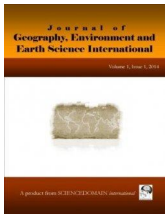

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Climate Change Adaptation and Mitigation in Ibadan, Oyo-State

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Authors' contributions

This work was carried out in collaboration between all authors. Author ASA wrote the abstract, introduction and the body of the manuscript. Authors PNM and OAO managed the plate, map and referencing and also contributed to the write-up of literature. All authors read and approved the final manuscript.

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ABSTRACT

Climate change poses major threat to Nigeria, particularly in the southwest region where Ibadan is a major city. There are several studies conducted at state, regional and national level but a continuous understanding of the knowledge and impact at a local level is required for appropriate interventions. Climate changes are caused either naturally or by human activities while the human activities pose major impact on the changes in climatic conditions thereby causing more harm to the developing countries such as Nigeria. Addressing climate change issues and promoting sustainability in the environment requires tangible progress in implementing mitigation and adaptation measures in the environment. This paper reviews the impacts of climate change on Ibadan and also discusses the adaptation and mitigation measures which must be implemented to prevent future damages. The populace of Ibadan should be continuously informed of the adaptive and mitigation measures so as to prevent future hazardous impact of climate change in their environment.

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Keywords: Climate change; impacts; mitigation; adaptation and environment.

1. INTRODUCTION

Over the years the issue of climate change has been a concern for the global community and it has gained much attention in recent time due to its progression, complexity and its undeniable influence on the environment. Climate change is real and indeed has major consequence on the environment which affects the socio economic and related sectors which includes biodiversity, water resources, food security, health, terrestrial and aquatic ecosystem (Amobichukwu and Egbinola 2013). Climate change, both frequent and intensified thunderstorms, incessant droughts, severe floods, destructive hurricanes, or monstrous tornadoes, has the capacity to affect several lives around the world. Some devastating events of climate change are the Kastina flood in July 2018 which claimed 44 lives, theextreme rainfall in Lagos on the 10th July, 2011 in which there was torrential rainfall for 14 hours produced 231 mm of rainfall; the 2011 floods in Lagos, Ibadan and Calabar that destroyed property, killed and rendered many people homeless; the 2010 Sokoto floods which washed away 20 villages, displaced 130,000 people, killed 6 persons, destroyed the Goronyo Dam, devastated farmlands, collapsed the major bridge linking Usumanu Danfodio University to Sokoto town; the March 2010 abnormal dust storm which enveloped Nigeria for about one week and led to multiple cancellation of flights nationwide; the 2012 floods in Makurdi, Lokoja, Yenogoa, the 2010 Pakistani floods which directly affected 20 million people through the destruction of property, livelihood and infrastructure, as well as, killing about 2,000 people, the historic Mississippi river floods of April/May 2011 (the likes of which has not been seen since 1937); the deadly tornado that struck Joplin, Missouri, U.S.A on May 24, 2011, killing 116 people in 20 minutes, injuring 400 others, and damaging about 2,000 homes, businesses, churches and a hospital; and it was the worst tornado in 60 years recorded in U.S.A. [1,2,3,4,5,6,7].

The Intergovernmental Panel on Climate Change (IPCC) which was constituted in 1988 by the World Metrological Organization (WMO) and the United Nation Environmental Program (UNEP) to make available authentic and authoritative information about climate change. Since then IPCC has reported adequate information on climate change and they are still working. Since 1990 till date they have been able to discover that climate change is majorly caused by human activities (anthropogenic). With over 100 years of climate data records, IPCC [8] has predicted that there is a strong relationship between emission of greenhouse gases and climate change and also between the sea level rise and global temperature which have severe consequences on the world at large.

Developing countries, in general, are said to be the most vulnerable to climate change due to their low adaptive capacity and growing dependence on resources that are sensitive to changes in climate which is synonymous to their limited financial capacity. Paradoxically, the same developing countries are also least prepared to tackle climate change.

Nigeria, of course, is one of the developing countries in sub-Saharan Africa that is currently experiencing more than its fair share of climate change impacts and is expected to be even more seriously affected by climate change largely due to its lack of preparedness and partly due to its low level of technology, widespread illiteracy and massive poverty (Imo Jackson Ekpoh 2014). General Circulation Models (GCMs) prediction for Nigeria suggest that climate change will the country through sea level rise along its coastline as well as alterations in the local climate which may witness more extreme rainfall in the south (leading to severe cases of flooding, erosion and mass wasting) and intensified aridity in the north (causing incessant droughts and desertification). These projections are consistent with current, real-time weather observations in Nigeria (Adesina and Odekunle, 2011; Odjugo, 2010; Ekpoh and Nsa, 2011; Ward, 2009). This review paper enumerates the drivers and; the effects of climate change on Ibadan with various adaptation and mitigation measures.

2. BRIEF HISTORY OF IBADAN

Ibadan, surrounded by seven hills, is the largest indigenous city in West Africa and is located in the South Western part of Oyo State of Nigeria. It is the capital city of Oyo State and is centered about latitude 7^0 23' 47'' North and longitude 3^0 55' 0'' East and it is located approximately 119km North-East of Lagos. Ibadan metropolitan area covers a total land area of 3,123km^2 of which the

main city covers 46333km^2 [9]. These include the banks of streams as well as isolated wetland areas that dot the city, which is enclosed by valleys and swamps. Eleven Local Government Areas are grouped together to what is called the Ibadan metropolitan area, Ibadan region or Ibadan land (Fig. 1). The overall population density of Ibadan metropolitan area is 586 persons per km^2. It is situated close to the boundary between forest and grassland, which makes it a melting point for people and products of both the forests and grassland areas. Ibadan hosts the premier University in Nigeria, The University of Ibadan. As a result of these historical antecedents, Ibadan has continuously witnessed influx of people which has contributed to its rapid growth both in population and physical expansion to cover a very large land mass. Its population is estimated to be about 3,034,200 in the year 2011 according to the National Population Commission. Ibadan's rainy season runs from March through October, though August sees somewhat of a lull in precipitation. This lull nearly divides the rainy season into two different rainy seasons. November to February forms the city's dry season, during which Ibadan experiences the typical West African harmattan. There are two peaks for rainfall, June and September.

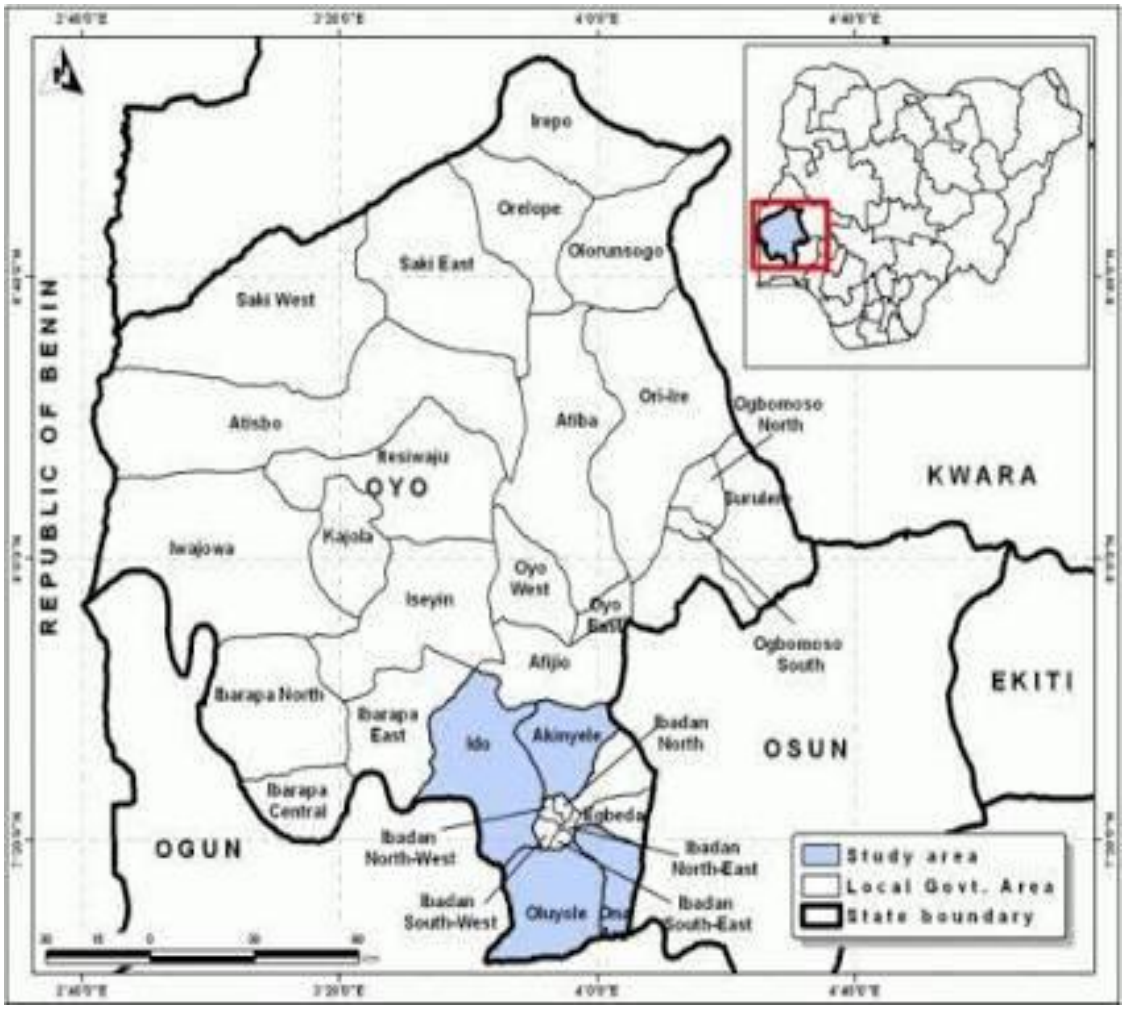

Fig. 1. Map of Oyo state showing Ibadan
Source: Adebowale Adeniyi

3. DRIVERS OF CLIMATE CHANGE

Climate change that is characterized by global warming has become a new reality, with deleterious effects, such as changes in weather patterns and seasonal cycles, disruption of ecosystems, depressed agricultural output, disruption of water needs and supply, food insecurity, human health problems, and energy disruption [10]. In developing countries like Nigeria, about 70 percent of the populations are engaged in agriculture and other income generating ventures that have strong reliance on the biophysical. Climate change is caused by two basic factors, which are natural processes (bio-geographical) and human activities (anthropogenic) [11];

1. The natural processes (bio-geographical): This includes the astronomical and extra-terrestrial factors. The astronomical factors which includes the eccentricity of the earth orbit, changes in the obliquity of the plain ecliptic and changes in orbital procession while the extra-terrestrial factors comprises of solar radiation quantity and quality among others [11].
2. The human activities (anthropogenic): it has been proven to be responsible for the ongoing equivocal climate change or global warming [12]. Human activities contribute major impact on climate change. The following are the highlight of human activities:

3.1 Industrialization

The existence of automobiles and other industrial activities causes the emission of carbon dioxide and other toxic gases which accumulate, thereby causing the emission of large composition of greenhouse gases into the atmosphere which depletes the ozone layers [11].

3.2 Water Pollution

Dumping of refuse and the exposure of water bodies to toxic and harmful chemicals posed great threats to both aquatic and terrestrial organisms.

3.3 Deforestation

Human activities which involve cutting of trees without replacement causes the reduction of carbon and also expose the soil to much sunlight radiation thereby causing land warming.

3.4 Burning of Fossil Fuel

Combustion of fossil fuel results to the emission of greenhouse gases such carbon dioxide (Co_2), methane (CH_4), chlorofluorocarbon (CFC) and nitrous oxide (N_2O), Sulphuric hexafluoride (SF_6) and others released into the atmosphere thereby causing depletion in the tropospheric zone (Smith 1994) [13].

3.5 Urbanization

Urbanization is regarded as a major driving factor of climate change because it is a transformation process from a traditional agricultural society to a modern metropolitan society, associated with major changes in social and economic structures. As an important component of climate change, its significance will undoubtedly continue to increase as the majority of the world's population is swarming into cities (Ottensmann, 1977; Zhao et al., 2002).

4. IMPACTS OF CLIMATE CHANGE

Changes in climatic conditions are projected to have enormous impact from local to global level. Increase in temperature and decrease in the precipitation (rainfall, snow, ice, fog e.t.c) in most part world are the greatest impact of climate change. These have resulted to positive or negative ecological impacts at different part of the world. The thawing of the Artic cool and cold temperate ice, the increasing rainfall in some parts of the world and expansion of the oceans as water warms has started impacting on sea level rise, coastal inundation and erosion [14]. The consequence of the sea level rise in Nigeria has inundated 3,400km^2 of the coastal region of Nigeria and if the sea level rise attains the projected 1m on or before 2100 then 18,400km^2 of the coastal region may be inundated [15,11]. Increasing temperature and decreasing rainfall results into regular drought and desertification. The Sahara desert as expanded to all directions almost engulfing the Sahelion region of Africa [16,17]. The global warming and reduction in the availability of rainfall results into minimal recharge of ground water resources, wells, lakes, and rivers in most part of the world majorly Africa which resulted to scarcity of water. It has been reported in Nigeria many rivers as dried up or seasonally navigable [18]. In agriculture, irregularity of rainfall patterns can lead a usual sequence of crop failure which resulted into shortage of food due to poor harvest. Climate

change resulting to dry weather condition will also affect livestock [19]. Some of the evidence of impact of climate changes in Ibadan are highlighted:

4.1 Flooding

Flood can be defined as an overflow of water that submerges which later dries off gradually [20]. The European Union (EU) Floods Directive defines flood as a covering of land by large volume of water [21]. Flooding may occur as an overflow of water from water bodies, such as a river or Lake, in which the water overtops or breaks, leaves, resulting in some of that water escaping its usual boundaries. Similarly, it may occur due to an accumulation of rainwater on saturated ground.

This natural phenomenon occurs when water runoff from the land exceeds the capacity of the stream channel. Poor urbanization like construction of building along flood plains, large scale encroachment into the river flood plains and large scale road construction with excessive land reclamation can lead to flood disaster [22]. It was reported that construction of structures along river course led to flood disaster in Ibadan on the night of 26th August, 2011[23].

Flooding also precipitates environmental health hazards, such as the outbreak of diseases arising from drinking surface water and well water which have been polluted as a result of flooding [24]. As communication links and socio-infrastructures such as power plants, bridges and roads are damaged and disrupted, some economic activities may come to standstill. Adetunji and Oyeleye [25] stated the causes and effects of flood in Apete, Ido Local Government Area, Oyo State, Nigeria. They selected 156 respondents in Apete area and analysed the data using descriptive statistics. According to their research report, the indiscriminate duping of refuse consequently blocking the inadequate drainage available and the prevalence of building constructions along water channels jointly account for flood in the study area. Adetunji and Oyeleye [25] further reported that flood has resulted into building collapse, injury and disease outbreak, in Apete.

Flood has been an incessant problem in Oyo State. Ibadan is drained by three major rivers. These are River Ogunpa, River Ona and River Ogbere, and each has numerous tributaries. Flooding problems in Ibadan was also attributed to land use factors. Notable among others is the indiscriminate and relentless construction of buildings on flood plains. There were over 26,553 buildings found within the statutory set-back of various streams and rivers in Ibadan (Task Force 2011). Deforestation has also been discovered as another contributory factor to the flooding problem in Ibadan. The destruction of natural forests, for example the depletion of the teak plantation buffering the River Ona on the Eleyele – Apete axis has aided flooding in Ibadan to the reduction of the infiltration and retention capacity of these areas. Some areas, such as Agala (Agala forests), were deliberately preserved in Ibadan under teak and cassia forests during the colonial period. The destruction of these forests has aided flooding in Ibadan Metropolis due to the reduction in the infiltration and retention capacity of these areas. This was confirmed by Akintola (1994) in a study on infiltration process in Ibadan city which indicated varying rates or capacities for different types of urban land-use surfaces.

Plate 1. Flood occurrence in Apete Area in Ibadan, Oyo state
Source: Akinyemi Gabriel

4.2 Agriculture

Obvious impacts from climate change are being witnessed in agriculture both positive and negative aspects. It is dependent on latitude, altitude and type of crop. There have been noticeable impacts on plant production, insect, disease and weed dynamics, soil properties and microbial compositions in farming systems (Khanal, 2009; Rosegrant et al., 2008). Although there are some evidence that agriculture in temperate regions of the world has benefitted in some ways from global warming the same report states with high confidence that "agricultural production and food security, including access to food, in many African countries and regions are likely to be severely affected by climate change". A slight change in the climatic condition will affect agriculture.

Food crop is particularly sensitive to climate change because crop yields depend largely on prevailing climate conditions (temperature and rainfall patterns) (Palatnik & Roson, 2009), Ibadan in Southwestern Nigeria is not exempted. The major food crops grown in Ibadan are cassava, yams, maize, and cocoyams, which are also sensitive to climate change. Subsistence crop production in Southwestern Nigeria is traditional and rain-fed, with very few areas under irrigation. Small-scale traditional irrigation has been practiced for decades in the area, where small streams are diverted seasonally for limited dry season cropping. Medium and large scale schemes are very few. Increase in temperature, at the same time, might affect both the physical and chemical properties in the soil. Increased temperature may accelerate the rate of releasing CO_2 resulting in less than optimal conditions for plant growth. When temperatures exceed the optimal level for biological processes, crop often respond negatively with a steep drop in net growth and yield. Heat stress might affect the whole physiological development, maturation and finally yield of cultivated crops (Khanal, 2009; Rosegrant et al., 2008).

Ogallah et al. [26] reported that there are variations in the quantities of harvested maize at Egbeda local government, Oyo state; Majority of the farmers (58%) attributed it to erratic rainfall, 23% said it was a combination of erratic rainfall, increase in temperature and sunshine hours, application of fertilizer with irrigation practices (6%), increase in sunshine hours (1%) and others (11%) attributed the variation in yield to erratic rainfall, increase in temperature and pest infestation. . All these variations can be attributed to change in the rainfall pattern which has changed in recent time, which gives credence to the reasons in the variations in the quantity of harvested crop and crop yield in the region.

Adeola [27] researched at Akinyele local government in Ibadan and reported that Crop destruction was associated with climate change effects (26%) and 2%t associated crop destruction with the scarcity of food items and the increase in food prices. Majority of the farmers complained that the early maize planted in the survey year was totally destroyed due to the sudden decline of the rain. Odewumi et al*.,* [28] also reported that the farmers submitted that the onsets of rains are now delayed which has effectively led to the shortening of the wet season to between four and six month instead of the average period of seven months recorded in past years. It was also revealed that in spite of the decrease in the amount of rainfall in recent years, the set time of occurrence of rainfall in the year is now between April and June in contrast to the past where rainfall started in early March. This has led to the reduction in the growing season of most crops as many farmers alleged they hardly get two to three planting seasons for maize which is considered an important staple food crop for consumption. This reported corroborated the findings of Adelekan and Bolarinwa [29] on the observed changes in planting seasons in Oyo state, Nigeria.

4.3 Forest Ecosystem

In Nigeria, the total value of both the wood and non-wood forest product as well as their environmental functions is enormous though not completely quantifiable (Moormann et al*.,* 1975). Mostly, the forest is underestimated in value within the National reckoning. Nigerian forest and woody vegetation resources include the high forest, woodland, bush lands, plantations and trees on farms. Each of these various resources contributes to production, protection and conservation functions. Studies have shown that forest reserves occupy about 10 million hectares in Nigeria, which accounts for about 10% of a land area of approximately 96.2 million ha (NFP, 2006). Over the years, the land area identified as forest lands have been decreasing steadily due to eruption of industries in Ibadan and thereby causing reduction in forested area and extinction of forest animals.

The riparian wetland forest and the surrounding light forest witnessed significant loss or degradation (of 45-70%), due to urban development activities resulting in increase of about 70% in build-up areas as at 2004 compared to the situation in 1984. This is no doubt a clear indication of anthropogenic activities or impact of urbanized activities within the catchment of Eleyele Wetland with attendant degradation and loss. However, unlike the riparian wetland forest and the light forest, the Eleyele wetland water body and surrounding dense forest are less affected with about 10% loss as at 2004. This may be attributed to the fact that most of the so-called dense forests are located on the surrounding hilly quartzite ridges with poor accessible for development compared to the light forest area at the low lying plains, in addition to the fact that some are planted forest reserves. Nonetheless, the observed minimal change in the extent of the wetland water body despite the obvious encroachment implies that the feeding channels are still kept open and that water, as usual; do find its level [30].

4.4 Adaptation Measures to Address the Impacts of Climate Change

Adaptation to climate change is an adjustment made to human, ecological or physical system in response to vulnerability [31]. Adaptation is also defined as the adjustments in natural or human systems in response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities [32]. Nigeria being one of the developing countries in Africa is already plagued with different environmental problems which have been directly linked to the on-going climate change [33,11,15,34]. Adaptation to climate change will entail adjustments and change at every level- from community to national and international. Majority of the environmental changes are incremental adaptive measures as well as implementing location specific adaptation and mitigation practices must be of central concern. Available evidences show that climate change will be global, likewise its impacts, but the biting effects will be felt more by the developing countries, especially those in Africa due to their low level of coping capabilities [35,36]. Communities must build their resilience, including adoption of traditional knowledge and diversifying their livelihoods to cope with current and future climate inconveniences. Local coping strategies and traditional knowledge need to be used in synergy with government and local interventions. Adaptation strategies will be more successful if they are identified and presented to local users [37].

4.5 Mitigation Measures to Address the Impacts of Climate Change

1. Reforestation: Forests do have the potential to contribute to adaptation strategies. Planting forests and sustainable forest management can aid in the protection of soil and land against detrimental impacts of flooding. Forests can be used to rehabilitate degraded land and maintain water quality by trapping sediments, taking up nutrients and immobilizing toxic substances.
2. Irrigation Farming: the farmers should improvise by investing in irrigation farming instead of focusing on rain-fed agriculture which might become unreliable as the impact of climate change increases.
3. Institution and Governance: policy makers should implement policies that will aid climate change adaptation measures.
4. Sensitization exercise: awareness on climate change should be done regularly by environmental agencies on the impacts of climate change in order for the inhabitants to prepare for any major effect.
5. Sponsorship of research work: money should be released by the government for researcher to carry out productive researches on climate change.

5. CONCLUSION

Climate change has a great impact on the environment and it thereby poses threats to living organism in the world at large. Effects of climate change on Ibadan has caused havoc in agriculture, forest ecosystem and flooding. Which has brought about loss of lives, livelihood, and forest extinction among others Therefore it is very important for awareness program on mitigation and adaptation process be done across the city so as for the residence to be aware of how they can help in working together with the rest of the world to reduce the effect of climate change in our society.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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