farming and hunting is prohibited there. Such beliefs and practices can serve as alternative tools in mitigating climate change in Nigeria, such as countering deforestation (Nkechi et al., 2016).

Agricultural education and extension curriculums should incorporate the knowledge and experiences of rural people, indigenous peoples and co-learning (such that extension agents also learn from others). This would help farmers to develop skills to address the effects of climate change (Dimelu et al., 2014). Policy makers should also consider **mainstreaming indigenous values and practice into policy guidelines** to address climate change issues. This would allow for more comprehensive measures (Nkechi et al., 2016).

Assessing local knowledge, whether indigenous or not, is important. In Warri, Nigeria, for example, community urban risk assessments revealed that Warri residents had valuable knowledge about flooding in the area – causes and local community adaptation choices

(Odemerho, 2014). The input of local knowledge can foster greater community acceptance and involvement in the implementation of flood management solutions arising from it (Odemerho, 2014). Local knowledge can be relied upon to develop a well-formulated grassroots adaptation strategy for urban flood risk management for resiliency, which can become the base for a successful national policy for action (Odemerho, 2014).

Institutional capacity

The government in Nigeria as well as different agencies have engaged in various efforts to combat climate change and its impacts, particularly in the agricultural sector which is central to the country's economy and wellbeing of its citizens (Ifeanyi-obi and Nnadi, 2014). Results achieved to date are poor, however, including ongoing agricultural losses despite access to weather information. This is a strong indication that **the effort of the government and other agencies is yet to be adequate (**Ifeanyi-obi and Nnadi, 2014).

Institutional capacity building (the long-term, ongoing process of enhancing the operating environment, knowledge, skills and access to information required by an institution to perform its functions) is necessary for all institutional stakeholders engaged in climate change adaptation in Nigeria (BNRCC, 2011). This includes Federal and State Government Ministries and agencies, Local Government Departments, the organised private sector, and civil society organisations. The House Committee on Climate Change was established to step-up advocacy across the media, civil society, private sector and government (Olapido, 2010). The aim of institutional or organisational capacity building is to enable these actors and their personnel to be able to develop and implement policies, programmes, projects and other measures to address climate change, within the context of good governance (BNRCC, 2011).

The implementation of effective adaptation response strategies requires **strengthening specialised climate agencies**, particularly the Special Climate Change Unit in the Federal Ministry of Environment (Olapido, 2010). There is also a **need for new institutions**, such as Public-Private-Partnerships organised along value chain lines, which can take research findings into the field and help smallholder farmers adapt to a changing climate (Avanlade et al., 2017). Cooperatives and other limited trades organisational opportunities can also contribute to supporting productive farming livelihoods (Idowu et al., 2011).

5. References

Abdussalam, A. F. et al. (2014). The impact of climate change on meningitis in Northwest Nigeria: An assessment using CMIP5 climate model simulations. *AMS100*. https://journals.ametsoc.org/doi/full/10.1175/WCAS-D-13-00068.1

Abraham, T. W. and Fonta, W. M. (2018). Climate change and financing adaptation by farmers in Northern Nigeria. *Financial Innovation,* 4(11). https://link.springer.com/article/10.1186/s40854-018-0094-0

Abdulkadir, A. et al. (2017). Climate change and its implications on human existence in Nigeria: a review. *Bayero Journal of Pure and Applied Sciences*, 10(2), 152-158. https://www.ajol.info/index.php/bajopas/article/viewFile/170772/160195

Achike, A. I. et al. (2019). Green house gas emission determinants in Nigeria: Implications for trade, climate change mitigation and adaptation policies. https://trapca.org/wp-content/uploads/2019/02/TWP1211-Green-house-gas-emissions-determinants-in-Nigeria-implications-for-trade-climate-change-mitigation-and-adaptation-policies.pdf

Ajaero, I., & Anorue, L. (2018). Newspaper framing and climate change mitigation in Nigeria and Ghana. *African Population Studies,* 32(2), 4228-4238. https://doi.org/10.11564/32-2-1195

Akande, A. et al., (2017). Geospatial Analysis of Extreme Weather Events in Nigeria (1985–2015) Using Self-Organizing Maps. *Advances in Meteorology*. https://doi.org/10.1155/2017/8576150

Akeh, G.I. and Mshelia, A.D. (2016). Climate change and urban flooding: Implications for Nigeria's built environment. https://www.preventionweb.net/publications/view/50865

Akinbami, C. A. O. et al., (2019). Exploring potential climate-related entrepreneurship opportunities and challenges for rural Nigerian women. *Journal of Global Entrepreneurship Research* 9(19), https://doi.org/10.1186/s40497-018-0141-3

Akuru, U.B. et al. (2017). Towards 100% renewable energy in Nigeria. Renewable and Sustainable Energy Reviews 71, 943–953. http://dx.doi.org/10.1016/j.rser.2016.12.123

Amadi, S.O. and Udo, S.O. (2015). Climate change in contemporary Nigeria: An empirical analysis of trends, impacts, challenges and coping strategies*. IOSR Journal of Applied Physics*, 7(2), 1-9. http://www.iosrjournals.org/iosr-jap/papers/Vol7-issue2/Version-3/A07230109.pdf

Amanchukwu, R. N. et al. (2015). Climate change education in Nigeria: The role of curriculum review. *Education*, 5(3): 71-79. https://www.researchgate.net/profile/Nwachukwu_Prince_Ololube/publication/283081778_Climate_Change_Education_in_Nigeria_The_Role_of_Curriculum_Review/links/56292c5508ae518e347c967b/Climate-Change-Education-in-Nigeria-The-Role-of-Curriculum-Review.pdf

Amobi, D. and Onyishi, T. (2015). Governance and climate change in Nigeria: A public policy perspective. *Journal of Policy and Development Studies*, 9(2), 199-210. https://www.arabianjbmr.com/pdfs/JPDS_VOL_9_2/17.pdf

Anabaraonye, B. et al. (2019). Educating farmers and fishermen in rural areas in Nigeria on climate change mitigation and adaptation for global sustainability*. International Journal of*

Scientific & Engineering Research, 10(4),1391-1398. https://www.ijser.org/researchpaper/Educating-Farmers-and-Fishermen-in-Rural-Areas-in-Nigeria-on-Climate-Change-Mitigation-and-Adaptation-for-Global-Sustainability.pdf

Ayanlade, A. et al. (2017). Comparing smallholder farmers' perception of climate change with meteorological data: A case study from southwestern Nigeria. *Weather and Climate Extremes* 15, 24–33. http://dx.doi.org/10.1016/j.wace.2016.12.001

BNRCC (Building Nigeria's Response to Climate Change). (2011). *National adaptation strategy and plan of action on climate change for Nigeria* (NASPA-CCN). Prepared for the Federal Ministry of Environment Special Climate Change Unit. http://csdevnet.org/wp-content/uploads/NATIONAL-ADAPTATION-STRATEGY-AND-PLAN-OF-ACTION.pdf

Dimelu, M. U. et al. (2014). Challenges In building climate change mitigation and adaptation capacity of extension professionals in Nigeria. *PAT June*, 10(1), 110-122. https://pdfs.semanticscholar.org/82c2/4dfe13159cd47be90c418d2c67b087f69991.pdf

Dioha, M. O. and Emodi, N. V. (2018). *Energy-climate dilemma in Nigeria: Options for the future*. IAEE Energy Forum. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=108&ved=2ahUKEwihv4iA2-7kAhVoc98KHWNKDtw4MhAWMDl6BAgQEAI&url=https%3A%2F%2Fwww.iaee.org%2Fen%2Fpublications%2Fnewsletterdl.aspx%3Fid%3D465&usg=AOvVaw3qHlxFJnRFCXox9HBg4d-I

Duru, N. P. and Emetumah, C. F. (2016). Evaluating the effects of information literacy on climate change awareness among students in Imo State University. *Archives of Current Research International*, 4(3), 1-10. https://www.researchgate.net/profile/Faisal_Emetumah/publication/305177025_Evaluating_the_Effects_of_Information_Literacy_on_Climate_Change_Awareness_among_Students_in_Imo_State_University/links/5784051008aee45b8442ef66/Evaluating-the-Effects-of-Information-Literacy-on-Climate-Change-Awareness-among-Students-in-Imo-State-University.pdf

Ebele, N. E. and Emodi, N. V. (2016). Climate change and its impact in Nigerian economy. *Journal of Scientific Research & Reports*, 10(6), 1-13. http://www.journaljsrr.com/index.php/JSRR/article/view/21917/40737

Elias, P. and Omojola. A. (2015). Case study: The challenges of climate change for Lagos, Nigeria. *Current Opinion in Environmental Sustainability*, 13, 74–78. https://reader.elsevier.com/reader/sd/pii/S1877343515000214?token=157FC47FCE33B92E5012D43084678311AECF686653F471D31E9469543A83864E8ABB5EDF3453A32B1ECA8EFDAFEB9F59

Elisha, I. et al. (2017). Evidence of climate change and adaptation strategies among grain farmers in Sokoto State, Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology* (IOSR-JESTFT), 11(3), 1-7. http://www.iosrjournals.org/iosr-jestft/papers/vol11-issue%203/Version-2/A1103020107.pdf

Elum, Z. A. and Momodu, A. S. (2017). Climate change mitigation and renewable energy for sustainable development in Nigeria: A discourse approach. *Renewable and Sustainable Energy Reviews* 76, 72–80. http://dx.doi.org/10.1016/j.rser.2017.03.040

Elum, Z. A. and Simonyan. J. B. (2016). Analysis of Nigerian insurers' perceptions of climate change, *SAJEMS NS*, 19(4), 549-561. http://dx.doi.org/10.17159/2222-3436/2016/v19n4a6

Elum, Z. A. et al., (2017). Climate change mitigation: the potential of agriculture as a renewable energy source in Nigeria. *Environmental Science and Pollution Research*, 24, 3260–3273. https://www.ncbi.nlm.nih.gov/pubmed/27933500

Enete IC (2014). Impacts of climate change on agricultural production in Enugu State, Nigeria. *Journal of Earth Science & Climatic Change*, 5(9), 234. https://www.omicsonline.org/open-access/impacts-of-climate-change-on-agricultural-production-in-enugu-state-nigeria-2157-7617.1000234.php?aid=32633

Fashae, O. and Onafeso, D. (2011). Impact of climate change on sea level rise in Lagos, Nigeria. *International Journal of Remote Sensing*, 32(24), 9811-9819. https://www.researchgate.net/publication/233199496_Impact_of_climate_change_on_sea_level_rise_in_Lagos_Nigeria

Federal Government of Nigeria. (2013). *Nigeria Post-Disaster Needs Assessment – 2012 Floods*. https://www.gfdrr.org/sites/gfdrr/files/NIGERIA_PDNA_PRINT_05_29_2013_WEB.pdf

Federal Ministry of Environment (2014). United Nations Climate Change Nigeria. National Communication (NC). NC 2. 2014. https://unfccc.int/sites/default/files/resource/nganc2.pdf

Hansen, J.W. et al. (2017). *A roadmap for evidence-based insurance development for Nigeria's farmers*. Research Program on Climate Change, Agriculture and Food Security (CCAFS). https://cgspace.cgiar.org/bitstream/handle/10568/89444/CCAFS_WP218.pdf

Ideki, O. and Weli, V.E. (2019) Analysis of rainfall variability using remote sensing and GIS in North Central Nigeria. *Atmospheric and Climate Sciences*, 9, 191-201. https://doi.org/10.4236/acs.2019.92013

Idowu, A. A. et al. (2011). Impact of Climate Change in Nigeria. *Iranica Journal of Energy & Environment*, 2(2), 145-152. https://www.researchgate.net/publication/228459699_Impact_of_Climate_Change_in_Nigeria

Ifeanyi-obi, C.C. and Nnadi, F.N. (2014). Climate change adaptation measures used by farmers in Southsouth Nigeria. *Journal of Environmental Science, Toxicology and Food Technology*, 8(4). https://pdfs.semanticscholar.org/a63d/22bf8b8ebde892a7c9d761ee1653e0e11df6.pdf

Jellason, N. P. et al. (2019). Climate change perceptions and attitudes to smallholder adaptation in Northwestern Nigerian Drylands. *Social Science*, 8(31). https://app.dimensions.ai/details/publication/pub.1111649369?and_facet_journal=jour.1137264

Madu, I. A. (2016). *Rurality and climate change vulnerability in Nigeria: Assessment towards evidence based even rural development policy*. Paper presented at the 2016 Berlin Conference on Global Environmental Change, 23-24 May 2016 at Freie Universität Berlin. https://pdfs.semanticscholar.org/508b/94cab07b84a703b44eca1089326cc98d7495.pdf?_ga=2.154518008.112403230.1572433568-162569160.1557482164

Madu, I. A. (2012). *Spatial vulnerability of rural households to climate change in Nigeria: Implications for internal security*. Robert S. Strauss Center for International Security and Law at

The University of Texas at Austin. https://www.strausscenter.org/research-reports?download=105:spatial-vulnerability-of-rural-household-to-climate-change-in-nigeria

Matemilola, S. (2019). Mainstreaming climate change into the EIA process in Nigeria: Perspectives from projects in the Niger Delta Region. *Climate*, *7*(2), 29. https://doi.org/10.3390/cli7020029

NEST (2011). *Gender and climate change adaptation: Tools for community-level action in Nigeria*. Ibadan, Nigeria: Nigerian Environmental Study/Action Team (NEST) – BNRCC. https://genderinsite.net/sites/default/files/BNRCC-Gender-Toolkit.pdf

Nkechi, O. et al. (2016). Mitigating climate change in Nigeria: African traditional religious values in focus. *Mediterranean Journal of Social Sciences,* 7(6), 299-308. https://www.mcser.org/journal/index.php/mjss/article/view/9612

Nnadi, O. I. et al. (2019). Impacts of variability and change in rainfall on gender of farmers in Anambra, Southeast Nigeria. *Heliyon 5*. https://doi.org/10.1016/j.heliyon.2019.e02085

Nzeadibe, T. C. (2011). *Climate change awareness and adaptation in the Niger Delta Region of Nigeria*. African Technology Policy Studies Network. Working paper, no. 57. Nairobi: Published by the African Technology Policy Studies Network. https://atpsnet.org/wp-content/uploads/2017/05/wps57.pdf

Odemerho, F. O. (2014). Building climate change resilience through bottom-up adaptation to flood risk in Warri, Nigeria*. Environment and Urbanisation*, 27(1), 139-160. https://journals.sagepub.com/doi/10.1177/0956247814558194

Ogbuabor, J. E. and Egwuchukwu, E. I. (2017). The impact of climate change on the Nigerian economy. *International Journal of Energy Economics and Policy*, 7(2), 217-223. https://dergipark.org.tr/en/download/article-file/361739

Okoroh, J. P. et al., (2016) Climate Change Mitigation and Adaptation Strategies Used by Farmers in Imo State, Nigeria. *Journal of Agricultural Extension,* 20(2), 130-142. http://dx.doi.org/10.4314/jae.v20i2.10

Olaniyi, O. A. et al. (2013). Review of climate change and its effect on Nigeria ecosystem. *International Journal of African and Asian Studies*, 1, 57. https://pdfs.semanticscholar.org/f9bd/9c18dfb45724a2a946a3854c756e62ad9f6b.pdf

Olapido, E. (2010). *Towards enhancing the adaptive capacity of Nigeria: a review of the country's state of preparedness for climate change adaptation*. Heinrich Böll Foundation Nigeria. https://ng.boell.org/sites/default/files/uploads/2013/10/nigeria_prof_oladipo_final_cga_study.pdf

Oluwole, J. et al. (2016). Assessment of level of use of climate change adaptation strategies among arable crop farmers in Oyo and Ekiti States, Nigeria. *Journal of Earth Science & Climatic Change*, 7, 369. https://www.omicsonline.org/open-access/assessment-of-evel-of-se-of-climate-change-adaptation-strategiesamong-arable-crop-farmers-in-oyo-and-ekiti-states-nigeria-2157-7617-1000369.php?aid=80244

Onwutuebe, C. J. (2019). Patriarchy and Women Vulnerability to Adverse Climate Change in Nigeria. https://doi.org/10.1177/2158244019825914SAGE

Osuafor, A. M. and Nnorom, N.R. (2014). Impact of Climate Change on Food Security in Nigeria. AFRREV STECH, 3(1). https://www.ajol.info/index.php/stech/article/view/103132

Otitoju. M.A. and Enete, A.A. (2016). Climate change adaptation: Uncovering constraints to the use of adaptation strategies among food crop farmers in South-west, Nigeria using principal component analysis (PCA). *Cogent Food & Agriculture*, 2. http://dx.doi.org/10.1080/23311932.2016.1178692

Ozor, N. et al. (2012). A framework for agricultural adaption to climate change in Southern Nigeria. *International Journal of Agriculture Sciences,* 4(5), 243-251. http://centaur.reading.ac.uk/28884/1/13425102734_5_4_IJAS.pdf

Sayne, A. (2011). *Climate change adaptation and conflict in Nigeria*. Washington, DC: USIP. https://www.usip.org/sites/default/files/Climate_Change_Nigeria.pdf

Shiru, M.S., et al. (2018). Trend Analysis of Droughts During Crop Growing Seasons of Nigeria. *Sustainability*, 10(3), 871. https://doi.org/10.3390/su10030871

Solomon, E. and Edet, O. G. (2018) Determinants of climate change adaptation strategies among farm households in Delta State, Nigeria. *Current Investigations in Agriculture and Current Research*, 5(3). https://lupinepublishers.com/agriculture-journal/fulltext/determinants-of-climate-change-adaptation-strategies-among-farm-households-in-delta-state-nigeria.ID.000213.php

Yahaya, O. and Nwabuogo, O. E. (2016). Renewable energy deployment as climate change mitigation in Nigeria. *Global Journal of Human-Social Science* 16(4). https://globaljournals.org/item/6195-renewable-energy-deployment-as-climate-change-mitigation-in-nigeria

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About this report

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