CLIMATE CHANGE AND GLOBAL WARMING: THE NIGERIAN PERSPECTIVE

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Abstract
Emphasis on climate change studies have been more on global whereas the effects are mainly at regional levels. It is on this premise that this study investigated climate change and global warming from the Nigerian perspective. Climatic data (Mean annual and monthly rainfall and temperature) from 30 synoptic stations, for 76 years were collected from the Nigerian Meteorological Agency, Lagos, between 1901-1938 and 1971-2008. Secondary data from different sources were also collected. These were analysed using time series, correlation and percentages among other statistical tools. The result shows that while temperature in Nigeria is increasing, the rainfall is decreasing. While global temperature for the past 100 years is $0.74^{O}C$ that of Nigeria between the two climatic periods under study is $1.78^{O}C$. Major spatial shifts were observed for example, southward shift in the divide between the double rainfall peak and single rainfall peak, and temporal shift in short-dry-season from August to July in Southern Nigeria. The result also shows that although rainfall is generally decreasing in Nigeria, the coastal region is experiencing slightly increasing rainfall recently. The current available pieces of evidence show that Nigeria, like most parts of the world, is experiencing not only regional warming but also the basic features of climate change. To reverse the trend, sustainable developmental measures were recommended.

Keywords: Global warming, climate change, short-dry-season, temperature, rainfall peak, sustainable development.

Introduction

Intergovernmental Panel on Climate (IPCC) (2007) defines climate change as a change in the state of the climate that can be identified (eg., by using statistical tests) by changes in the mean and /or the variability of its properties, and that persists for an extended period typically decades or longer. Although the length of time it takes the changes to manifest matters, the level of deviation from the normal and its impacts on the ecology are most paramount (Odjugo, 2010). Climate change is the end product of a changing climate. Climate change is said to exist when the level of climatic deviation from the normal is very significant over a long period of time (preferably centuries) and such deviations have clear and permanent impacts on the ecosystem (Odjugo, 2009a; 2009b). It should be emphasized that global or regional climate has never been static but variability is an inherent characteristic of climate. For example, the global temperatures have changed from glacial through cold, moderate and warm during different geological times as shown in Table 1.

Table 1: Global climate since the pre-Cambrian period

Era	*Period*	*Age by radio activity in million*	*Climate*

		years	
Quaternary	Recent (Holocene)	1	Glaciation in temperate latitudes
	Pleistocene		
Tertiary	Pliocene	13	Cool
	Miocene	30	Moderate
	Oligocene	60	Moderate to warm
	Eocene		Moderate becoming warm
Mesozoic	Cretaceous	110	Moderate
	Jurassic	155	Warm and equable
	Triassic	190	Warm and equable
Palaeozoic	Permian	210-240	Glacial, becoming
	Carboniferous	260-300	moderate
	Devonian	310-340	Warm, becoming glacial
	Silurian	340	Moderate, becoming
	Ordovician	400	warm
	Cambrian	510	Warm
			Moderate to warm
			Cold, becoming warm
Pre-Cambrian		560	Glacial

Source: Ayoade (2003)

Climate change is different from the generally known term as climatic variability which means variation in the mean state and other statistics of climate on all spatial and temporal scales beyond that of individual weather event. Such temporal scale variations could be monthly, seasonal, annual, decadal, periodic, quasi-periodic or non-periodic. Climate change is of two facets namely global warming and global cooling. Global warming is a gradual but systematic increase in average global temperatures experienced for a very long period of time while the reverse is true for global cooling. The ongoing global warming has taken about four decades without reversing. IPCC (2007) shows that the current warming of the earth's climate is unequivocal caused by anthropogenic forces as is now evident from observations of increases in global average air and ocean temperatures. If the current warming continues unabated for a prolong period, it will attain a new climatic status – warm or hot climate – with its effects on man and the ecosystem.

The key to understanding global climate change is to first understand what global climate system is, and how it operates. At the planetary scale, the global climate is regulated by how much energy the Earth receives from the Sun. However, the global climate is also affected by other flows of energy which take place within the climate system itself (Fig. 1a). This global climate system is made up of the atmosphere, the oceans, the ice sheets (cryosphere), living organisms (biosphere) and the soils, sediments and rocks (geosphere), which all affect, to a greater or less extent, the movement of heat around the Earth's surface. The atmosphere however, does not operate as an isolated system. Flows of energy take place between the atmosphere and the other parts of the climate system, most significantly the world's oceans. The significance of the oceans is that they store a much greater quantity of heat than the atmosphere. The top 200 metres of the world's oceans store 30 times as much heat as the atmosphere. Therefore, flows of energy between the oceans and the atmosphere can have dramatic effects on the global climate.

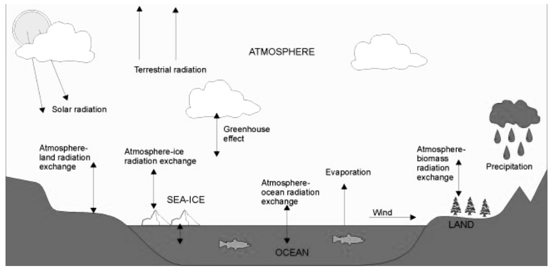


Fig 1a: The Earth's climate system responds to changes not just in the atmosphere but also the oceans and the ice sheets, and over longer periods of time, movements of the Earth's crust and even the evolution of life itself.

A drastic change in the climate systems either due to natural forces or unsustainable human activities results in climate change. The latter is regarded as the basic cause of on-going climate change and the advanced countries are most responsible (DeWeerdt, 2007). IPCC (2007) shows that observed climatic data from developed countries reveal significant change in many physical and biological systems in response to global warming but there is remarkable lack of geographic balance in data and literature on observed changes with marked scarcity in developing countries. It is on this premise that this paper is structured to assess the causes, rate and effects of climate change and global warming with emphasis on Nigeria.

Materials and Methods

Mean monthly and annual temperatures and rainfall from 30 synoptic stations (Fig 9) between 1901-1938 and 1971-2008 in Nigeria were collected from the Nigerian Meteorological Agency, Lagos and Meteorological Department in some Airports. Although there are more than 30 meteorological stations in Nigeria, the study was limited to 30 stations because of consistency in available climatic data since the establishment of the stations. Moreover the selected stations are true representative of the various climatic belts of Nigeria. Two climatic elements (temperature and rainfall) were used in this study. These climatic elements were measured regularly in the stations used and these climatic elements best determine the prospects as well as the ecological and socio-economic problems of Nigeria. Data from different secondary sources were also used.

The research covers a period of 76 years. This is to enable us capture the period when climate change signals were not an issue (1901-1938) and when they are stronger (1971-2008). With 76 years, two climatic periods of 38 years each can be studied and this will provide a better platform to investigate the changes within the climatic periods. The mean annual temperature data were used to construct the isothermal maps of Nigeria, while the rainfall data were used to construct the isohyets maps of Nigeria for the two climatic periods. With these maps, the analysis of the spatial pattern of climate change in Nigeria was carried out. The temporal climatic changes over the years were examined by employing the time series.

Results and Discussion

Causes of climate change

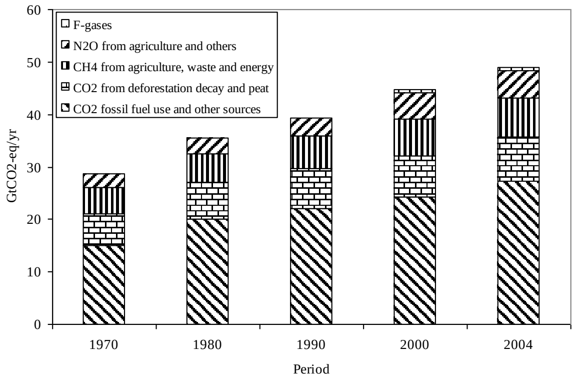
Climate change is caused by two basic factors namely natural processes (biogeographical) and human activities (anthropogenic). The natural processes are the astronomical and extraterrestrial factors. The astronomical factors are the eccentricity of earth's orbit, obliquity of ecliptic and orbital procession. The extraterrestrial factors include solar radiation quantity (sunspot) and quality (ultra violet radiation change). A high solar quality and quantity and period of perihelion (when the earth is nearest to the sun), result in heating up of the earth surface which lead to global warming. The incident radiation on the earth during aphelion (when the earth is farthest away from the sun) is always low and if this combines with low solar quality and quantity, global cooling is experienced.

Volcanic eruptions also lead to both global warming and cooling. Through volcanic eruptions, lot of gases, vapour and particulate matter are emitted into the atmosphere. Such emissions influence the atmospheric chemistry thereby creating short –term cooling and long- term heating of the atmosphere. Prominent examples of such eruptions of great magnitude were Krakatoa eruption in 1883, Mount Agung in 1963 and Mount Pinatubo in 1992.

The human activities that cause climate change include transportation, industrialization, urbanization, burning of fossil fuel, agriculture, water pollution, changes in land cover and deforestation among others. While some of these factors (industrialization, transportation, burning of fossil fuel, etc) emit greenhouse gases (GHGs) into the atmosphere, others, such as deforestation and water pollution reduce the rate of carbon sink thereby enhancing GHGs concentration in the atmosphere (Fig 1b). The concentrated GHGs in the atmosphere has two basic implications. It not only depletes the ozone layer thereby allowing more solar radiation into the earth's surface, it also traps the outgoing heat from the earth's surface.

The greenhouse gases (GHGs) include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), chlorofluorocarbons (CFCs) and sulphurhexafluoride (SF_6). Global GHGs emissions due to human activities have grown since pre-industrial times, with the increase of 70% between 1970 and 2004 (Fig 2). As at 2004, the contributions of each of the GHG to the atmosphere are shown in Figure 3. It is obvious that CO_2 is the most important contributor to the GHG. It contributed 76.7% of the GHG. Its annual emissions grew by about 80% between 1970 and 2004. The contribution of different anthropogenic sectors to GHGs as at 2004 is presented in Figure 4. While energy supply topped the list, waste and wastewater emitted the least GHGs into the atmosphere. The contribution of CO_2 for the past millennium is shown in Figure 5. Information from the ice cores data shows a gradual increase prior to industrial period which was 280ppmv (part per million by volume). This increased to 375 ppmv by 2005 and it is estimated to double (750 ppmv) or triple (975 ppmv) by the year 2100 (Fig 5).

Fig 1b: Causal factors of climate change.
Source: Odjugo (2010)



Source: IPCC (2007)

Fig 2: Global annual emissions of anthropogenic GHGs (1970-2004)

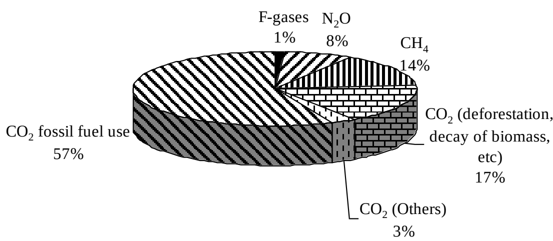


Fig 3: Share of different anthropogenic GHGs in total emissions in 2004 in terms of carbon dioxide equivalents (CO_2-eq). Source: (IPCC 2007)

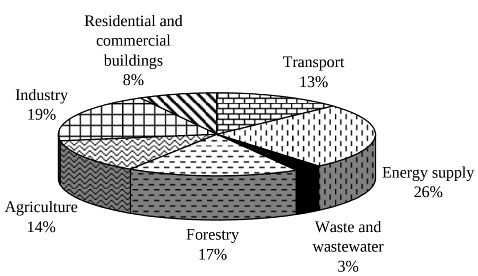


Fig 4: Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO_2-eq

Source: IPCC (2007)

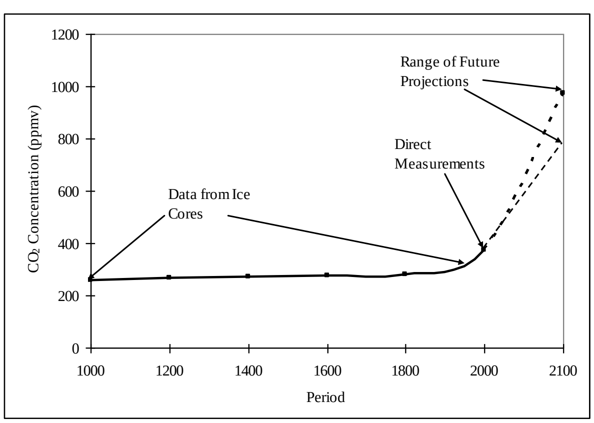


Fig. 5: CO_2 concentration for the past millennium
Source: CDIAC on line

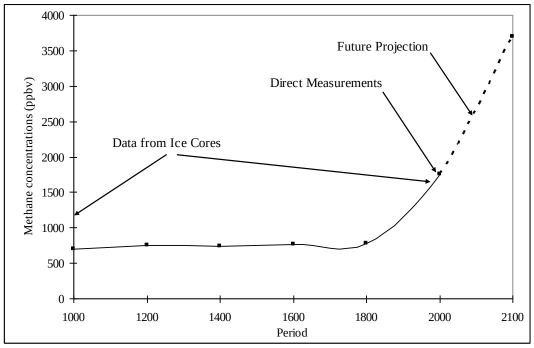


Fig. 6: Trends in methane concentration over the past millennium and future projections
Source: Hengeveld et al (2005)

Next to CO_2 is methane (CH_4) which contributed 14.3% of the GHGs to the atmosphere. Like CO_2 the contribution of CH_4 grew sharply after the pre-industrial period of the 18th century (Fig 6). The pre-industrial value of CH_4 was 700ppbv (part per billion by volume). This increased to 1774 ppbv by 2005 and it is expected to rise to 3700ppbv by 2100 (Fig 6). The natural source (swamp decay) contributed 38% to atmospheric CH_4 followed by fossil fuel (17%), animals (17%), rice (10%) and landfill (8%). The nitrous oxide (N_2O) contributed 7.9% of the GHGs and its current contribution is 319 ppbv. The F-gases (HFCs, PFCs, CFCs, and SF_6) combined contributed 1.1% as at 2004.

There is high level of agreement and much evidence to show that with the current climate change mitigation policies and related sustainable development practices, global GHGs emissions will continue to grow over the next few decades. The IPCC Special Report on Emissions Scenarios (SRES, 2000) projects an increase of global GHGs emissions by 25% to 90% between the year 2000 and 2030, with fossil fuels maintaining their dominant position of the global energy mix to 2030 and beyond (IPCC, 2007).

The developed nations emit more of the GHGs. While they accounted for over 75% of the total emissions, the developing nations are responsible for less than 25%. Industries, water pollution and agricultural productions to a large extent and vehicular fumes to a lesser degree are the major sources of greenhouse gas emissions in the developed world. Nigeria like most developing countries is not an industrialized nation so automobiles are therefore the major sources of air pollution in the urban areas. This is because most vehicles imported into the country are either fairly used or old ones which emit lot of carbons into the atmosphere. Carbon emissions from motorcycles are even worst than those from vehicles in Nigeria. Most commercial motorcycle riders in Nigeria usually add engine oil to the petrol, which automatically turns the petrol into gasoline. Although gasoline burns slower than petrol, it emits more carbons. The motorcycle riders therefore save fuel at the expense of the environment. The failure of the Power Holding Company of Nigeria (PHCN) to provide efficient and effective electricity has resulted in majority of Nigerians buying generators to provide individual thermal electricity, and these do not only constitute noise pollution but also emit a lot of carbons into the atmosphere. Gas flaring is another source of GHGs emission in Nigeria. Nigeria is the largest gas flaring nation in the world. She flares more than 70% of her natural gas (Odjugo, 2005; 2007).

Effects of climate change

Climate change has started impacting and will continue to affect global

temperatures, water resources, ecosystems, agriculture and health among others. Continued GHGs emission at or above the current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century. The world temperature variation since 1860 when direct temperature measurement started is shown in Figure 7. The global temperatures were below average until the late 1930s when alternating cooling and warming started. This trend continued up to the 1980s when a renewed and pronounced warming continued till date. 1998 is recorded as the warmest individual year followed by 2002. Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global temperatures since 1860. Between 1906 and 2005, the global temperature increased by 0.74^{O}C (0.56 to 0.92)^{O}C (IPCC, 2007).

In Nigeria, temperature has been on the increase (Fig 8). The increase between 1901 and 1938 was not much. The increase became so rapid since the early 1970s. The mean temperature between 1901 and 1938 was 26.04^{O}C while the mean between 1971 and 2008 was 27.83. This indicates a mean increase of 1.78 ^{O}C for the two climatic periods. This is significantly higher than the global increase of 0.74^{O}C since instrumental global temperature measurement started in 1860. Should this trend continue unattended to, Nigeria may experience between the middle (2.5^{O}C) and high (4.5^{O}C) risk temperature increase by the year 2100. The result is a clear indication that Nigeria is experiencing global warming at the rate higher than the global mean temperatures. The observed temporal increase is also evident in the spatial increase (Fig 9). Between 1901 and 1938, the southernmost part of the country was marked by 25.5 ^{O}C isotherms while the northernmost was 28.5 ^{O}C. With the global warming becoming more pronounced, the southernmost part was marked by 26.5 ^{O}C isotherms and the north 30 ^{O}C. The study also noticed that the increase in temperature is more in the northern part of the country than in the southern part (Fig 9).

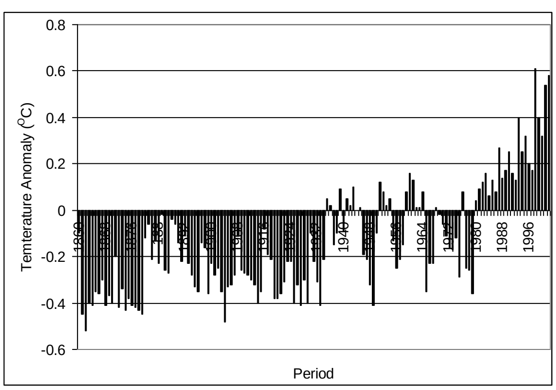


Fig. 7: Observed world temperature changes between 1860 and 2005
Sources: (IPCC, 1996; Danjuma, 2006)

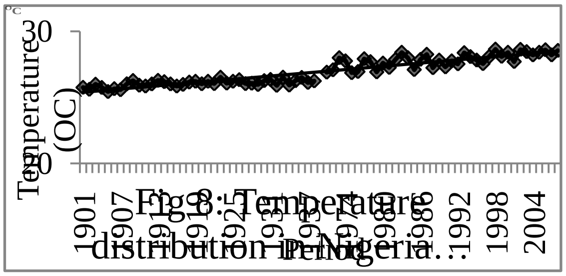
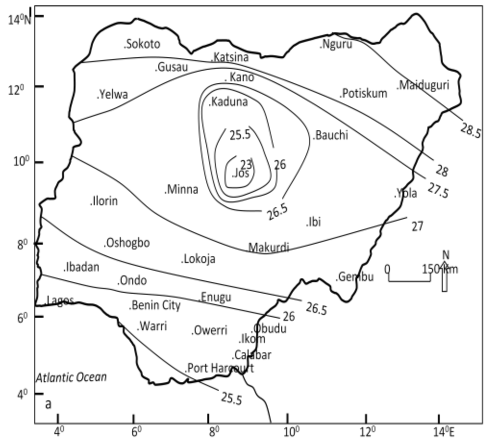


Fig 8: Temperature distribution in Nigeria...



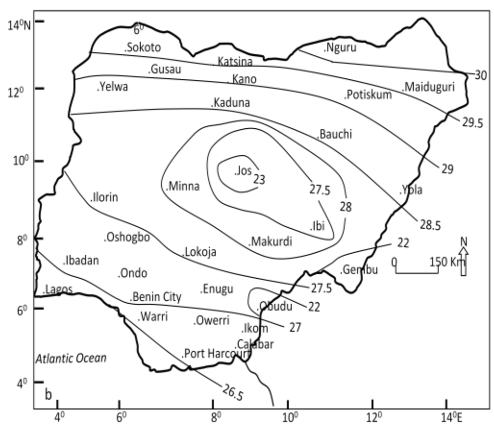


Fig 9: Spatial pattern of mean air temperature in Nigeria (a)1901-1938 (b) 1971-2008

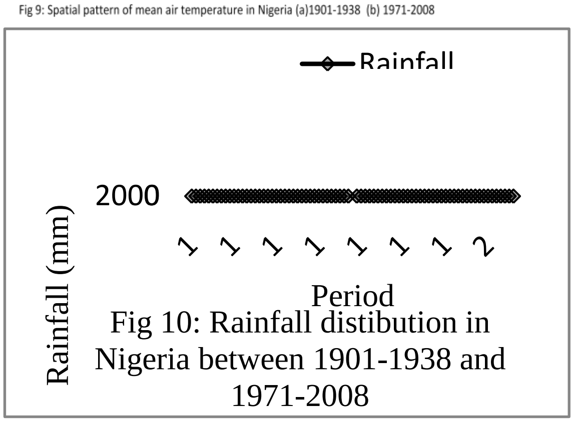


Fig 10: Rainfall distibution in Nigeria between 1901-1938 and 1971-2008

The temporal rainfall pattern in Nigeria shows a declining trend. Between 1901 and 1938, rainfall decrease was negligible but by 1971-2008 the decline became so pronounced (Fig 10). The mean rainfall value for the 1901-1938 was 1571 mm while it deceased to 1480 in 1971-2008. This shows a decrease of 91 mm between the two climatic periods. The decreasing rainfall and increasing temperatures are basic features of global warming and climate change. Spatially, a declining trend is also noticed. In the 1901-1938 climatic period, the 600 mm isohyets engulfed Nguru, but is was replaced by 500 mm during the 1971-2008 climatic period. Moreover, prior to 1938, the 1200 mm isohyets that was found close to Kaduna, has dropped to Minna axis (Fig 11). Odjugo (2005b; 2007b) also observe that the number of rain-days dropped by 53% in the north-eastern Nigeria and 14% in the Niger Delta coastal areas while rainfall intensity is increasing across the country.

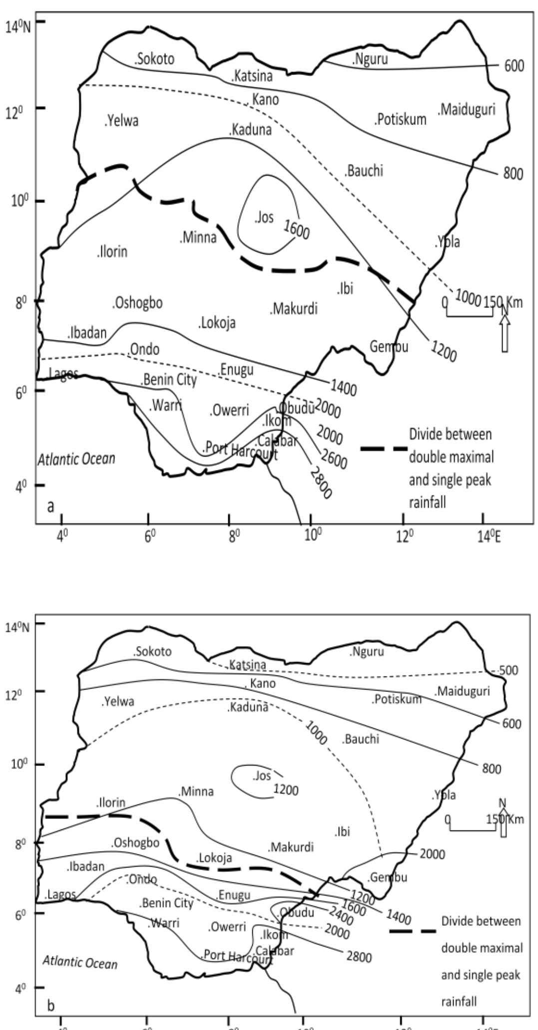


Fig 11: Spatial pattern of rainfall in Nigeria (a) 1901-1938 (b) 1971-2008

Although there is a general decrease in rainfall amount in Nigeria, the coastal areas like Warri, Brass, Port-Harcourt, Calabar and Uyo among others have experienced slightly increasing rainfall in recent years (Fig 11a and b). It is expected that the 2800 mm isohyets of the southernmost part of Nigeria in 1901-1938 (Fig 11a) be replaced by say 2700 or 2600 mm in 1971-1938, but a critical look at Fig 11b shows that Port Harcourt and Ikom that were within 2600 mm is now replaced

by that of 2800 mm. Another major disruption in climatic patterns of Nigeria which shows evidence of climate change and global warming is the shift in short-dry-season (popularly known as August Break). In the 1901-1938 climatic period, short-dry season was experienced more during the month of August but since the 970s, it is being experienced more in the month of July.

Another prominent change in rainfall pattern in Nigeria is that the areas experiencing double rainfall maximal is undergoing gradual shift in the short-dry-season (locally referred to as August Break) from the month of August to July. The short-dry- season is a brief period of low rainfall (dry spell) that separates the two rainfall peaks. In 1901 – 1938, the short dry season occurred 31 years in the month of August and 7 years in July. By 1971 – 2008, the short dry season occurred 11 years in the month of August, 23 years in the month of July and 4 years for both months. This implies that the dry spell which used to occur in the month of August followed by heavy rains in the month of September (1901-1938) now shifted to July followed by wet period in the months of August and September (1971-2008).

Adaptation and Mitigation Options

Societies have a long record of managing the impacts of weather and climate-related events. A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to climate change in the future. Adaptation is necessary in the short and longer term to address impacts resulting from the warming that would occur even for the lowest stabilization scenarios. To adapt adequately, sustainable measures are needed not only to revise the on-going regional warming, but also to enhance the rainfall trend and patterns. To do this effectively, sound knowledge of the weather and climate is a must. This demands establishment of more well-equipped weather observatory stations and such weather information is made available to the public. With this, the climatic trend will be known by many and individuals could think of adaptive measures most suitable to them at the cheapest cost. Such data will also help in accurate weather forecast and predictions which will assist in preventing weather related disasters through early warning.

Since concentration of GHGs in the atmosphere is the main reason for tropospheric warming, sustainable ecological measures are required to reduce their rate of concentration in the atmosphere. Such measures include afforestation, forest management, reduced deforestation, harvested wood product management, use of forestry products for bio-energy to replace fossil fuel use, tree species improvement to increase bio-mass productivity and carbon sequestration, improved remote sensing technologies for analysing of vegetation/soil carbon sequestration potential and mapping land use change. With regards to waste, mitigation measures are in form of landfill CH_4 recovery, waste incineration with energy recovery, composing of organic waste, controlled waste water treatment, recycling and waste minimization, bio-covers and bio-filters to optimise CH_4 oxidation should be adopted.

There is high confidence that neither adaptation nor mitigation alone can avoid all climate change impacts. However, they can complement each other and together can significantly reduce the risk of climate change. Many impacts can be reduced, delayed or avoided by mitigation, so key sectors mitigation technologies need to be developed. These key sectors include energy supply, transportation, buildings, industries, agriculture and forestry and waste (IPCC, 2007).

For energy efficiency, there is the need to switch from the use of fuel to gas, nuclear power, renewable heat and power (hydropower, solar, wind, geothermal and bio-energy), early application of carbon dioxide capture and storage (CCS) (for example storage of removed CO_2 from natural gas), CCS for gas, biomass and coal-fired electricity generating facilities, advanced renewable energy including tidal and wave energy, concentrating on solar and solar photovoltaic (DeWeerdt, 2007). On transport, there should be more fuel-efficient vehicles, bio-fuels, modal shift from road transportation to rail and public transport systems, non-motorised transport in relatively short distances (cycling and walking), land-use and transport planning, higher efficiency aircrafts, advanced and hybrid vehicles with more powerful and reliable batteries.

Architectural design of building should be such that have efficient lighting and day- lighting, more efficient electrical appliances and heating and cooling devices, improved cooking stores, improved insulation, passive and active solar design for heating and cooling, recovery and recycling of fluorinated gases, integrated design of commercial buildings including technologies such as intelligent metres, that provide feedback and controls. Industries should practice more efficient use of electrical equipment, heat and power recovery, material recycling and substitution, have a better control of non-CO_2 gas emissions and a wide array of process-specific technologies, CCS for cement, ammonia and iron manufacture and inert electrodes for aluminium manufacture.

There is urgent need for improved crop and grazing land management to increase soil carbon storage, restoration of cultivated peaty soils and degraded lands, improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions, improved nitrogen fertiliser application technique to reduce N_2O emission, dedicated energy crops (sugar cane and maize) to replace fossil use, improved energy efficiency and improvement of crop yields.

No single technology can provide all of the mitigation potentials in any sector. Mitigation potentials can only be achieved when adequate policies are in place and barriers removed. A wide range of barriers limit both implementation and effectiveness of adaptation measures. The capacity to adapt is dynamic and is influenced by a society's productive base, including natural and man-made capital assets, social networks and entitlements, human capital and institutions, governance, national income, health and technology.

Conclusion

The paper shows that climate change is caused by both anthropogenic and natural factors. What we are experiencing now is global warming caused by anthropogenic factor (human activities) and when the on-going warming continue unabated for decades or centuries with significant ecological impacts then, the earth will attain a changed climate (warm or hot climate). The human activities that cause global warming are transportation, industrialization, urbanization, agriculture, deforestation, water pollution and burning of fossil fuel among others. These either emit greenhouse gases into the atmosphere or reduce the rate of carbon sinks. The implication is that global warming is being experienced with global temperatures rising by $0.74^{O}C$ since 1860 while that of Nigeria increased by $1.79^{O}C$ and rainfall decreased by 91 mm within the two climatic periods.

The impacts of climate change are global but it will hit harder on developing countries because of their poor status and low adaptive capacity. To reverse the impacts, appropriate measures are needed to reduce the rate of greenhouse gases emissions while adequate adaptation and mitigation strategies should be applied. To do this, efficient and effective energy supply based on solar, wind, geothermal and bio-energy should be encouraged. Fuel efficient vehicles and aircrafts alongside mass transportation and non-motorised means of transport are needed. While deforestation should be reduced, afforestation and forest management should be encouraged.

Advanced countries like the U.S.A, Canada, United Kingdom and Japan etc, have been putting things in place both to reduce the emission of GHGs and mitigate the effects of climate change but there is no evidence that Nigeria has started anything with respect to emission reduction and preparedness for mitigation measures. We hope that the bill on climate change and the recommendation to establish climate change commission will have appropriate political backing to start GHGs emission cut and mitigation measures against climate change in Nigeria.

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