Article DOI: https://doi.org/10.37284/ajccrs.2.1.1583

African Journal of Climate Change and Resource Sustainability
ajccrs.eanso.org
Volume 2, Issue 1, 2023
Print ISSN: 790-962X | Online ISSN: 790-9638
Title DOI: https://doi.org/10.37284/2790-9638

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Carbon Emission, Impact on Climate and Mitigation Strategies in Nigeria

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Article DOI: https://doi.org/10.37284/ajccrs.2.1.1583

Date Published:

22 November 2023

Keywords:

Rainfall, Flooding, Greenhouse Gases, Developing Countries, Climate Smart.

ABSTRACT

Climate change is a global issue, and organizations worldwide have been gathering to develop strategies to reduce global warming and mitigate its effects. Nigeria is not left out as the country faces changes in rainfall patterns, rising temperatures, rising sea levels, flooding, drought and desertification, and land degradation. This review paper investigated the current state of carbon emissions in the country and identified the major contributors. Additionally, the paper highlighted the consequences of carbon emissions and its effects on climate in the different sectors and parts of the country. Furthermore, the review paper suggested various mitigation and adaptation strategies employed with case studies and those that should be applied to decrease emissions at different levels. Lastly, it also discussed the participation of developed countries in climate financing to ensure a green climate. Urgent actions by governments to invest in climate education and renewable energy are required.

APA CITATION
Adebisi, J. K. & Adebisi-Adelani, O. (2023). Carbon Emission, Impact on Climate and Mitigation Strategies in Nigeria *African Journal of Climate Change and Resource Sustainability*, *2*(1), 197-209. https://doi.org/10.37284/ajccrs.2.1.1583.

CHICAGO CITATION
Adebisi, Joy Kehinde and Oluyemisi Adebisi-Adelani. 2023. "Carbon Emission, Impact on Climate and Mitigation Strategies in Nigeria". *African Journal of Climate Change and Resource Sustainability* 2 (1), 197-209. https://doi.org/10.37284/ajccrs.2.1.1583

HARVARD CITATION
Adebisi, J. K. & Adebisi-Adelani, O. (2023) "Carbon Emission, Impact on Climate and Mitigation Strategies in Nigeria", *African Journal of Climate Change and Resource Sustainability*, 2(1), pp. 197-209. doi: 10.37284/ajccrs.2.1.1583.

IEEE CITATION
J. K., Adebisi & O. Adebisi-Adelani. "Carbon Emission, Impact on Climate and Mitigation Strategies in Nigeria", AJCCRS, vol. 2, no. 1, pp. 197-209, Nov. 2023.

MLA CITATION
Adebisi, Joy Kehinde & Oluyemisi Adebisi-Adelani. "Carbon Emission, Impact on Climate and Mitigation Strategies in Nigeria". *African Journal of Climate Change and Resource Sustainability*, Vol. 2, no. 1, Nov. 2023, pp. 197-209, doi:10.37284/ajccrs.2.1.1583.

INTRODUCTION

Climate change is caused by various factors, with human activity directly or indirectly being a major contributor. Anthropogenic activities, such as industrialization, burning of fossil fuels, urbanization, gas flaring, and agriculture, emit

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significant amounts of greenhouse gases (Atedhor, 2023). These activities cause the release of greenhouse gases (GHGs) into the atmosphere leading to warming. Therefore, rising GHGs emissions are generally recognized as the main driver of climate change (Gavurova et al., 2021). However, certain human activities reduce carbon sinks, such as deforestation, land use changes, water pollution, and agricultural practices, also contribute to the problem. The evidence is clear that human factors are responsible for ongoing climate change and global warming (IPCC 2007).

The highest contributors to greenhouse gases are carbon dioxide (CO2), chlorofluorocarbons (CFCs), methane (CH_4), and nitrous oxide (N2O). CO_2 has the highest rate of emission followed by CH4, CFCs, N_2O, and others like halons, tropospheric ozone, and sulfur hexafluoride (SF6). Although CO2 is the highest contributor, it has a lower potency. For example, a gram of CH4 has 23 times higher effects than the same volume of CO2 and a gram of SF6 has 22,000 times the effects of CO2 concerning tropospheric ozone depletion (Msumba, 2006). The lifetime of CO2 in the atmosphere varies but is low compared to others. However, it is a concern due to its heavy release in almost all anthropogenic activities when compared to other greenhouse gases.

Organizations worldwide have been gathering to develop strategies to reduce global warming and mitigate its effects. Nigeria is is also affected by these changes, it is experiencing rising temperatures, variable rainfall, rise in the sea level, flooding, drought and desertification, land degradation, frequent extreme weather events, loss of biodiversity, and so on. (Elisha et al., 2017). The intensity and length of rainfall in Nigeria have increased, causing flooding in various areas (Enete, 2014). Furthermore, rainfall is expected to increase in future, and the flooding and submersion of coastal lands will be worsened by rising sea levels (Akande et al., 2017). Droughts have also become a norm in Nigeria, and are expected to continue in Northern Nigeria, due to the decline in precipitation and a rise in temperature

Climate change affects different areas in varying ways; some parts of the world become colder or warmer, while others become more flooded or arid. With a tropical climate, Nigeria experiences low precipitation in the North and high precipitation in parts of the Southwest and Southeast. As a result, the North is susceptible to aridity, drought, and desertification, while the South is prone to flooding and erosion (Akande et al., 2017). Beyond these changes, there is also an impact on ecosystem services which can be seen in the different sectors such as Agriculture. Onwutuebe (2019) noted that over 70 percent of the country's population practices agriculture as their primary occupation and source of livelihood. These agricultural products are mostly dependent on rainfall, and the variability experienced in recent times has been a concern to many farmers while in some other regions, flooding is destroying agricultural produce (Ogbuabor & Egwuchukwu, 2017). Other sectors that have been affected are but are not limited to the health, Economy, Energy supply, and Forestry.

The objectives of this review paper are to:

- Analyse the current state of carbon emissions in the country, including the identification of the main contributors and the amount they emit.
- Identify the impacts of carbon emissions on climate and their effects on related sectors.
- Identify mitigation strategies that could be applied to decrease emissions at different levels.

STATE OF CARBON EMISSION

Nigeria prides itself on having the largest economy and population of any African country. By the end of the century, Nigeria is projected to overtake China as the world's second most populous country with a current population of 223.8 million (World Population Prospects, 2022). In 2019, it was Africa's second-highest emitter of greenhouse gases, after South Africa. The country's economy is solely based on oil and gas exports. Profits from fossil fuels currently account for 93% (resource trade. earth) of

Article DOI: https://doi.org/10.37284/ajccrs.2.1.1583

Nigeria's total export revenue. Oil and gas production in Nigeria has been connected to significant societal inequalities and environmental catastrophes. Right from her discovery of fossil fuel in 1956, there has been a rise in the emission of Carbon. Nigeria began diversifying its economy in 1960 after gaining independence, with sectors including industry, manufacturing, agriculture, finance, and tourism (Sulaiman & Abdul-Rahim, 2018). However, these sectors rely heavily on fossil fuels for energy, leading to increased CO2 emissions.

Additionally, human activities such as deforestation, bush burning, ranching, and construction contribute to rising atmospheric GHG levels (Ogundipe et al., 2020). In addition, carbon releases increase with economic expansion in most African countries, this implies that as the population increases in African countries, agriculture, fossil energy consumption, and waste generation will likely expand and as a result trigger higher greenhouse gas emission. It is therefore feared that emissions from the continent of Africa would increase significantly (Ayompe et al., 2021). Most of Nigeria's energy consumption is from non-renewable sources such as oil and gas, resulting in high carbon emissions. This has led researchers and policymakers to investigate the connection between economic growth and environmental pollution caused by carbon dioxide (CO2) emissions. Due to global warming and concerns over limited energy resources, CO2 emissions are a significant contributor (Mohammed et al., 2013).

Nigeria is highly dependent on fossil fuel, in actual fact, an increase in the price of oil and gas products means an increase in the price of almost all commodities in the country, as this sector drives most of the services rendered. The state of the economy is a very important factor that leads to the deforestation of the forests to make money. Considering the increasing population of Nigeria and her heavy dependence on fossil fuel as a major source of energy consumption, the available forest coverage is not enough to absorb greenhouse gas emissions (Owolabi, 2019). In the report of Ogundipe et al. (2020), they found that there is a direct relationship between fossil fuel consumption and carbon emissions in Nigeria. A 1% increase in fossil fuel consumption results in a 78% increase in carbon emissions. The country's widening population and lack of access to clean energy sources have increased dependence on non-renewable fuels, dirty sources mostly for household needs of cooking and heating, business, and industrial needs, leading to dangerous gaseous emissions. More than 70% of Nigerians living in rural areas depend on wood (mostly referred to as Firewood) and the country uses more than 50 million tonnes of firewood annually (Oyedepo, 2014). This has been a major cause of deforestation in the country which has led to a decrease in the number of trees that can trap these greenhouse gases.

As of 2021, the carbon emission in a database published by Ritchie et al. (2020) in "Our World Data" the state of emission from fossil fuels in Nigeria per capita was about 0.64 tons of CO_2 released per head in a country with over 204 million persons just from fossil fuel, other ways by which Carbon can be emitted were not included in the above. The annual rate of emission is shown in (*Figure 1*). This data only captured emissions from fossil fuels but did not include other sources like land use change. To obtain data on CO_2 emissions from deforestation and bush burning or fire cases in Nigerian forests, data from the Global Forest Watch observed that in 2010 Nigeria's natural forests covered 12% of the land area, totalling 10.9 million hectares. However, in 2022, the country lost 105 thousand hectares of natural forest due to land use change, resulting in 69.7 million tons of CO_2 emissions (*Figure* 2).

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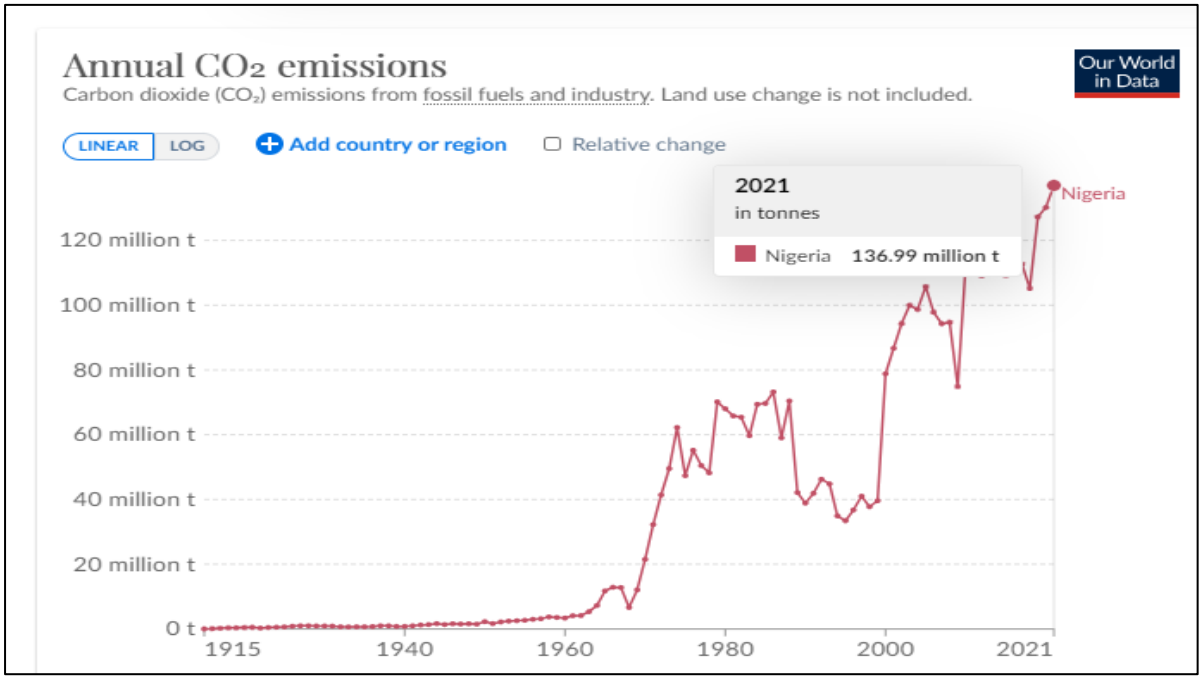
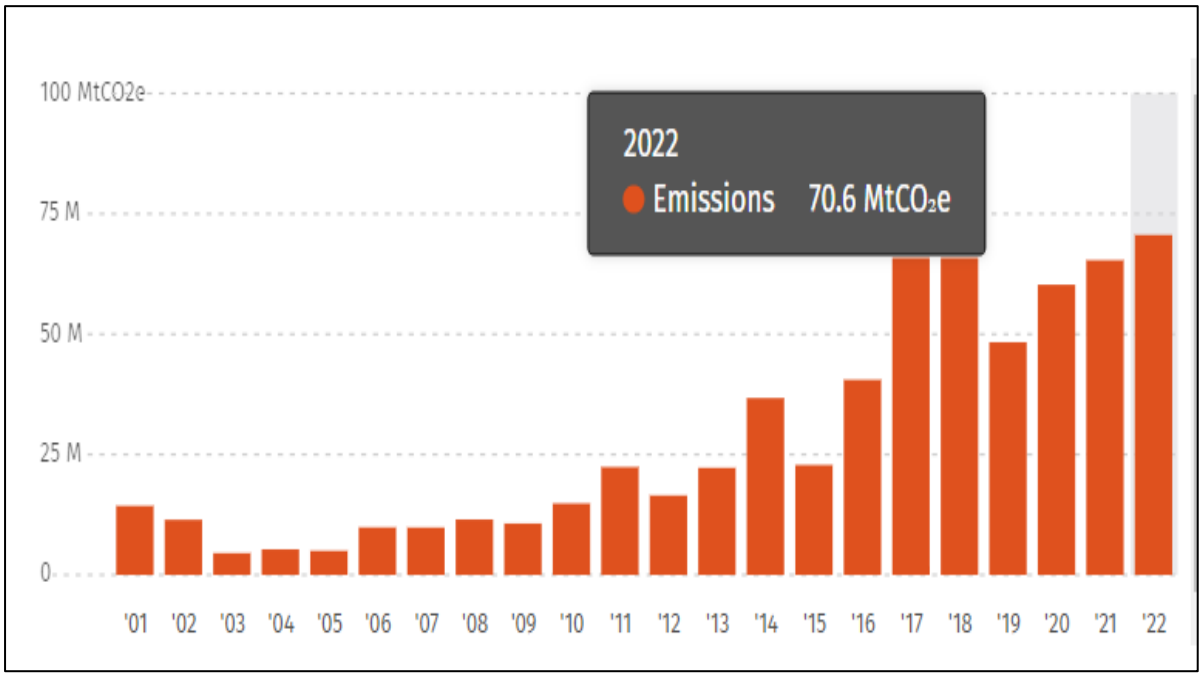
Figure 1: Annual rate of CO2 emission



Source: Our World in Data (Ritchie et al., 2020)

Figure 2: Emission from land use change



Source: Global Forest Watch (2023)

Charcoal production is another major source of emission in Nigeria. Charcoal and fuel wood are commonly used as energy sources for household cooking (Tunde et al. 2013). Nigeria produces the most charcoal in Africa and ranks second in the world (FAO, 2014). Moreover, there has been a consistent increase in annual charcoal production in Nigeria (*Figure 3*). In a report by Sakala et al. (2023) on the effect of charcoal production on carbon cycling in Sub-Sahara Africa, they noted that the increasing population and urbanization in the region are expected to drive up the demand for charcoal by about 7% in the future. This can lead to deforestation and degradation of forests and

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other ecosystems thus threatening carbon storage. It is estimated that charcoal production contributes up to 7% of the total deforestation in tropical ecosystems each year, resulting in 71.2 million tonnes of CO2 and 1.3 million tonnes of CH4 emissions (Chidumayo & Gumbo, 2013). Africa's charcoal production has increased sixfold from 5.5 million tonnes in 1961 to 35.2 million tonnes in 2020 (FAO, 2022). After considering 6 different biomes that included a tropical rain forest which is typical of Nigeria, they concluded that even though high biomass biomes can produce a lot of charcoal, they are at a greater risk of losing more carbon and it takes longer for their above-ground carbon stocks to recover compared to lower biomass biomes fully. The prolonged recovery period observed means that the charcoal production practices currently used in Sub-Saharan Africa are not environmentally sustainable. This is especially true for tropical rainforests and montane forests where it takes longer for vegetation and litter carbon stocks to recover (Sakala et al., 2023)

Figure 3: Nigeria's Charcoal Production from 1990 to 2013.

Year	Production in metric tons
2013	4,193,352
2012	4,107,172
2011	4,022,763
2010	3,940,089
2009	3,850,113
2008	3,762,200
2007	3,676,300
2006	3,592,327
2005	3,510,292
2004	3,420,800
2003	3,333,589
2002	3,248,602
2001	3,165,781
2000	3,085,072
1999	3,006,209
1998	2,922,971
1997	2,872,535
1996	2,763,475
1995	2,646,794
1994	2,542,902
1993	2,420,873
1992	2,314,797
1991	2,210,445
1990	2,131,778

Source: James et al. (2019)

IMPACT ON CLIMATE

The emission of carbon and other greenhouse gases has an impact on the climate which has been reviewed by different authors Adebayo et al. (2012) studied the changes in the agro-climatic condition in the northern part of Nigeria. They observed that the mean temperature is increasing, annual rainfall is decreasing, the onset date of rain is increasing (delayed onset), the cessation date of rains is decreasing (early cessation), and while length of the rainy season is reducing. Similarly, monthly rainfall in May, July, August, and October is decreasing while monthly rainfall in June and September is increasing. The decrease in May, July, and August rainfall leads to the persistence of dry spells in the state especially in July and August. This report also revealed that floods usually accompanied an increase in rainfall in September in recent years. Also, Odjugo (2010) extensively studied the climate change impact in Nigeria, considering its implication in diverse

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areas like meteorological variation experienced providing clear evidence of climate change because of the increasing rainfall in most coastal areas and decreasing rains in the continental interiors. He observed that the number of rain days dropped by 53% in north-eastern Nigeria and 14% in the Niger Delta Coastal areas.

Furthermore, he revealed that ecological implications that arise due to sea-level rise in coastal areas could lead to sea incursion, invasion, and destruction of mangrove ecosystems, coastal wetlands, and coastal beaches. The worst impact is population displacement, which may result in a communal crisis experienced by those in Lagos, Bayelsa, Delta, and Cross River States in Nigeria. Beyond this, other ecological implications are desertification and drought amongst others. Likewise, Bello et al. (2012) reported the impact on agriculture and food security; they deduced that climate change is responsible for a decrease in Nigeria's arable land cultivation. The coastal plains are being affected by sea incursion and the desert encroachment, which is accompanied by sand dunes, is taking away farmland and grazing areas from farmers. Additionally, droughts and decreased rainfall are causing shorter growing seasons, leading to crop failure and a shortage of food. The effects of climate change are already affecting livelihood and will have greater effects in the future (Sylvester & Abdulquadir, 2015). In Bauchi State Nigeria, the impact can be seen in the production of Maize which is their forte; In Bauchi, maize is one of the most important cereals for both human and animal consumption (FAO, 2013).

Sowunmi (2010) indicated that maize requires temperature between 21 ^{o}C and 30 ^{o}C for optimum production. If the current trend of increased temperature persists, the production of maize in Bauchi will be greatly reduced if not impossible. Not only is the increase in temperature affecting food production but the drying up of wells was also observed by Sylvester and Abdulquadir (2015) to be partly related to the high rate of evaporation that has occurred in recent times due to the increase in temperature as supported by EPA and IPCC (2007). Moreover, research conducted by Adebisi-Adelani (2013) on the perception of farmers to climate change noted that farmers began to notice a decline in the production of Citrus and Tomato in the North-eastern part of Nigeria where they attributed it to flooding, in the Southwest, farmers attributed these changes to irregularity in rainfall pattern.

In the most recent years, a major challenge in Nigeria has been flooding, especially in the coastal areas the number of families displaced by flooding. Globally, floods are recognized as a regular and natural occurrence that has been increasing in magnitude over time. (Raikes et al. 2019). In Nigeria, the regularity and scope of occurrence of floods have greatly increased in recent years due to climate change especially in riverine communities (Buba et al., 2021). Flood is also the most expensive climate change-related event globally that has resulted in residual losses and damages (Robinson et al., 2021). According to a report by the Nigerian Meteorological Agency in 2012, there was a normal to above-normal amount of rainfall with high-intensity downpours during July, August, and September. This led to flooding across the country, with the most severe flooding occurring in the north-central and coastal states between September and mid-October. While some experts attribute the floods to natural hydrological systems, others suggest that climate change, caused by rising temperatures, may have played a role in the heavy precipitation, glacier melt, and ocean thermal expansion. (Olarenwaju et al., 2019).

In Nigeria, certain States in the coastal areas such as Lagos, Rivers, and Cross Rivers, as well as States that border the rivers like Benue, Kogi, and Anambra States are highly prone to floods. Climate change raises a variety of health issues. Climate change can be linked to higher temperatures, leading to increased production of several secondary pollutants, increasing the incidence of allergy and cardio-respiratory disorders as well as the mortality rate (Nwoke et al., 2009). In summary, the impact of carbon emissions does not end with just impacting the climate, it affects every other process such as Agriculture, food production, the human health.

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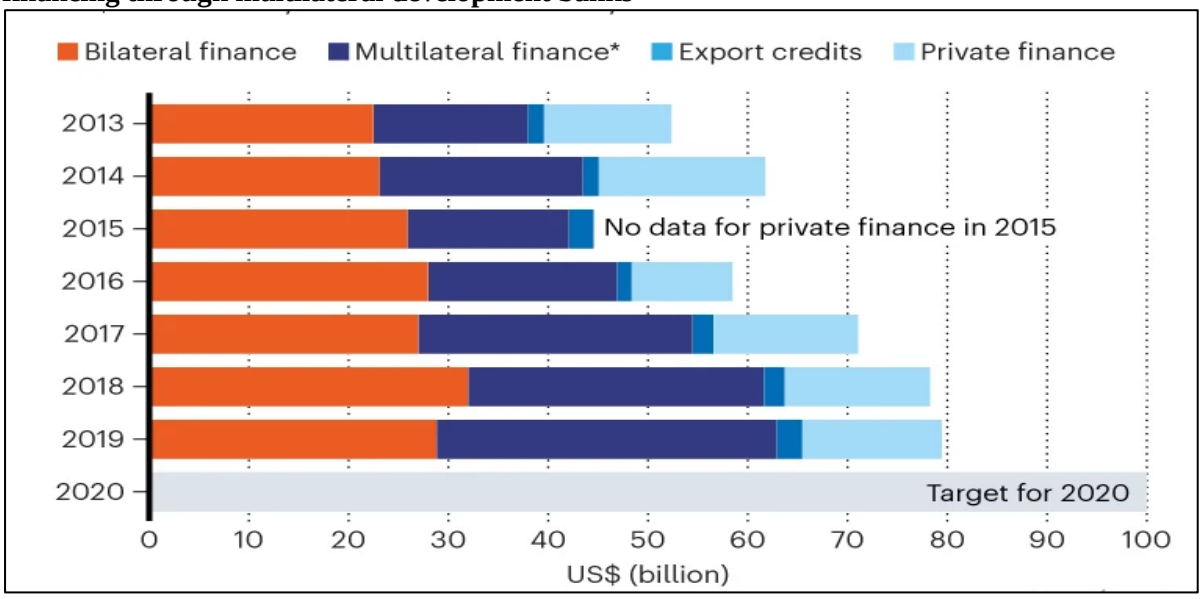
CLIMATE CHANGE MITIGATION

Climate change mitigation refers to human actions aimed at reducing greenhouse gas emissions in order to prevent global warming and the resulting increase in the Earth's temperature (Schulze et al., 2019). To achieve these several frameworks have been established to which Nigeria belongs they are, the 2015 Paris Agreement, the UN Framework Convention on Climate Change, as well as the Sustainable Development Goals all established to develop adaptation, mitigation, and resilience towards climate change (UN, 2022). Developing effective climate change mitigation strategies requires skills, education, knowledge, and resources to increase awareness and involve all stakeholders. Over the years, contribution has been made by developed countries to developing countries to combat climate change by 2020 as agreed in the Copenhagen Convention in 2009 to donate $ 100 billion yearly, but this target has not been met (UN, 2022). Climate financing by the developed countries as of 2019 showed that these countries are lagging behind concerning the pledge (*Figure 4*). The COVID-19 pandemic has made it harder for developed countries to fulfil their annual promise of providing $100 billion in climate finance to developing countries (Schalatek, 2021). Climate change mitigation cannot be done singlehandedly but through joint effort, it can be achieved. Studies have shown that the level of awareness of climate change phenomenon is still low in developing countries like Nigeria (Nzeadibe et al., 2010). It is necessary to reduce the usage of fossil fuels and implement policies on land use change to combat emissions. The following are Mitigation strategies that should be focused on in Nigeria:

Figure 4: Climate Financing provided by Developed countries from 2013, which includes financing through multilateral development banks*



Source: OCED, 2021

Renewable/Clean Energy

Renewable energy has been presented to the world as the energy source of the future for sustainable development since 1972. They include energy derived from wind, sun, bio-organic materials, and so on. In Nigeria, the energy sector is the most important sector for climate change mitigation. It is important to control the emission of greenhouse gases by moving towards renewable energy development. In a report by Power Technologies, Nigeria's power generation capacity stood at 7.5GW, with 15.6% of this generated by renewables, as of 2019. Conversely, 74.0% of the energy consumed in 2019 was produced by generators, and 40% of households own and use fuel-powered generators for at least 6.8 hours daily (Punch Newspape Nnodim, 2023). The use of renewable energy is currently in place

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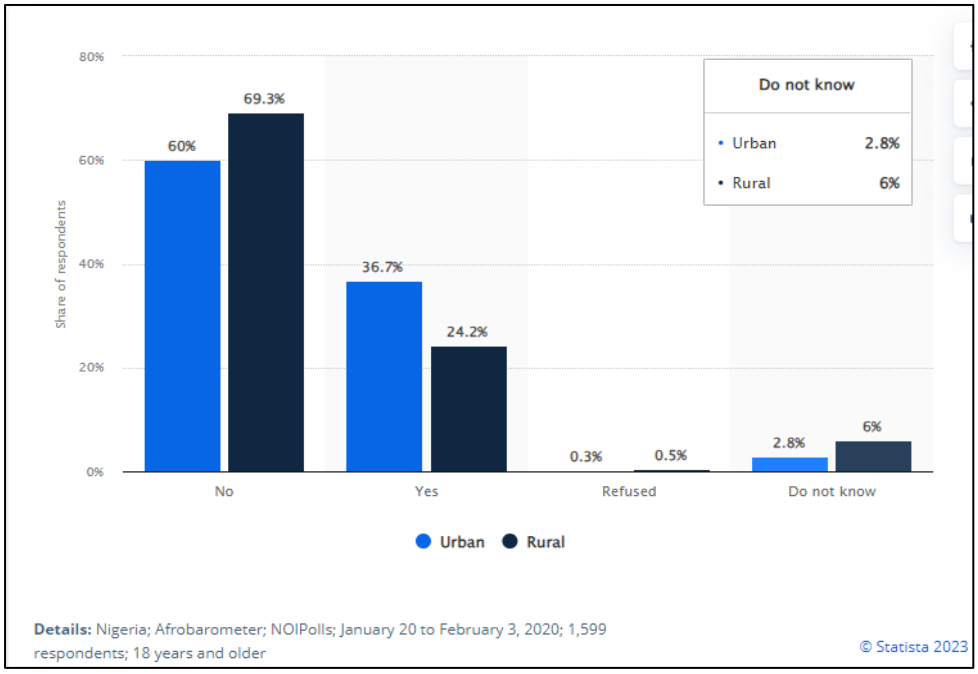
but it is insufficient, the development of solar energy is new with growing interest among elite citizens. Although Nigeria is making progress in renewable energy policy and legislation, few existing projects exist. (Elum & Momodu, 2017). The renewables report by IRENA shows that renewable energy sources can meet nearly 60% of Nigeria's energy demand in 2050. This could cut the country's demand for oil by 65% and natural gas by 40% and could see renewables account for 47% of total energy demand by 2030, and 57% by 2040, impressive figures for a country without an established history of renewable investment. Developing innovative financing schemes that will reduce the cost of low-carbon technologies for consumers in addition to making it a profitable project for investors is necessary (Dioha & Emodi, 2018).

Education, Lifestyle Choices, and Reforestation

A significant number of Nigerians are not aware of the events occurring around them (*Figure 5*), making it difficult for them to take action without knowledge. Nonetheless, some youths are taking action and raising awareness, albeit gradually. Government policies can also contribute to creating awareness and influencing the impact of their decision-making. For instance, many Nigerians are ignorant of the fact that it is cheaper to use solar energy sources than, using fuel power generators, the cost of maintenance and even fuel in itself is high. Awareness and campaigns should be targeted towards the reduction in the usage of fossil fuels. Advocating for a sustainable lifestyle choice among Nigerians is of utmost importance. These include less meat consumption, phasing out of inefficient appliances, and greater access to and use of public transportation, use of bicycles should be encouraged as so much considered as a means of transport. Policies that regulate the use of public transport with bad engines should be put in place. Public infrastructure and services for effective waste reduction also need to be encouraged (Onah et al., 2016). The rate of reforestation in Nigeria is only about 10 percent of the rate at which the Nigerian Natural Forest is being deforested (Elum & Momodu, 2017). There is an urgent need for more aggressive tree planting. Trees play a very important role in storing carbon, hence the need to reforest and afforest new areas. The role of implementing already established government policies cannot be overemphasized.

Figure 5: Awareness of Nigerians on the topic "climate change"



Source: Afrobarometer

Article DOI: https://doi.org/10.37284/ajccrs.2.1.1583

Climate Smart Agriculture

Given the effects of climate change on agriculture, farmers must adjust to these impacts while also implementing mitigation measures. African nations must incorporate both climate change adaptation and mitigation strategies into their plans and investments for agricultural development. (Nwajuiba et al., 2015). Climate Smart Agriculture (CSA) is not a new concept, but rather a collection of methods that aim to increase productivity sustainably, promote food security, and reduce carbon emissions (FAO, 2010). Agriculture is considered climate-smart when it adopts these practices. Climate-smart agriculture encourages the transformation of agricultural systems and policies, resulting in increased food production, improved food security, and affordable food, thereby reducing poverty while protecting the environment and building resilience against climate change.

Case Study 1

A study by Adebisi et al (2022) aimed to assess the usage of Climate-smart Agricultural practices (CSAP) in the north-central part of Nigeria. The study was carried out in the Kwara State (8º30'N and 5º00'E), Nigeria, in 2019. The State occupied a land area of about 32,500 km^2, a population of around 2.37 million persons and a density of 42.5 km^2, sixteen local government areas, and four main ethnic groups (Yoruba, Nupe, Fulani, and Baruba) (KSG 2013). This study used primary data collected through a structured questionnaire from farming households in a state that mainly practices subsistence farming. The respondents were selected using a three-stage sampling technique. Firstly, zones A and B were randomly selected out of the four agricultural zones in the state. Secondly, five villages were randomly selected from each zone using the Agricultural Development Project village listing. Lastly, nine farming households were randomly selected from a list of farming households generated in each village. In total, 90 respondents were interviewed for this study. The collected data were analysed using descriptive statistics, adaptation strategy use index, food security index, and logistic regression model. Descriptive statistics such as frequency, percentage tabulation, use of central tendency, and dispersion (mean, mode, median, and standard deviation) were used to describe the socio-economic and demographic characteristics of the respondent. It was observed that Crop rotation was the most adopted CSAP used in the study area and that 16.67 % of the respondents were low users, 53.33 % medium, and 30 % high users of CSAP. According to the research, the implementation of climate-smart agricultural practices (CSAP) has led to an improvement in food security among farming households. Out of the population, 58.9% are now food-secured, while 41.1% remain food insecure.

Case Study 2

A study by Onyeneke et al. (2017) was conducted on the use of CSA in the south-eastern region of Nigeria. The study was conducted in the five states of southeast Nigeria namely Abia, Anambra, Ebonyi, Enugu, and Imo States. Southeast Nigeria is in the rainforest ecozone of the country. Latitudes 5°N–6° N of the equator and longitudes 6°E and 8°E. The zone occupies a total land mass of 10,952,400 hectares with a population of 16,381,729 people (National Population Commission, 2006). The climate of the area is that of the tropical rainforest, which allows for the cultivation of food crops like yam, cassava, vegetables, rice, etc., and livestock production. For the study, they employed the cluster and multistage random sampling techniques. Firstly, they divided the area into five clusters, corresponding to the five States - Abia, Anambra, Ebonyi, Enugu, and Imo. Within each State, randomly selected two Local Government Areas (LGAs) and, from each LGA, two communities were randomly chosen. Finally, they randomly selected eight farmers from the list of farmers in each community, which was obtained from the extension agents working in those communities. In total, ten (10) Local Government Areas, twenty (20) communities, and one hundred and sixty (160) farmers were used for the study. The primary data collection instruments were a structured questionnaire and a focus group discussion guide. The questionnaire was designed

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to gather information on farmers' socioeconomic characteristics, their knowledge of climate-smart agriculture in the area, and their adoption of practices relevant to CSA.

Report from the focus groups identified the CSA practices employed by farmers in the areas such as mixed cropping, crop rotation, agroforestry, mulching, and cover cropping amongst others. It was observed that 73.75% of farmers used Cassava varieties that were suitable for flooding, while 71.80% of farmers engaged in mulching. This high usage of mulching can be attributed to its ability to protect soil against erosion, suppress weeds, increase water infiltration, and promote soil biological activities. Additionally, 58.75% of farmers practiced crop rotation, 73.75% engaged in agroforestry, and 63.75% used cover cropping. These practices have helped farmers in Nigeria adapt to climate change. There is a need to continue to promote these practices among farmers in Nigeria, ensuring food security.

CONCLUSIONS AND RECOMMENDATIONS

This study provides an overview of current emissions and their impact on the climate, as well as the steps being taken to create a sustainable system. It is important to note that the causes for emissions are based on the choices of individuals, for instance, the use of charcoal and fuel wood is more common among the low or middle-income class while the use of fossil fuel and other sources is common in industrial areas or cities. Also, case studies on the adaptation of farmers to the impact of climate change were presented in the study. This review clearly shows that global warming affects Nigeria, in addition to other countries. While Nigeria's carbon emissions are not as high as those of the US and UK, they are the second largest emitter in Africa. Due to Nigeria's poor economic status it is more difficult to cope with climate change consequences. Various authors have suggested mitigation strategies, but implementation is lacking. Government bodies and agencies have the bulk of responsibility for taking action, climate financing needs to be worked on, and also the need to ensure that the investments made annually to increase awareness, mitigate, and adapt to the warming climate are efficiently put to use. The government requires urgent action to contribute to global efforts in combating climate change. Deforestation among rural dwellers for fuel wood and coal is still challenging as many cannot afford to use other means for their domestic activities. Most importantly, individual citizens should own up to the responsibility of curbing the effects of climate change through a change of lifestyle, attitude, knowledge, and skills

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