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Climate Change, Impacts and Mitigation: Nigerian Experience

Sola Ogunyemi[1], R.O. Awodoyin[1]* and O.S. Olubode[2]

1. Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria.
2. Department of Biological Sciences and Biotechnology, College of Pure and Applied Sciences, Caleb University, Lagos, Nigeria

*Corresponding author: e-mail: <frawodoyin@yahoo.com>

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ABSTRACT

Climate has continued to change for millennia. The various anthropogenic factors have accelerated the change to the extent that what used to be subtle natural changes have become measurable and observable changes. These anthropogenic factors have resulted in the generation of greenhouse gases (GHGs) and their emission to the atmosphere and the depletion of the ozone layer. The GHGs, especially carbon dioxide (CO_2) generated from various combustion activities; methane (CH_4) generated from rice paddies and flooded areas as a result of anaerobic fermentation, and from ruminating cattle and nitrous oxide (N_2O) generated from decomposition of nitrogen fertilizers and livestock wastes trap some of the heat (infrared) that radiate from the earth. The ozone layer at the upper stratosphere which shields the earth specifically from the ultraviolet (UV) light is constantly being destroyed by the immense quantities of chlorine released by volcanoes and other natural emissions, and by chlorine released from human-made chlorofluorocarbons (CFC, HCFC, HFC, PFC). The most visible effect of climate change is global warming, which has disrupted the thermodynamic balance of the earth, with some regions unnaturally gaining more heat than the others. This rise in earth temperatures has resulted in continued melting of ice caps, glaciers and sea ice, resulting in a rise in global sea levels of between 20cm and 60cm. The Nigerian Niger Delta is under threat of climate related flooding, habitat destruction and species loss. The coastal erosion in the Niger Delta occasioned by sea-level rise is already a menace, especially, regarding destruction of mangrove vegetation which constitutes an important stabilizing system in the brackish ecosystem. Already, 18,803 square kilometers was reported destroyed and 0.21 million people displaced by up to 2-meter coastal sea-level rise. The receipt of increased UV on earth not only increased the temperature on earth, but has serious implications on human health, causing melanoma skin cancer, cataracts and sunburn and altering human's immune system. Afforestation, reforestation, zero-tillage, replacement of fossilized fuels with environment-friendly fuels and energy sources like bio-diesel and sustained public awareness programmes are suggested as ways to mitigate the emission of GHGs.

Keywords: Anthropogenic effects, climate change, global warming, greenhouse gases, ozone layer depletion.

INTRODUCTION

Climate change and its resultant global warming are realities that all must be active to combat. This report sought to describe climate and climate change, the anthropogenic causes of climate change, a general overview of how climate change has impacted our world and some mitigating measures of the impacts.

What is Climate and climate change?

Climate is defined as the average weather experienced over a long period (Ayoade, 2002). This includes temperature, relative humidity, wind and rainfall patterns. It is important to note that the climate of the earth is not static and has changed many times in response to a variety of natural and anthropogenic causes. However, anthropogenic causes are significantly responsible for much of the instability that we currently experience, and which have had and continue to have many grave environmental implications.

Climate change is not a new phenomenon since it has been occurring for millennia. For instance, the biota was altered by the climatic conditions during the ice-age, the pleistocene, the Holocene and other ages (Hongaton *et al.*, 2001). In the Pleistocene, many species of birds and mega fauna like dinosaurs became extinct. In modern times, the rate of climate change has become accelerated to the extent that what used to be subtle natural changes have become measurable and observable changes. The fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) asserts that human activity is the primary driver of the observed changes in climate.

The generation of greenhouse gases (GHGs) and their emission to the atmosphere, and the depletion of the ozone layer are the major causes of the current climate change.

Though these naturally occur, anthropogenic activities have aggravated them.

The Greenhouse Theory

Global warming is primarily caused by the greenhouse effect, which results basically from the trapping of some of the heat that radiate from the earth back to the space. Some of these return to the earth by re-radiation. "Greenhouse effect" is a phrase popularly used to describe the increased warming of the earth's surface and lower atmosphere due to increased concentrations of carbon dioxide, other atmospheric gases and water vapour near the earth's surface (Ramanathan, 1988). These gases, like the glass panels of a greenhouse, let heat in but prevent some of it from being radiated back into the atmosphere. With more heat trapped near the earth's surface, ocean surface temperatures rise, more water enters the atmosphere and the earth's surface temperature increases.

Carbon dioxide, stemming from burning of wood, coal, oil and natural gas, is the most prevalent greenhouse gas (GHG) accounting for 77% of the emission. Other greenhouse gases are methane (CH_4; 14% of emission), nitrous oxide (N_2O; 8% of emission) and Chlorofluorocarbons (HFCs, PFCs, SF_6; 1% of emission). The sources of green house gases include deforestation, road traffic, residential buildings, oil/gas processes, livestock and manure, cement production, rice paddies, etc (Table 1). Some of the gases, especially CO_2, are mopped up by afforestation, other land uses and reforestation activities.

Agricultural activity plays a significant role in GHG emission, mainly by producing methane (CH_4), the second most important GHG, though it is difficult to assess these emissions with accuracy. Methane is mainly produced by anaerobic fermentation, especially in rice paddies and flooded areas (marshes and ponds). Also, ruminating cattle emit nearly 100 million tonnes of methane into the atmosphere each year (Anon, 2008). Also, the decomposition of nitrogenous fertilizers and livestock wastes generate ample nitrous oxide (N_2O).

Historically, GHG concentrations in the Earth's atmosphere have undergone natural changes over time and these changes have given rise to changes in climate. For example, warmer periods were associated with higher atmospheric greenhouse gas concentrations and cooler periods with lower greenhouse gas concentrations. Hardy (2003) noted that those changes were part of natural cycles and occurred over periods of tens of thousands to millions of years. Recent human-induced changes in the atmospheric chemistry have occurred over decades (Ramanathan, 1988). What worries the environmentalists is the steadily rising concentration of greenhouse gases which, consequently, would trap too much heat.

Table 1.**Anthropogenic sources of GHGs and their percentage gas emissions**

Anthropogenic activity	Percent of Emissions	Anthropogenic activity	Percent of Emissions
Deforestation	18.3	Air Transport	1.6
Road Traffic	9.9	Waste Water and Other Wastes	1.6
Residential Buildings	9.9	Rice Cultivation	1.5
Oil/Gas Processes	6.3		
Agriculture Soils	6.0	Coal Mining	1.4
Commercial Buildings	5.4	Agriculture Energy Use	1.4
Livestock and Manure	5.1	Aluminum and Non-Ferrous	1.4
Other Industry	5.0	Foods and Tobacco	1.0
Chemicals	4.8	Pulp, Paper and Printing	1.0
Cement	3.8	Machinery	1.0
Unallocated Fuel Combustion	3.5	Other Agriculture	0.9
Iron and Steel	4.0		
Harvest Management	2.5	**Some GHGs Mop up Activities**	
Rail and Other Transport	2.3	Reforestation	0.5
Landfills	2.0	Other Land Use	0.6
Technology and Development Losses	1.9	Afforestation	1.5

Source: Gingold (2009).

Ozone Layer Depletion

Ozone (O_3) is the naturally occurring form of oxygen, spread in the upper stratosphere which shields the earth specifically from the ultraviolet (UV) light. "Ozone is constantly created by the action of sunlight on oxygen molecules. Ozone is destroyed by the immense quantities of chlorine released by volcanoes and other natural emissions, and by chlorine released from human-made chemicals. Chlorofluorocarbons (CFC, HCFC, HFC, PFC) are capable of depleting the earth's protective ozone layer (Miller, 1990). The human-made CFCs, known as *freons*, are stable, non-toxic and nonflammable chemicals

introduced in 1930 as coolants in air-conditioners and refrigerators, and as propellants in aerosol spray cans. As a result of discarding of aerosol cans, leaking of refrigerating and air-conditioning equipment and burning of plastic foam products used in insulation, CFCs are released to the atmosphere where they may stay for 22 to 111 years.

The chlorine and bromine released by CFCs speed up the breakdown of ozone molecules into oxygen gas at the stratosphere. One atom of chlorine may break down 100,000 molecules of ozone. In 1980s researchers reported that each year, up to 50% of the ozone in the upper stratosphere over the Antarctic is destroyed from September through November (Miller, 1990).

Table 2. Greenhouse and ozone-layer depleting gases and their characteristics

Greenhouse gases	Chemical formula	Pre-industrial concentration (ppbv)	Concentration in 1994 (ppbv)	Atmosphere lifetime (years)[a]	Anthropogenic sources	Global Warming Potential (GWP)[b]
Carbon dioxide	CO_2	278,000	358,000	Variable	Fossil-fuel combustion; Land-use conversion; gas flaring; Cement production	1
Methane	CH_4	700	1,721	12.2 ± 3	Fossil fuels; Rice paddies; Waste dumps; Livestock production	21[C]
Nitrous oxide	N_2O	275	311	120	Fertilizer use; Industrial processes; Combustion	310
CFC-12	CCl_2F_2	0	0.503	102	Liquid coolants	6,200-7,100[d]
HCFC-22	$CHCLF_2$	0	0.105	12.1	Liquid coolants	1,300-1,400[d]
Perfluoro-methane	CF_4	0	0.070	50,000	Production of aluminum	6,500
Sulfur hexa-fluoride	SF_6	0	0.032	3,200	Dielectric fluid	23,900

Note: ppbv = parts per billion volume; 1 ppbv of CO_2 in the Earth's atmosphere is equivalent to 2.13 million metric tons of carbon.
[a]No single lifetime for CO_2 can be defined because of the different rates of uptake by different sink processes.
[b]Global Warming Potential (GWP) for 100-year time horizon.
[c]Includes indirect effects of tropospheric ozone production and stratospheric water vapor production.
[d]Net GWP (i.e. including the indirect effect due to ozone depletion).

Source: UNEP (2001).

Apart from CFCs, other chlorine-containing chemicals such as carbon tetrachloride, methyl chloroform used as cleaners and degreasers, and methyl bromide used as soil fumigant in the control of nematodes and burrowing rodents, are a major cause of ozone depletion in the stratosphere.

According to Rolando *et al* (1991), depletion of the ozone layer increases the amount of ultraviolet radiation reaching the earth from the sun. Such increase in radiation has serious implications on human health. It increases the incidences of melanoma skin cancer (*which now kills over 9,000 Americans every year*), cataracts and sunburn and alters man's immune system.

Anthropogenic causes of climate change

Specifically, some examples of the major human-related causes of climate change in our time include:

- **Deforestation**: This produces about 10% of global N_2O emissions and 18% of the general green house gases. The Food and Agriculture Organization reported that the world is losing about 200 km^2 of forest a day, with Africa loosing

twice the global average. One billion and six hundred tonnes of CO_2 are emitted by land use change, largely by deforestation (Gingold, 2009).

- **Oil and gas processing and consumption**: Over 7 billion tonnes of CO_2, is emitted globally each year through fossil fuel use and flaring of gas (Plate 1). Fossil fuel includes petroleum, diesel, kerosene, aviation oil, charcoal, etc.
- **Agricultural productions**: The United Nations Environment Programme (UNEP) reported that between 20 and 25% of all CO_2 emissions are caused by burning forests to clear the land for farming. Methane is another greenhouse gas released into the atmosphere from paddy rice cultivation, wetland farming and manure production from livestock farms, the production and use of fertilizers, and the use of chlorine-containing agro-inputs.
- **Transportation**: Combustion of fuel for road, rail, air and water transportation. Motorbike transportation system in Nigeria has increased the CO_2 emission. The motorbike, having two-stroke engine is characterized by incomplete combustion.
- **Industrial processes**: Cement production, waste water generation, mining, and chemical production also emit CO_2 to the atmosphere,
- **Domestic activities**: The foods consumed are subsequently burnt up in the body to release heat and exhaled carbon-dioxide into the atmosphere. Similarly, the use of electric generators in most homes and offices in Nigeria has worsened the toxic gas emission.

Plate 1. Gas flaring as recorded in Delta State, Nigeria.

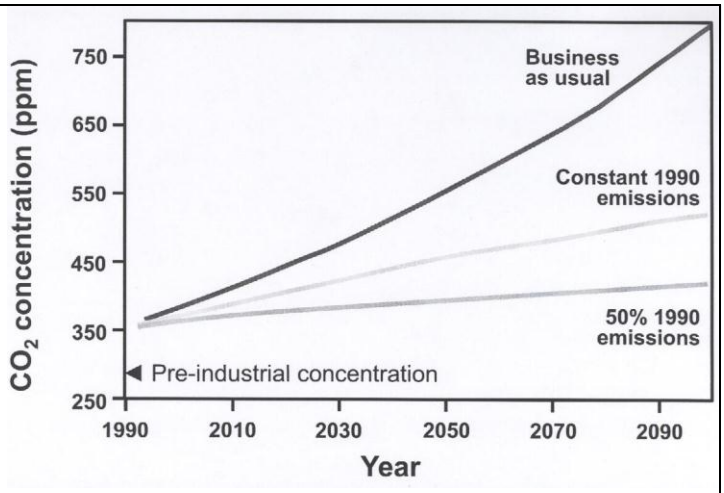

Figure 1: Trends in actual and predicted concentrations of carbon dioxide under various senarios. Source: IPCC.

Effect of Climate Change – Global Warming

The most visible effect of climate change is global warming. The global warming, a situation which causes the earth to be excessively heated up, has disrupted the thermodynamic balance of the earth with some regions unnaturally gaining more heat than the others. This heat gain may result in unprecedented changes, such as the loss of the polar ice caps and El Niño changes across continents bordering the Atlantic ocean (Anon, 2005).

It is now known that the average temperature of the earth has increased by 0.74^{o}C over the last 100 years. About 0.4^{o}C of the warming occurred since the 1970s and the average temperature is expected to rise by 2^{o}C in 2050. As at 1990, the concentration of CO_2 in the atmosphere was 350 ppm, and expecting constant emission based on 1990 value, the CO_2 concentration in the atmosphere was projected to be 385 ppm in 2009. This has already resulted in anomalies in climatic data, especially in the 21st century based on 1961-1990 trend of increase. Many places in

Africa and other continents are experiencing either increased or decreased temperature or rainfall. For instance, many regions of the Sahara and sub-Sahara West Africa are experiencing up to 2^{o}C rise in temperature, whereas some parts of Far East are witnessing between 1^{o}C to 3^{o}C drop in temperature. Yet many parts of Atlantic ocean are gaining heat, much of the Pacific ocean is losing heat (National Climatic Data Centre/NESDIS/NOAA, 2007).

Global Warming and our world

Most experts agree that the greenhouse effect would raise the average temperature by between 1.5^{o}C and 4.5^{o}C before the middle of this century. An increase of one degree Celsius makes the Earth warmer now than it has been for at least a thousand years. Out of the 20 warmest years on record, 19 have occurred since 1980, and the three hottest years ever observed have all occurred in the last eight years (Anon 2009).

This rise in earth temperatures will result in continued melting of ice caps, glaciers and sea ice, with changes in rainfall parameters and intensification of tropical cyclones. The elevation will result in a rise in global sea levels of between 20cm and 60cm by the end of the century.

The Stern report of 2006 on the economics of climate change underscores the social, environmental and economic costs of climate change. For the temperate climate (e.g. United Kingdom), climate change means hotter, drier summers, more heat waves, milder wetter winters, higher sea levels and increased flood rise in coastal areas. Worldwide, there will be more intense heat, flooding, more food shortages and spread of diseases where people are particularly vulnerable to changes in the weather. The regions of the Northern hemisphere have recorded the greatest temperature rises; they now have very cold days in winter and more very hot days in summer (Anon, 2005).

The impacts of climate change are already being experienced across the globe. While climate change will affect everyone, it is expected to have a disproportionate effect on peasants in developing countries. Apart from the adverse impact of rising sea levels, there will be more frequent coastal storms, threatening the lives and livelihood of coastal communities. Other real and potential impacts include;

- increased incidence of extreme weather events;
- substantial reductions in surface water resources leading to accelerated desertification in sensitive arid zones;
- greater threats to health (such as malaria);
- threat to biodiversity (including the bleaching of coral species on the east African reef systems); and
- threat to agricultural production. A predicted decline of 12% in production in Africa by 2080 (Anon, 2008).

As the earth gets hotter, disasters like hurricanes, droughts and floods become more frequent. For example, recent reports in the Cable News Network of Saturday 12 June 2010 were as follows:

I. Flash flood in the Arkansas State, USA that cleared through a campsite, with rivers exceeding their levels by 6m left 16 people dead and 17 people missing.
II. Rains that continued to lash over central and southern China had forced millions of people out of their homes.
III. Famine as a result of continued drought is hitting hard on Kenya, Ethiopia and other Eastern and Northern African countries leaving people with untold hardship.

International rivers in Africa may be sensitive to even moderate reductions in rainfall, as projected for much western and southern Africa. Such reductions in rainfall could threaten sub-regional/regional security through increase in inter-communal and inter-state conflicts over scarce water resources and threaten the sustainability of hydro-electric power generation, if not managed in a proactive manner.

Overall, the projected impacts of unmitigated climate change in Africa are likely to have significant impacts on human livelihoods, health, water resources, agricultural production and food security (Table 3). All these would undermine economic prosperity across much of the continent.

Table 3. Climate change impacts in developing countries

	Environmental impacts	**Socio-economic resources and sectors affected**
1	Changes in rainfall patterns,	Water resources
2	Increased frequency and severity of floods, droughts, storms, heat waves	Agriculture and forestry
3	Changes in growing seasons and regions	Food security
4	Changes in water quality	Human health
5	Sea level rise	Infrastructure (e.g. transport)
6	Glacial melt	➢ Settlements: displacement of inhabitants and loss of livelihood ➢ Coastal management ➢ Industry and energy ➢ Disaster response and recovery plants

Also, the Arctic sea is melting. The summer thickness of Arctic ice is approximately half of what it was 50 years ago.

These changes may alter world's ocean currents and affect most ocean dwelling biodiversity, leading to:

1. Gradual extinction of some species that have uniquely adapted to milder ocean currents.
2. Rise in Sea-surface temperatures, which would result in loss of one-quarter of world's coral reefs (some fauna such as corals cannot live in warmer seas).
3. Storm and flooding damage in populations that inhabit small islands and low-lying coastal areas (such as Lagos, Nigeria). Specifically, there has been a rise in sea level in the 20th century by 10-20 cm due to melting of glacier ice and expansion of warmer sea water. Projected sea level rise of as much as 85 cm is predicted in the next 100 years – a veritable threat to people and all biodiversity occupying the coast, wetlands and coral reefs. In the last 10 years floods have caused more damage than the previous 30 years in Victoria Island, Lagos, leading to erosion and destruction of biota not adapted to flood.

Climate change is already affecting many places and communities in Africa. The continent now experiences more droughts in the already dry areas but increased rainfall and flooding in areas that are usually wetter. The impacts of climate change in Nigeria serve as an example of what will happen in many other parts of Africa. From mangroves and rainforests on the Atlantic coast in the south to the savanna in the north bordering the Sahara, Nigeria has a variety of ecosystems. These include mangrove swamp, fresh water swamp, lowland rainforest (wet and dry), derived savanna, guinea savanna, sudan savanna and sahel savanna. While excessive flooding during the past decade has impacted negatively on farming in coastal communities, desertification is ravaging the sahel, and fast extending to the sudan savanna ecology.

The situation is very grim for Africa, being the hottest and the second driest continent in the world, with Deserts and arid zones covering more than 60% of its total land area. Fresh water is unevenly distributed across countries and regions due to variability in rainfall patterns. For example in Nigeria, the total annual rainfall in the coastal lying mangrove swamp is as high as 2500mm distributed over about 11 months and as low as 250mm in the sahel spanning just about 3 months.

Ninety-five percent of Africa's agriculture is rain-fed, whereas only 5% of crop area is irrigated. By implication, water scarcity is obviously a major cause of hunger in African continent. Also in Africa, 6% of agricultural lands, 31% of pasture and 19% of forests and wooded areas are degraded due to erosion and/or due to chemical and physical damage (FAO, 2005). On the whole, the impacts of the unstable change in climate have resulted in socio-economic problems across many human settlements, especially in Africa. Some of these include climate-related conflicts that threaten the ability of millions to get enough to eat by keeping farmers from land, increased pest pressure, decreased host tolerance/resistance, increased resistance to pesticides, new pest problems (secondary pests becoming primary), and pest range expansion.

Regarding food for human population, the impacts of climate change are more pronounced with regard to food availability, food access and nutrient access. According to

Pinstrup-Anderson and Herforth (2008), climate change affects food availability and food security through direct effects on crop yield, rangelands, increased CO_2 levels, variations in temperatures, precipitation and length of growing season, increases in soil pests and diseases and altered soil fertility (e.g. through desiccation and salination).

Food security is defined in relation to food access and nutrition access. That is, not just having access to food but to quality foods that are nutritious. Access to food is affected by direct impacts of climate change on agricultural zones, which affects jobs and incomes, and the macro-economy. This in turn shapes livelihood in a number of ways in the form of social protection, direct effects on human health and susceptibility to diseases such as malaria and HIV/AIDS which undermine livelihood capability and food security. Access to food is also affected by indirect alteration of climate change to socio-economic aspects of livelihood, food systems and development processes through human responses. Nutrient access is affected by direct effect on the nutrient contents of foods, including protein contents, glutin contents of grains and toxin levels. This has direct effect on human health on the regard to poor ability to absorb nutrients, increased vulnerability to disease infections such HIV/AIDS and malaria; and poor sanitation systems and drinking water.

Climate Change and the Nigerian Situation

Nigeria is located in tropical Africa; therefore, the climate is generally hot and humid, with average temperature of 26.4^{o}C. February and March have the highest temperature (33^{o}C), and August has the lowest monthly temperature of 21^{o}C. The country receives an average of 1626 mm of rain per year. On average, there are 121 days in a year with 0.1 mm of precipitation. The driest month is January with an average of 40 mm of precipitation across 2 days. The wettest month is June when an average of 336 mm of rainfall occurs in 20 days. Average annual relative humidity is 84.7%. The average monthly relative humidity ranges from 80% in March to 88% in June, July, September and October. Sunlight hours on average range between 3 hours per day in July and August; and 6.7 hours per day in February. There is an average of 1885 sunlight hours per year, that is, 5.2 hours per day. On the average, the country experiences an entirely frost-free year. (Climate Temperature Information – Nigeria, 2010).

However, meteorological data have shown that rainfall pattern in Nigeria has changed in the past decades, beginning in the 1960s (Oladipo, 1995). According to him, the continued below-mean rainfall in the last two decades in Nigeria is an indication of abrupt change in climate. This has affected food security since the agricultural sector, especially, in Southern Nigeria is highly sensitive to rainfall pattern.

In light of the global climate change phenomenon, Nigeria has been empirically assessed to be one of the nations suffering from climate change. According to Apata *et al* (2010), hunger-related deaths could double if grain production does not keep pace with population growth in an unfavourable climate. Specifically, the Nigeria Niger Delta (second largest in the world) is under threat of climate related flooding, habitat destruction and species loss. Likewise, World Bank has ranked agricultural land degradation, fisheries depletion, deforestation, biodiversity loss and water hyacinth expansion as environmental issues in the Niger Delta needing high priority attention (Table 4).

Table 4: Ranking of environmental isssues in the Niger Delta, Nigeria by the World Bank

Category	High Priority	Moderate Priority	Lower Priority
Land Resource Degradation	Agricultural land degradation Flooding (Moderately high)	Coastal erosion Riverbank erosion	Sea level rise
Renewable Resource Degradation	Fisheries depletion. Deforestation Biodiversity loss Water hyacinth expansion	Fisheries habitat degradation	Mangrove degradation Nypa palm expansion
Environmental Pollution	Sewage Vehicular emissions Municipal solid waste Toxic and hazardous substances	Oil pollution Industrial effluents Industrial air emissions Industrial solid wastes	Gas flaring

Source: Apata *et al.* (2010)

The coastal erosion in the Niger Delta occasioned by sea-level rise is already a menace, especially, regarding destruction of mangrove vegetation which constitutes an important stabilizing system in the brackish ecosystem (Uyigue and Agho, 2007). Already, thousands of square kilometers of land area is lost, while millions of people once living in the Niger Delta have been displaced by the coastal sea-coastal sea-level rise (Tables 5 and 6). The

situation is so grave that as much as 15,000 square kilometers of land could be lost by year 2100 with just a meter rise in sea level (Table 5).

Table 5: Total land loss due to coastal erosion and inundation estimated from different scenarios of sea level rise

	Low Estimate				High Estimate			
Sea level rise (m)	0.2	0.5	1.0	2.0	0.2	0.50	1.0	2.0
Land loss in the Niger Delta (km^2)	284	7,453	15,125	18,398	2,865	7,500	15,332	18,803

Table 6: Estimated number of people (in millions) displaced by sea level rise at different scenarios of sea level rise

Sea level rise (m)	0.2	0.5	1.0	2.0
Number of people displaced in Niger Delta (millions)	0.10	0.25	0.47	0.21

MITIGATING THE IMPACTS OF CLIMATE CHANGE

Afforestation/reforestation: Since the bulk of greenhouse gas emissions is carbon dioxide, and deforestation contributes largely to carbon dioxide discharges, it is quite logical that among the practical solutions to global warming, and consequently climate change, are preservation and conservation of forests and planting of more trees. The countries in Sub-Saharan Africa, Asia and South America are increasingly benefitting from global drive to factor economic returns into afforestation/reforestation by investing in carbon sequestration/carbon trade and the conservation of natural carbon stocks carbon trade and by designing saleable adaptation and resilient projects such as REDD (Reducing Emissions from Deforestation and Forest Degradation, a program proposed by the United Nations). The REDD initiative is implemented by estimating national forest carbon stocks, monitoring sources of forest emissions, and implementing a carbon finance mechanism through which developing countries would be paid for measurable and verifiable emission reductions (WBCFU 2006, 2008).

Furthermore, government agencies, every school and every community should take the tree planting activities beyond mere ceremony to practical involvement. The moderating bodies of the tertiary institutions in the country should emulate the National Universities Commission by insisting on '***greening***' the campus environment for accreditation and re-accreditation.

The Urban road-side tree planting should be accorded utmost importance. Government agents approving plans for houses and other utilities should encourage, at least planting of hedgerows in homes. Such hedgerows will sequester some of the CO_2 generated from the kitchens, car exhaust and exhalation from human beings and animals.

Contreras (1997) suggested other remedial measures such as the efficient use of energy resources; popularization of organic farming and waste recycling technologies; and substantial shift from the use of fossilized fuels like coal, oil and natural gas to a more environment-friendly fuels and energy sources from the sun, wind, ocean current, biogas, bio-diesel, waterfalls, geothermal and others.

Bio-diesel is presently receiving attention in the country by the Energy Commission of Nigeria, Abuja. The Commission is planning to establish plantations of *Jatropha curcas* (Common name: Physic nut; Plate 1), oil-extracting and treatment plants in Kano State. *Jatropha* (Yoruba*: lapalapa or ologbotuje*) has been part of our socio-cultural development. It is being used as boundary plants and it is non-invasive. It has very high oil contents of 42%. As it has gained much recognition in Ghana, India, Thailand, Mali and South Africa. Nigeria can adopt the technology to biodiesel to drive heavy engines and operate industrial machineries. Its plantations, in addition to mopping up CO_2, will curb desertification and erosion, and improve, most especially, the savanna parklands.

Sustainable Agriculture: Agricultural activities and Industrial Revolution have caused climate change because of their contribution of GHGs and ozone-depleting gases. In mitigating the global warming effect, there is now widespread evidence of how farmers and the general populace can help reduce the emissions of GHGs by avoiding deforestation, reducing the use of chemical fertilizers, incorporating nitrogen into the soil, avoiding the loss of organic matter, and improving the use of manure. At the same time, farmers can help sequester carbon by restoring the natural vegetation where this is possible and efficiently managing their soils.

Sustainable agriculture such as 'zero tillage' and agroforestry should be considered by all stakeholders. The absence of tilling and harrowing in no-tillage agriculture

avoids disturbing layers of soil. The non-disturbance of top soil combined with the rotation of crops and permanent ground cover limits the oxidation of organic matter in the soil, thus reducing emission of carbon dioxide by-product to the atmosphere.

Watson (2000) observed that a new global challenge program that couples advances in agricultural science with research to mitigate climate change and adapt agriculture to its anticipated effects could have profound effects on the global environment. Research could therefore focus on:

1. developing rice varieties and water-management practices that will reduce methane emissions;
2. breeding of crop varieties that can resist higher temperatures, tolerate greater disease and insect pressures, and withstand exposure to drought and excess water;
3. evolving more efficient use of nitrogen fertilizers;
4. developing simpler and more accurate ways to measure soil carbon; and
5. developing farming systems that sequester carbon dioxide more effectively.

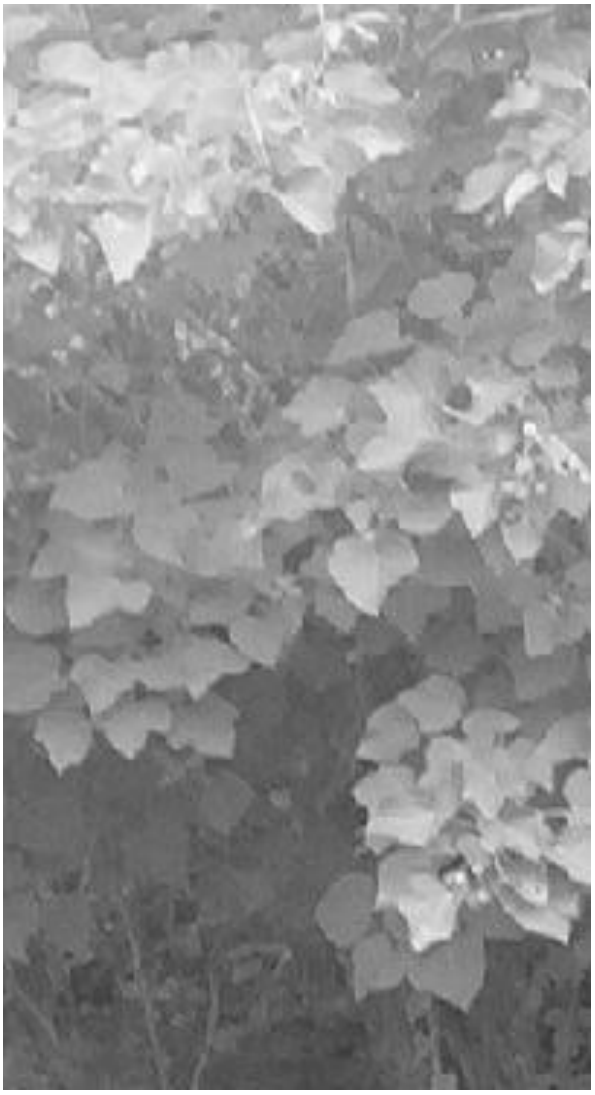

Plate 1. A stand of *Jatropha curcas* L. in Ibadan, Oyo State, Nigeria.

Agroforestry is a dynamic, ecologically based natural resource management system that involves integration of trees on farms and in the agricultural landscape. The practice diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. Also, it contributes to climate change mitigation, since trees and shrubs mop up more carbon dioxide than crops. The IPCC reports that agroforestry has the potential to sequester nearly 600 Mt carbon dioxide a year by 2040.

Public Awareness: Members of the public are entitled to timely and correct information. Addressing the crisis of climate change and global warming should start from scientists, the media and concerned agencies to provide the public with reliable, updated and easy – to – understand scientific information on what climate change and global warming mean, their causes and implications. Also, they should be well informed on how to mitigate the effect.

CONCLUSION

Climate change is real and its impacts portend grave consequences for individuals, organizations and governments. All hands must be on deck to respond to these changes and responsibly mitigate them as quickly as possible. Therefore, all must join hands together to do something specific at individual, institutional, governmental and global levels towards addressing our climate change challenges. Whatever happens:

- Wanton deforestation must stop;
- Gas flaring must cease;
- Anthropogenic emission of green house gas must be reduced;
- Populace must work together to ensure the success of ‘greening’ and ‘re-greening’ the earth programme by maintaining, at least, a stand of trees or ornamental hedgerow in every compound;
- Farmers should maintain stands of trees on farms to sequester carbon dioxide;
- Farmers should adopt environment-friendly methods such as solarization in the control of soil-borne nematodes; and
- All Educators should create awareness about climate change, global warming and ways to mitigate the effects.

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