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Climate Change, Effect and Adaptation Strategies in Nigeria

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Abstract

Change is inevitable in every part of the world. It is something that we cannot run away from or avoid. One thing that does not change is 'change' itself. One should consider the outcome of change, which could be positive or negative. Therefore, change is everywhere, regardless of how one looks at the environment. There have been changes in the political, economic, and socio-cultural beliefs of people all over the world; they are fundamental as they provide the basis of human existence. But today, what should be considered the most critical change is the one occurring in the Earth's climate system, and it is so significant as it affects the overall environment of man. The prominent and permanent feature of world climates today is change. This ranges from variability through fluctuations, trends, and abrupt to gradual changes due to alterations in the Earth-atmospheric energy balance. This study considers the structure of the atmosphere, components of the atmosphere, the solar source of the Earth's energy, climate change, its effects, and adaptation strategies.

Keywords: Climate, Climate change, Adaptation, Strategies, Nigeria.

1 | Introduction

Meteorologists observed that the atmosphere is subdivided into layers based on temperature and zones of temperature changes. The layers consist of the troposphere, stratosphere, mesosphere, and thermosphere. The earth's atmosphere, a complex fluid system of gases and suspended particles, did not originate at the beginning of the planet. As of today, the atmosphere has been derived from the earth itself by chemical and

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biochemical reactions. Although the fluid system forms a gaseous envelope around the earth, its boundaries are not easily defined. They can be arbitrarily defined as the earth atmosphere interface and space interface.

Gases like nitrogen, oxygen, argon, carbon dioxide, water vapor, etc., together make up the total volume of the atmosphere. Together with suspended particulates, viz dust and soot, they constitute the gaseous turbidity, particularly in the troposphere. However, the composition of the atmosphere and so also its structure are variable in time and space. The vertical layer can be shown in *Fig. 1*.

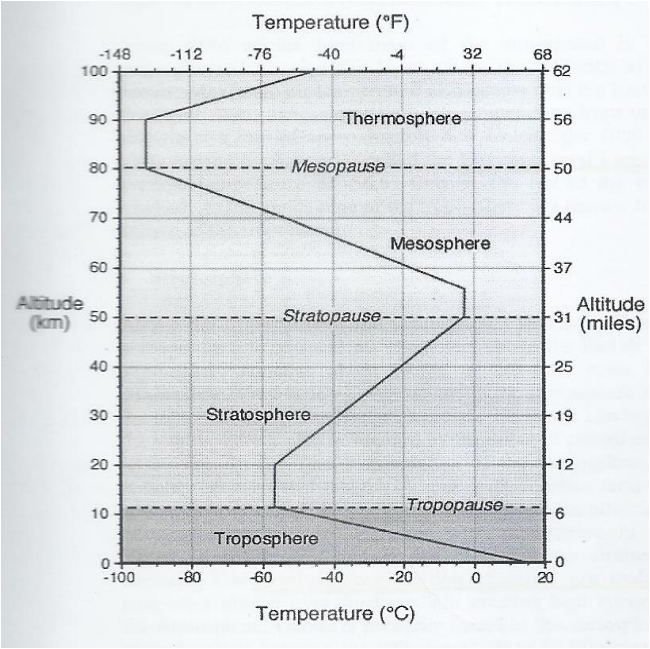

Fig. 1. The vertical layer [1].

The first layer is called the troposphere, and its depth varies from 8 to 16 km. This layer at the poles is roughly half as thick as the tropics, and its average depth is about 11 kilometers.

In this layer, maximum air temperature occurs near the earth's surface. As height increases, the air temperature drops uniformly with altitude at a rate of 6.5^0C per 100 meters (environmental lapse rate). The transition zone between the troposphere and the stratosphere is known as the tropopause.

The second layer is called the stratosphere. It extends from an average altitude of 11-50 kilometers above the earth's surface. The temperature remains constant with height in the first 9 kilometers of the stratosphere. This zone of constant temperature is called an isothermal layer from an altitude of 20-50 kilometers; temperature increases with an increase in altitude. This is due to localized concentrations of ozone gas molecules. These molecules absorb ultraviolet sunlight, creating heat energy that warms the stratosphere. Ozone is primarily found in the atmosphere at varying concentrations between 10-50 kilometers. A discontinuity layer between the stratosphere and mesosphere is known as 'stratopause.'

The third layer is also called the mesosphere. This is the layer where temperature decreases with height to reach a minimum of about -90^0C around 80 kilometers. It lies on the top of the stratosphere, where temperature reverses, or a minimum temperature level is experienced, and it is called 'menopause.'

The fourth layer is called the thermosphere. Here, the temperature increases with height owing to the absorption of ultraviolet radiation by oxygen atoms. The temperature in this layer can be greater than 1200^0C. While these temperatures seem extreme, the amount of heat energy involved is small. The amount of heat stored in a substance is controlled by its mass.

The ozone layer is a region of concentration of the ozone molecule (O_3) in the earth's atmosphere. It sits at an altitude of about 10-50 kilometers, with a maximum concentration at an altitude of approximately 25

kilometers. The ozone layer naturally shields earth's life from the harmful effects of the sun's ultraviolet radiation. Ozone is both a natural and artificial Greenhouse Gas (GHG).

Ozone can be destroyed naturally by the absorption of ultraviolet radiation and by the collision of ozone with other atmospheric atoms and molecules. A severe reduction in the concentration of ozone in the ozone layer could lead to:

I. An increase in the incidence of skin cancer.
II. Cooling of the earth's stratosphere and some surface climatic effects.
III. Adverse impact on crops and animals.
IV. A significant increase in cataracts and sun-burning.
V. Suppression of immune systems in organisms.

Ozone plays a vital role by absorbing almost all of the short-wavelength ultraviolent radiation and much of the long-wavelength ultraviolet radiation from the sun.

2|The Solar Source of the Earth's Energy

The sun is the primary source of earth's energy. Almost all the energy that drives the various systems, viz: climate systems, ecosystems, hydrologic systems, etc., found on the earth originates from the sun. Solar energy is created at the sun's core when nuclear fusion fuses hydrogen atoms into helium. For each second of this nuclear process, 700 million tons of hydrogen are converted into 695 million tons of helium [2]. The remaining 5 million tons are turned into electromagnetic energy radiating from the sun's surface into space. The total energy emitted from the sun's surface is approximately 63,000,000 watts per square meter (W/m^2 or Wm^{-2}) [2].

The energy emitted by the sun passes through space until planets and other celestial objects intercept it. The intensity of solar radiation striking these objects is determined by a physical law of inverse square law, which states that the intensity of the radiation emitted from the sun varies with the squared distance from the source. As a result of this law, if the intensity of radiation at a given distance is one unit, the intensity will become only one-quarter at twice the distance. At three times the distance, the intensity will become only one-ninth of its original intensity at a distance of one unit, and so on. Given the amount of energy radiated by the sun and the amount of energy radiated by the sun and the average earth-sun distance of 149.5 million km, the amount of the radiation intercepted by the outer limits of the atmosphere can be calculated to be around 1370 W/m^2. For general purposes, the sun's energy output can be considered constant.

2.1|The Earth's Sun Energy Budget

Out of all the sunlight that passes through the atmosphere annually. Only 51% is available at the earth's surface to do work. This energy is used to heat the earth's surface and lower atmosphere, melt and evaporate water, and run photosynthesis in plants. Of the remaining 49%, 4% is reflected space by the earth's surface, 26% is scattered or reflected space by clouds and atmospheric particles, and atmospheric gases, particles, and clouds absorb 19% (see *Fig. 2*).

How air (atmosphere) is heated

The atmosphere is always heated through radiation (long or heat waves) from the earth's surface. This radiation is retransmitted out of 51% of the sun's total energy budget back to the atmosphere. The temperature of the atmosphere varies with height above the earth's surface. The atmosphere is heated mainly by these three main processes.

I. Radiation: this is simply the direct heating of a body by transmitting heat waves. The long waves from the earth's surface heat the air in close proximity to the ground. The earth is heated by short-wave energy from the sun, and the air is heated by long-wave energy from the earth.

II. Convection: convection currents are upward movements of warm air at a higher temperature than its surroundings; they are less dense and lighter and, therefore, tend to rise. By conventional heating of the atmosphere, air is heated by the earth, expands, and rises; cold air flows in and is warmed by the earth.

III. Conduction: this is how air is heated directly in the daytime by contact with the earth's surface. Since the air tends to be heated in these three ways, the air near the surface, on the whole, attains the same temperature as the ground with which it is in contact.

However, the ground temperature depends upon the amount of solar radiation reaching the earth's surface and the character of the surface receiving that radiation [1].

3 | Climate Change

Ayoade [3] referred to climate change as a change in the general circulation of the atmosphere on which climate ultimately depends. In its definition, the Inter-Governmental Panel on Climate Change (IPCC) said it is a statistically significant variation in either the climate's mean state or its variability, persisting for an extended period (typically) decades or longer. Also, the United Nations Framework Convention on Climate Change (UNFCC) defined it as attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability observed over comparable periods.

Global warming or climate change is the measurable increase in the average temperature of the earth's warming brought on by rising levels of heat-trapping gases, known as GHGes, in the atmosphere [1]. GHGes retain the radiant energy (heat) provided to earth by the sun in a process known as the greenhouse effect. Before the industrial revolution of 1740, these GHGes occurred naturally in the atmosphere, and they are so significant that without them, the earth would be too cold to be inhabited by flora and fauna. Since the inception of the industrial revolution, as mentioned above, human activities via construction, manufacturing, modern cultivation, and transportation are adding more and more GHGes to have now reached dangerous levels in the earth-atmosphere [4]. For example, carbon dioxide levels, the powerful and dominant GHG, have risen by 35% since 1750, largely from burning fossil fuels such as coal, oil, and natural gas. With more GHGes in the mix, the atmosphere acts like a thickening blanket and traps more heat.

Other significant GHGs include sulfur hexafluoride ($5F_6$), nitrous oxide (N_2O), chlorofluorocarbons CFC-11 (CCL_3F) and CFC-12 (CCL_2F_2), and methane (CH_4) [5].

Table 1. The main GHGes [5].

Greenhouse Gases	Chemical Formula	Pre-Industrial Concentration	Concentration in 1994	Atmospheric Lifetime (Years)**	Anthropogenic Sources	Global Warming Potential (GWP)*
Carbon-dioxide	CO2	278000 ppbv	358000 ppbv	Variable	Fossil fuel combustion land use conversion cement production	1
Methane	CH_2	700 ppbv	1721 ppbv	122+ 0.3	Fossil fuels Rice paddles Waste dumps Livestock	21"
Nitrous oxide	N_2O	275 ppbv	311 ppby	120	Fertilizer industrial processes combustion	310

Table 1. Continued.

Greenhouse Gases	Chemical Formula	Pre-Industrial Concentration	Concentration in 1994	Atmospheric Lifetime (Years)**	Anthropogenic Sources	Global Warming Potential (GWP)*
CFC-12	CCL_2F_2	0	0,503 ppby	102	Liquid coolants. Foams	6200-7100****
HCFC-22	CHCIF2	0	0,105 ppbv	12,1	Liquid coolants	1300-1400****
Perfluoromethane	CF4	0	0,070 ppby	50000	Production of aluminium	6.500
Sulphur hexa-fluoride	SF_6	0	0,032 ppbv	3200	Dielectric fluid	23 900 90

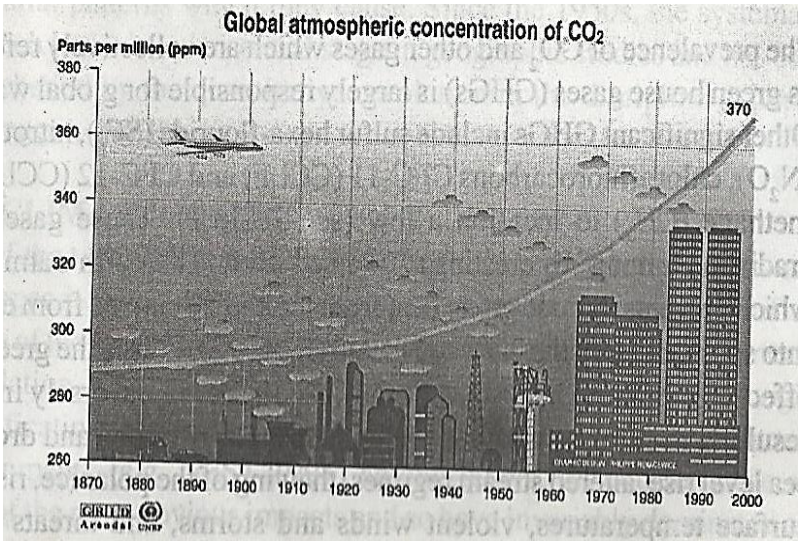

Fig. 2. The greenhouse effect [5].

As the earth heats, climate processes are adversely impacted, resulting in extreme weather events, particularly floods, and droughts, sea level rise, altered stream regimes, thawing of the polar ice, rise in sea surface temperatures, violent winds and storms, and threats to food securities among others [5]. In their insight into the global contribution and burden of climate change, Sokona et al. [6] believed that Africa contributed the least to the generation of GHGs that had brought the deleterious changes and is, unfortunately, suffering the most from the impacts. This is mainly due to her weak adaptive capacity from poor economic development and deep-rooted poverty. However, many predictions of scientists on global torments of climate change cum global warming are already happening:

I. Polar regions are gradually being heated up, and glaciers and sea ice are melting, raising the ocean/sea level.

II. Mountain glaciers worldwide continuously change, and ice sheets are receding globally.

III. Frequent and more intense storms, especially in the warmer world, cause damage to cities and biomass.

IV. Intensive evaporation from soil and evapotranspiration from leaves causing untold dryness and extension of aridity worldwide.

V. As the temperature warms, the surface layer of the oceans and seas also gets warmed up, expanding in volume and thus raising sea level, in conjunction with snow melting already itemized. This ocean/sea level is

complicated and has even destroyed lives in the island and coastal regions; coastal and beach erosion has increased, etc.

VI. Heat stress, both during the day and night in the warmer regions, kills people. New diseases are spreading that have virtually no cure. Old diseases like fever prove medication impotent. The upsurge of cancers of different types kills rampantly.

VII. There are also shifts in the lifecycles of many plants and animals, such as flowers blooming earlier and birds hatching earlier. Many species have begun shifting where they live or their annual migration pattern due to warmer temperatures.

3.1|Evidence of Climate Change in Nigeria

The duo of scholars Siyanbola et al. [7] sounded a warning at a national conference held in Nigeria in 1993 that climate change would produce significant changes in the physical and human environment, and we must be prepared to face the challenges that the change would elicit. Schellnhuber [8] thought that the consequences of climate change are enormous, and a full-scale change would compel us to change from doing things in a more familiar manner or probably to them in the right ways. It would affect all sectors of the economy and human security in general.

There is evidence of climate change in the country in 2016. This evidence, as stated by Merem et. al [9], is in the form of rising temperatures, more frequent and persistent heat and cold waves, severe coastal and inland floods, and ravaging wind storms. Notable flood events were experienced in about 20 states of the federation in 2016 and also already experienced in several areas in 2017. Though dry spells observed in 2016 were not as pronounced as those observed in 2015, severely extreme temperatures were observed in many parts of the central and northern states between February and June 2016 [9]. During these periods, the daytime maximum temperatures persistently exceeded 43^0C in the cities of the north of Kano, Nguru, Maiduguri, Sokoto, and Yola [9].

These support the IPCC's regional projection of the emerging climate scenario for West Africa. IPCC projects the likelihood of warming in the west African region by about 3-4^0C, corresponding to about 1.5 times the global near-surface temperature. It is estimated that, by 2100, parts of the Sahel are likely to emerge as the most vulnerable, showing likely agriculture losses of between 2 and 72 of the Gross Domestic Product (GDP).

3.2|The Impact of Climate Change in Nigeria

In Nigeria, the ensuing change has brought irregular rainfall patterns quite different from Nigeria's registered rainfall pattern. Though there has not been a reduction in the annual volume of rainfall, experience has shown that rainfall is sometimes concentrated in a few months, and long intra-seasonal droughts may be more prominent. Often, in a few years past, the onset of rainfall was February-April, then a period of drought till June, then heavy rainfall may persist till October or early November; we often have rainfall throughout August, which is supposed to be a break. Another effect related to this is the feeling of high heat immediately after rainfall; in addition, the diurnal range of temperature is drastically reduced, meaning that high heat is still trapped on the earth till midnight or early morning, especially in southern Nigeria.

Climate change has caused bad flooding in the interior of Nigeria, such as Benue, Kogi, Oyo, Ogun, Osun, etc., possibly due to the overflow of the rivers, streams, and dams. Continuous coastal flooding is also in Lagos, Badagry, Port Harcourt, Calabar, and other coastal areas. This is due to the ocean surge that is quite predominant now [10].

Another serious effect of climate change in Nigeria is desert encroachment. The Sahara desert is drastically expanding from its previous fringe down south. Yobe, Maiduguri, northern Kano, Sokoto, Katsina, and Gombe have become desert land. Rivers in these areas are drying off; Soils, too, are seriously losing moisture through high evaporation. This has increased government expenditure by providing dams and boreholes for

irrigation. Ujah [11] categorically stated Nigeria had lost about 63.83% of its farmland to desertification, a considerable loss and a monumental impact of climate change on life and living due to food insecurity.

Another precarious condition of climate change in Nigeria is the dryness of lake Chad, which is too well known [12]. Some sixty years ago, the lake flourished as one of Africa's largest natural lakes, supporting large populations of farmers, fishermen, and herdsmen. It had a surface area of about 25,000 km². Today, it is estimated that the lake's surface area may only be about 5,000 km² and an overwhelming percentage of the population it supports is gone [12]. The growing increase in aridity caused this [10].

Vegetation is another part of the environment that is affected the most by climate change in Nigeria. There has been vegetation change, which means degradation or outright loss of vegetation cover. This degradation and outright loss of vegetation cover occurs in the tropical rainforest and the northern savanna. Many valuable tree species are almost extinct to the extent that artocarpus communis (bread fruit tree) and cola trees are now sawn for planks. Savanna, too, has nearly become bare land all due to environmental change agents and man. Through agriculture and extensive animal grazing, many animals inhabiting the degraded vegetation die off or migrate far away.

In addition to these impacts is the recent upsurge in Fulani herders insurgence. They now lead their cattle to graze southward of the country in farmers' cultivated farms. This often leads to fracas and incessant killings by the Fulanis. They couldn't stay to graze in the north again since the grassland was no longer what it used to be. Several lives and properties are lost almost daily in several states of Nigeria, such as Benue, Niger, Enugu, Delta, Oyo, Ondo, Delta, Taraba, etc. Ortom [13] lamented and affirmed when addressing the UN that 1,878 lives were lost to the lingering clashes in Benue alone.

4 | Adaptation Strategies

The inadequacy of meteorological stations in Nigeria about 54 stations when the country ought to have 9000- has been a major setback to adequate observations and records of climate in Nigeria. This shows that many areas are not yet covered for weather observations. Aside from this, little effort is made to adapt to this climate change in Nigeria. Some of the efforts we can make as a people are here under-explained.

Adesina [5] highlighted three main perspectives to responding to climate change. The first is research into the science of change to engender a clearer understanding of the critical issues. This has included the development of guidelines for National GHG Inventories [14] for estimating GHG emissions at the national levels to plan activities to control emissions. Second is mitigating the change by adopting technological, economic, and behavioral strategies that can assist in halting or slowing down the change process. The third, according to him, is to adapt to the change.

Governments of all levels and their policymakers, with the generality of the people of this country, should be more proactive in environmental controls and protections. We must vehemently control manufacturing industries to drastically reduce smoke, dangerous gases, and other atmospheric impurities they send to the air body. There is supposed to be a high rate of fines for erring industrialists. We should not put more premium on taxation derivable from that industrialist to the detriment of our environment. We should make sure that different agents charged for the assignment of a healthy environment, such as Osun State Environmental Protection Agency (OSEPA), Lagos State Environmental Protection Agency (LASEPA), Federal Environmental Protection Agency (FEPA), etc., are well-equipped with modern scientific equipment for continuous reading and recording of atmospheric dangerous gases. Specific fees should be made to compel industries operating in Nigeria to clear the atmosphere and conduct environmental-related programs.

Another point that is very germane in climate change palava is the population. The higher the population, the higher the environmental degradation and the higher the climate change. We need to strategically cut down the population rate in order to reduce the free ranching of herdsmen across the country. We also need to drastically reduce the mining of solid minerals and gas and oil exploration. Reducing the population will also checkmate the rate of destruction of biomass through farming and lumbering.

A strategy for harmless, adequate, and sustainable energy for industrial and domestic uses is important for an effective environmental haven for good living. The government's awareness of the need to effectively address the electricity issue is highly commendable. However, we need to stop politicking about it and focus appropriately on programs that will realistically help improve the energy supply for all sectors of the economy. There is supposed to be full support for research on alternative energy supply. Still, we have to budget a considerable amount of money and employ foreign experts to improve hydroelectricity in our country. Hydroelectricity functions in Japan, and it can also function here if we invest massively in it since there is potential for the sub-sector here, too. Research to convert gas flaring to domestic cooking gas is long overdue. Biogas development should not be left out, too. All these will enhance better cheaper and more environmentally friendly energy instead of different sizes of mobile energy-generating machines that aggravate climate change.

Also, the government of the federal republic of Nigeria should urgently abolish the importation of jalopy cars and jaundiced-engine vehicles to Nigeria. Trucks should either be stopped or reduced, and a proper multimodal transportation system should be embarked upon with new vehicular modes. All these will reduce dangerous fumes that are inimical to the atmosphere through which climate change emerges.

We also need to restrategize our forestry sector. Afforestation is essential nationwide; nobody should be allowed to penetrate such forests to fall trees or kill animals. There should be a means of watering such forests that may be grown in the drier areas of Nigeria. This will enable the forest to function more as a natural carbon 'sink' through photosynthesis. More oxygen will be diffusing to the earth-atmospheric environment, too. Also, periodic microclimate processes will always occur, which can cause wetness in a small environment through increased moisture from evapotranspiration in the air. The need to grow forests in this nation is quite important.

Last but not least, these strategies are the efficient storage and utilization of water resources. One of the consequences of climate change is irregular rainfall and prolonged drought. Rainfall events bunched up in fewer months in many areas, then intervening dry spells during growing seasons are now rampant. The water sector, therefore, deserves greater attention than what we have given it presently in the country. This irregularity in rainfall and prolonged dryness is already a threat to food production and drinking water. Strategizing supplementary water irrigation during dry spells or full-scale irrigation in areas with protracted dryness is necessary. There are two things to do here: improve water storage, such as larger volumes of water for retention during rainfall, which can be useful in the dry period. Two, infrastructures needed to distribute water to farms are essential. With this strategy, we won't make the previous mistakes of old irrigation schemes, many of which are now dry. We should also continue to improve on this irrigation issue so as not to run into a water loss at any time.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

All data are included in the text.

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