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Climate Change in Contemporary Nigeria: An Empirical Analysis of Trends, Impacts, Challenges and Coping Strategies

S.O. Amadi [1*] andS.O. Udo [2]
[1]*Dept of Physics, Geology and Geophysics, Federal University Ndufu-Alike Ikwo, Ebonyi State.*
[2]*Dept of Physics, University of Calabar, Calabar,*

Abstract: *Trends in the present-day climate of Nigeria were investigated by analyzing the historical temperature and rainfall data records in the context of climate change. The associated potential impacts and coping strategies were examined. The data for the study were collected from the archives of the Nigerian Meteorological Agency, (NIMET), Oshodi Lagos and spanned from 1950 – 2012. The basic data consist of monthly mean daily minimum and maximum temperatures and monthly rainfall totals in six meteorological stations selected from the various agro meteorological zones in Nigeria. These stations are Maiduguri, Kaduna, Makurdi, Enugu, Ibadan and Calabar. These basic data were converted to annual rainfall totals and annual mean daily minimum and maximum temperatures for the analyses. The non-parametric Mann-Kendall's (M-K) rank correlation tests, Time series plots and simple linear regression are the statistical tools used for the analyses. The M-K test results indicate upward trends in minimum and maximum temperature that are significant at the 1% level in all the stations. The M-K test results indicate average downward trends in rainfall for Maiduguri, Kaduna and Makurdi of which only Makurdi is significant at the 5%level. The M-K trend tests further indicate upward trends in rainfall for Enugu, Ibadan and Calabar which are not statistically significant at the chosen significance levels of 1% and 5%. All the M-K trend tests are corroborated by the Time series plots. The potential effects of these trends, the challenges therein, and some coping strategies to help in environmental management are discussed.*

Keywords:Climate Change, Rainfall trends, Temperature trends, Impact, environmental management.*

I. Introduction

The study is designed to investigate the trends in climatic parameters in Nigeria by analyzing the historical temperature and rainfall records as indicators of climate change. Climate change is perhaps the most serious environmental threat to mankind globally, especially in African through its impacts. Climate change strikes at the root of the foundation of world economic system and energy use especially in Africa where most economic activities are climate-sensitive. The understanding of how climate change may affect individual countries and regions within a country is, therefore, a topical issue for research. It is necessary to explore how local and national climates may already be changing using the most widely used climate change indicators. This will enable policy makers, environmental managers and authorities at local and national levels to design appropriate and effective mitigation and adaptation mechanisms.

According to IPCC(2007), climate change refers to a change in the state of climate that can be identified (e.g 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. Parry et al (2007) viewed climate change as a change in climate which is attributed directly or indirectly to human activities that alter the composition of the global atmosphere, and which is in addition to natural climate variability observed over comparable time periods. Nevertheless, climate change is different from climate fluctuations or climate variability. These terms denote inherent dynamic nature of climate on various time scales which could be monthly, seasonal, annual, decadal, periodic, quasi-periodic or non-periodic (Odjugo, 2010). Changes brought about by natural processes are usually termed climate variability. Such natural processes include volcanic eruption, plate tectonics, solar variability (sun spot activity), changes in the eccentricity of the earth's orbit and EL NinoSouthern Oscillation (ENSO). On the other hand, climate change is often used for human-induced changes in climate.

The anthropogenic factors create an alteration in the radiative forcing, bringing about alteration in balance between incoming and outgoing radiation in the earth's surface. These anthropogenic radiative forcing factors are changes in the concentration of greenhouse gases (GHGs) in the atmosphere, changes in the aerosol concentration and land use changes. The two natural processes that influence radiative forcing are solar activity and volcanic activity. In this way, climate change could be viewed as any change in climate overtime in a particular region or location, whether due to natural variability or as a result of human activities. Human activities affect the earth's energy budget by changing the emissions and resulting atmospheric concentrations of radiatively important gases and aerosols and by changing land surface properties. Changes in the global energy budget derive from either changes in the net incoming solar radiation or changes in the outgoing long wave radiation. Changes in the net incoming solar radiation derive from the changes in the sun's energy output or changes in the earth's albedo (the amount of radiant energy reflected by the earth's surface back to the atmosphere). In addition, some aerosols increase atmospheric reflectivity, while others such as particulate black carbon are strong absorbers and also modify shortwave (solar) radiation. Indirectly, aerosols also affect the cloud albedo. This is because many aerosols serve as cloud condensation nuclei (CCN). This implies that changes in aerosols types and distribution can cause small but important changes in cloud albedo and cloud lifetime. Human activities enhance the greenhouse effect (GHE) directly by emitting GHGs such as CO_2, CH_4, N_2O, CFCs, SF_6, HFCs, CO, NOx, SO_2 and O_3. Furthermore human activities are affecting both the energy and water budget of the earth by changing the land surface properties, including redistributing the balance between latent heat and sensible heat fluxes. Land use changes such as clearing and burning of forests to prepare farmlands change the characteristics of vegetation, seasonal growth and carbon content (Houghton, 2003; Foley, 2005). In this way, carbon storage (carbon sink) in the vegetation is reduced and CO_2 is added to the atmosphere accompanied, by changes in the reflectivity of the land (surface albedo), rates of evaporation and long wave emissions.

The preceding paragraph goes to prove that evidently, climate change is linked to human actions, and in particular from the burning of fossil fuels and changes in land use. Climate change whether driven by natural or human forcing or both, can lead to the changes in the likelihood of the occurrence or strength of extreme weather events or both and their resulting adverse impacts. This paper is tailored towards the following aims and objectives:

i. To evaluate the trends in historical rainfall and temperature data in Nigeria as indicators of climate change.
ii. To assess the resulting potential impacts associated with the trends obtained from evidence-based knowledge.
iii. To examine the mitigation and adaption measures to cope with the threats.

II. Study Area

Six stations drawn across major agro ecological zones in Nigeria are used.

Fig. 1map of Nigeria showing the meteorological stations used in the study

Table 1 below gives the details of the stations used for the study.

Table 1: Description of stations used in the study

Station Name	Latitude (°N)	Longitude (°E)	Altitude (m)	Ecological Zones
Maiduguri	11.51	13.05	591	Sahel Savanna
Kaduna	10.42	7.19	645	Sudan Savanna
Makurdi	7.42	8.37	113	Guinea Savanna
Enugu	6.28	7.34	142	Guinea Savanna
Ibadan	7.22	3.59	234	Tropical Rain Forest
Calabar	4.58	8.21	62	Swamp Forest

III. Data And Methodology

3.1 The Data

The basic data which comprise monthly mean daily minimum and maximum temperatures and monthly rainfall totals were collected from the Nigerian Meteorological Agency, (NIMET), Oshodi, Lagos for the period 1950 – 2012, covering a period of 63 years.

3.2Data Quality Check

The monthly data were scrutinized. Some missing observations were noticed but not replaced. The missing observations ranged from 2% to 5% of the data length. Shongwe et al, (2006) suggested the use of data from stations with missing records not greater than 5%. This was adopted in this research work. A preliminary step in analysis of data homogeneity is to plot the time series of the original data on a linear scale. This was done in this case. Visual inspection of the plots revealed that the data are homogeneous.

3.3 Methodology

The original monthly data were converted to annual data for the analysis. The Mann-Kendall's (M-K) rank correlation test was used to detect the presence, direction and significance of the trends. The M-K tests were executed using the SPSS package. The trend magnitudes were estimated using the least square method of the simple linear regression model. The linear regression model was executed using MATLAB. The Time series plots with trendlines were executed using the MATLAB. The non-parametric M-K tests possess higher statistical power than their parametric counterparts in trend detection in climate studies. This is because the M-K tests do not require normality of the data distribution; they are robust against outliers and missing data, and they represent a measure of monotonic dependence whether linear or not (Turkes, 1996; Turkes, 1999; Turkes et al, 2008; Zhihua et al, 2013; De Luis et al, 2000). Detailed discussion of M-K trend tests abound in the literature (e.g Turkes, 1996; Turkes, 1999; Turkes et al, 2008; Zhihua etal, 2013; Raietal, 2010).

3.3.1 The Mann-Kendall (M-K) Correlation Test

Within the M-K test, the data $(x_1, x_2, \dots, x_n)$ of time series as null hypothesis, H_o, are independent identically distributed random samples. Given n size data for n≥10, the M-K test statistic S is defined as follows (Rai et al, 2010; Zhihua et al, 2013):

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i) \dots\dots\dots\dots\dots (1)$$

where x_j and x_j are the sequential data for the i^{th} and j^{th}terms, and j >i

$$\operatorname{sgn}(x_j - x_i) = \begin{Bmatrix} 1 \ , x_j > x_i \\ 0, \quad x_j = x_o \\ -1 \quad x_j < x_i \end{Bmatrix} \dots\dots\dots\dots\dots\dots\dots\dots (2)$$

when S is a large positive number, later values exceed earlier values and upward trend is indicated. When later values are less than earlier values, S is negative and downward trend results. Under the null hypothesis of independent and randomly distributed random variables, when n ≥10, the S statistic is approximately normally distributed, with zero mean and variance as follows (in the absence of ties):

$$\sigma^2 = \frac{n(n-1)(2n+5)}{18} \dots\dots\dots\dots\dots\dots\dots.. (3)$$

The value of S and $\boldsymbol{\sigma}^2$are used to compute the Z statistic, which follows a normal standardized distribution thus:

$$Z = \begin{cases} \dfrac{S-1}{\boldsymbol{\sigma}}, \ S > 0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..(4) \\ 0 \ , \ S = \ 0 \\ \dfrac{S+1}{\boldsymbol{\sigma}}, \ S < 0 \end{cases}$$

The null hypothesis H_o that there is no trend is rejected when the absolute Z value computed by eqn (4) is greater than the critical value $Z_{\alpha/2}$at a chosen level of significance α. Conversely, the alternative hypothesis H_1 that the data follow a monotonic trend over time is accepted. The test statistic tau (τ) is computed as

$$\tau = \frac{S}{n(n-1)/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

In this study, the Zvalue is tested at the 1% and 5% significance levels. The trend is upwards for positive values of Z and downwards for negative values of Z. The test statistic τ (Kendall's tau b) has a range of -1 to +1, and is analogous to the correlation coefficient in regression analysis. The null hypothesis is rejected when the tau b (τ) is significantly different from zero. To test the trend significance, Z is computed and the cumulative probability for a standard normal distribution at /Z/ is found. For a two tailed test, the value of the cumulative probability is multiplied by 2 to obtain the p value. If the p value is below a given level of significance, the trend is significant.

IV. Results And Discussion

The results are presented in tables and graphs. Tables 2,3 and 4 display the M-K tests results for minimum temperature, maximum temperature and rainfall respectively. The trend significance and estimated trend magnitudes are also indicated in the tables. Table 2 indicates that the trends in minimum temperature are increasing and are significant at the 1% level in all the stations except Kaduna which indicates an upward trend that is significant at the 5% level. Table 3 indicates that the trends in maximum temperature are upward which are significant at the 1% level in all the stations. Table 4 shows a downward trend in rainfall in three out of the six stations. These stations with decreasing trends are Maiduguri, Kaduna and Makurdi. Only Makurdi shows a significant downward trend at the 5% level. Enugu, Ibadan and Calabar show upward trends that are not significant at the chosen significance levels. While the minimum and maximum temperature trends indicate a general upward trend in all the ecological zones, the rainfall trends appear to exhibit a pattern across the latitudinal bands and ecological zones. It could be established from the results that the Sahel Savanna region (Maiduguri), the Sudan Savanna region (Kaduna) and the Guinea Savanna further up north (Makurdi) are experiencing decline in rainfall. Even though Enugu and Makurdi are within the Guinea Savanna ecological zone, latitudinal location, local scale features and other internal dynamics of the climate system may account for the contrasting trends as these factors could play a role in local climate. With the exception of Kaduna, minimum and maximum temperature trends appear to increase from the coastal regions to the inland regions. This result captures the influence of topography and altitude in producing local minimum value over Kaduna station with altitude of 645m above mean sea level (Table 1).

Fig. 2 displays the Time series anomaly plots for the annual mean daily minimum temperature for the stations. The trendlines are also shown. Fig 2 gives a representation of general upward trends in all the stations as indicated by the trendlines. Fluctuations in annual mean daily minimum temperature are equally evident from the plots. Fig 3 shows the Time series anomaly plots for the annual mean daily maximum temperature. Trendlines reveal upward trends in all cases while the fluctuations in annual mean daily maximum temperatures are quite obvious from the plots. Fig 4 shows the Time series anomaly plots of annual rainfall totals. The directions of the trends as revealed by trendlines are not quite obvious for Enugu and Calabar plots. This situation is also captured in Table 4 where the tau b values for Enugu and Calabar are very low. In general, figs 2, 3 and 4 agree perfectly with tables 2,3 and 4 respectively. In other words, the M-K test results are corroborated by the Time-series anomaly plots. In this way the Time series anomaly plots could be viewed as additional piece of information.

Table 2: M-K trend tests results for minimum temperature and estimated trend magnitudes.

Station	Kendall's tau b	P value	Trend estimates		
			^{o}C per year	oC per decade	Average estimate for the period (^{o}C)
Maiduguri	0.454**	0.000	0.05	0.50	3.15
Kaduna	0.203**	0.019	0.01	0.10	0.63
Makurdi	0.458**	0.000	0.03	0.30	1.89
Enugu	0.408**	0.000	0.02	0.20	1.26
Ibadan	0.495**	0.000	0.04	0.40	2.52
Calabar	0.407**	0.000	0.03	0.30	1.89

** Trend significant at 1% level (2 – tailed)* Trend significant at 5% level (2 – tailed)

Table 3: M-K trend test results for maximum temperature and the trend estimates.

Station	Kendall's tau b	P value	Trend Estimates		
			^{o}C per year	oC per decade	Average estimate for the period (^{o}C)
Maiduguri	0.396**	0.000	0.026	0.26	1.64
Kaduna	0.471*	0.000	0.013	0.13	0.82
Makurdi	0.439**	0.000	0.027	0.27	1.70
Enugu	0.374**	0.000	0.025	0.25	1.58
Ibadan	0.510**	0.000	0.014	0.14	0.88
Calabar	0.460**	0.000	0.023	0.23	1.45

** Trend is significant at 1% level (2 – tailed)

Table 4: M-K trend test results for rainfall and the trend estimates

Station	Kendall's tau b	P value	Trend Estimates	
			mm per year	mm per decade
Maiduguri	-0.133	0.125	-7.633	-76.33
Kaduna	-0.165	0.055	-3.609	-36.09
Makurdi	-0.175*	0.043	-9.071	-90.71
Enugu	0.048	0.581	0.715	7.15
Ibadan	0.137	0.113	1.326	13.26
Calabar	0.008	0.929	8.045	80.45

* Trend is significant at 5% level (2 – tailed)

V. Implications Of The Result

The significant upward trends in minimum and maximum temperatures across the stations have serious implications on the environment and the socio-economic development of Nigeria. The declining trend in rainfall in the Savanna region of northern Nigeria (although with only Makurdi significant) and the increasing trend in the south (though not significant at the chosen significance levels) equally have environmental and socio-economic implications for Nigeria and her citizenry. These implications are viewed on the basis of how they can impact on major sectors of the economy, namely, agriculture, health, water resources, human settlement and energy.

5.1 Impacts On Agriculture And Economic Resources

Rising temperature and declining rainfall in northern Nigeria can cause drought and desertification. The Sahelian region of Nigeria could face desert encroachments and subsequent loss of farmlands and grazing fields. Increasing temperature will increase the rate of evapotranspiration and changes in soil moisture. This could lead to crop failures and is a threat to food security. Decreasing rainfall trends can shorten the length of growing season and affect crop productivity since crops require conducive climate to thrive. In the coastal areas, sea incursions as a result of rising sea levels can cause flooding of farmlands and some oil installations since most of the oil industry activities are located in coastal areas. This could cause serious economic setback.

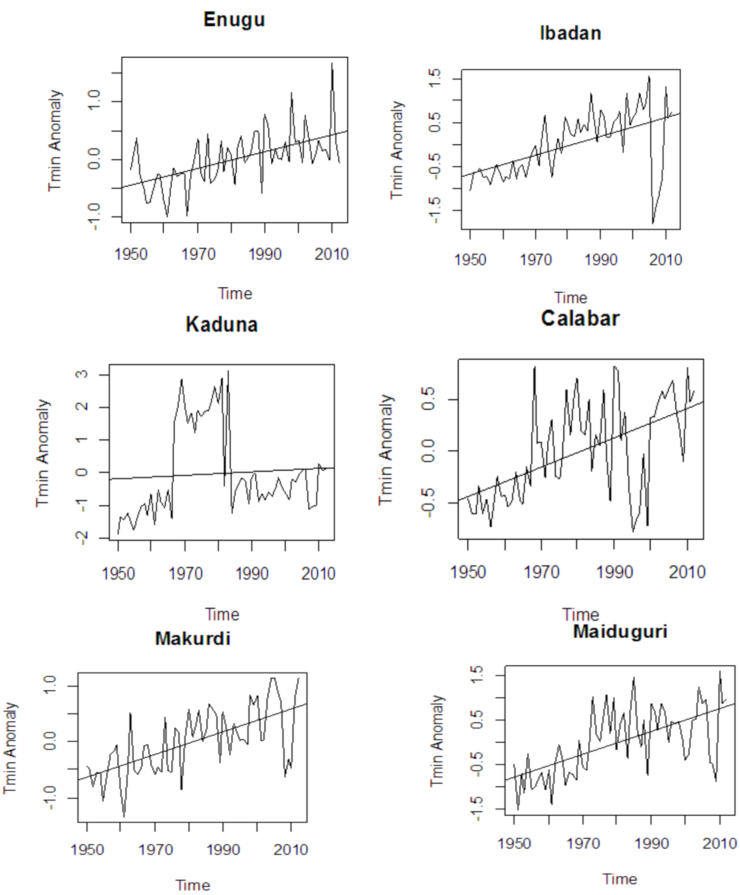


Fig.2: Time series anomaly plots for Minimum Temperature

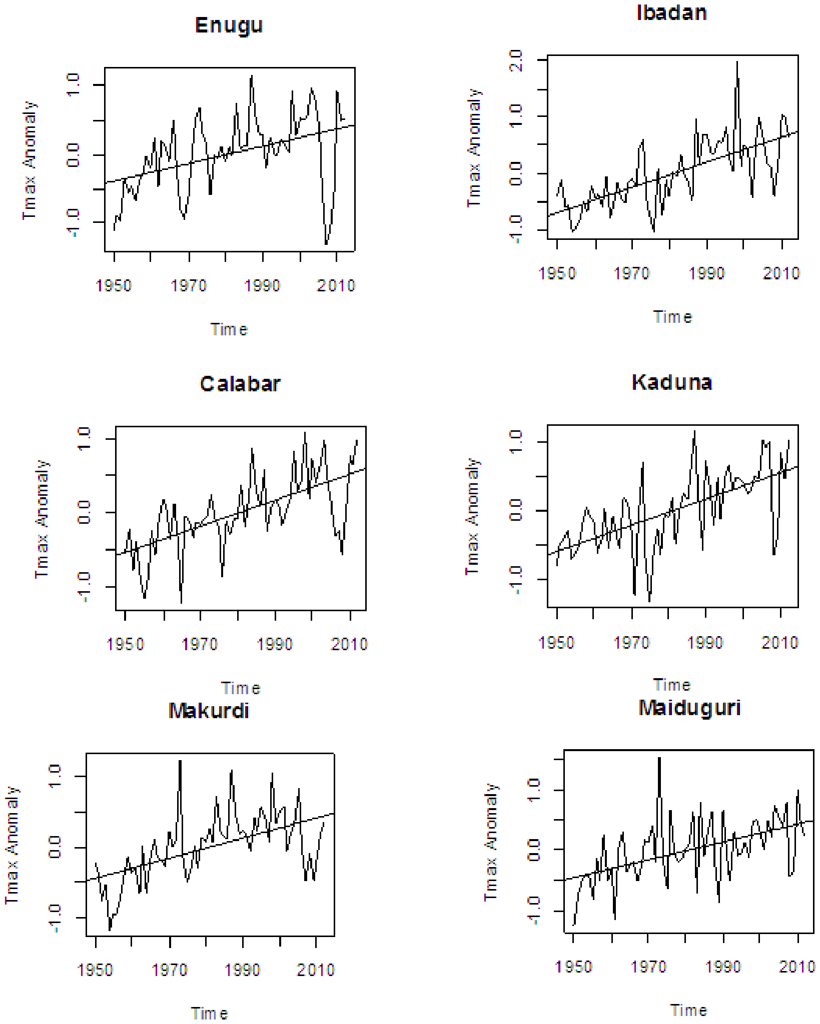
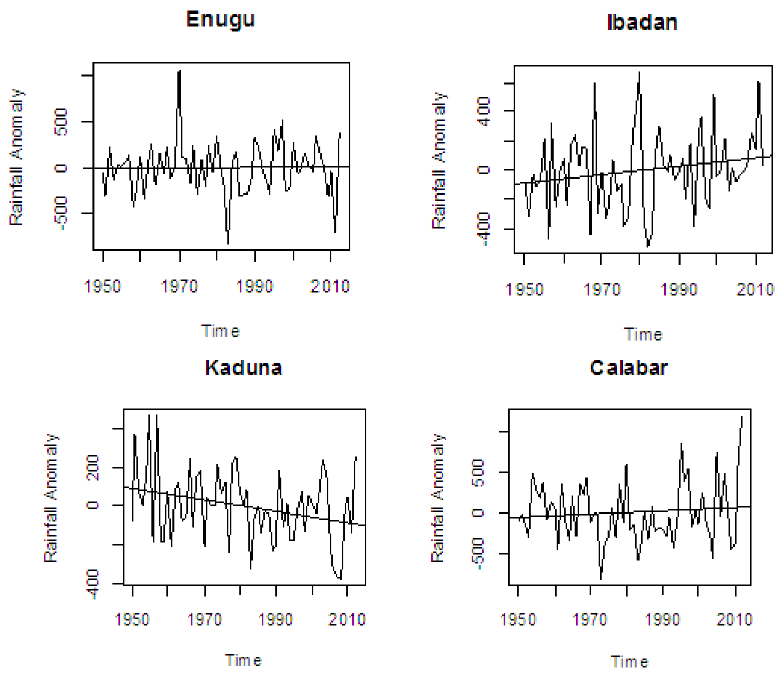


Fig.3: Time series anomaly plots for Maximum Temperature



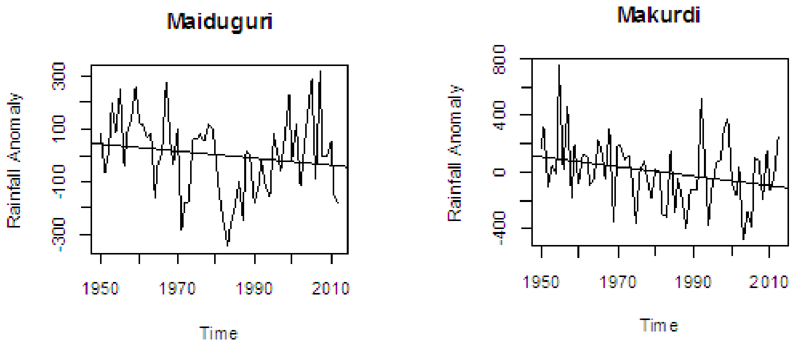


Fig.4: Time series anomaly plots for Rainfall

5.2 Health – Related Impacts

According to IPCC (2007), high temperature brings on its toll incidence of heat waves. Abiodun et al, (2011) reported that heat waves occur when the maximum temperature is greater than 35^{o}C for 3 days or more consecutively. High temperature can trigger off incidences of quite a number of tropical diseases linked to high temperature such as heat cramps, heat strokes, cellebro-spinal-meningitis, malaria, including new risks of emergence of chronic diseases (WHO, 2003). Incidence of high temperature will likely aggravate the epidemics. The Nigerian Southern region by virtue of upward rainfall trends has high risk of malaria because of the increase in number of breeding sites for 'Anopheles' mosquitoes. According to Abiodun et al, (2011), high temperature and low seasonal variations in temperature also favour the development of mosquitoes: temperature affects the biting rates of mosquitoes and the production rates of the plasmodium parasite within the mosquito. Furthermore, Riziki (2010) observed that people living in flood-prone areas are exposed to flood-related health hazards such as cholera and dysentery.

5.3 Water Resources Impacts

Increasing temperature and declining rainfall have the incidence of altering all aspects of hydrological cycle in the northern part of the country. There could be minimal recharge of ground water resources, wells, rivers and lakes in these areas. This will cause water stress. As a testimony to this, according to Odjugo (2010), many rivers have been reported to have dried up or are becoming more seasonally navigable while Lake Chad shrunk in area from 22, 902 km^2 in 1963 to a mere 1304 km^2 in 2000.

5.4 Impacts On Human Settlements

Floods, droughts and desert encroachment can affect human settlements. Rising sea levels can cause ocean surges and severe flooding in coastal and riverine areas. Drought and desertification can cause settlement destabilization further inland. Coastal inundation can cause heavy financial losses and even deaths because of extreme weather events, particularly floods and rainstorms. In the northern part of the country, the probable loss of conducive climate for settlements, farming and grazing activities have prompted massive emigration and resettlements of people to areas less threatened by desert encroachment. Such migrations bring on their toll social effects like the increasing spate of communal clashes amongst Fulani herdsmen and farmers that are rampant in the middle belt of Nigeria, notably in Benue and Nassarawa States in recent episodes. Several deaths were occasionally recorded in the clashes. Some that are destabilized as a result of unfavourable climate migrate to the urban areas to beg for alms, thereby increasing the already tense urbanization problem.

5.5 Energy Related Impacts

Temperature increase in the tropics will affect how much energy we need and when we need it. As temperature increases, more people in Nigeria will need to keep cool by using electric fans and air conditioners, which uses a lot of electrical energy. In addition, flooding and drought can affect hydropower adversely as energy resource. All these shall create stress in energy consumption. Again, electronic components usually fail consequent to stresses upon them arising from high temperatures and other surrounding/environmental conditions (environmental stress).

VI. Recommended Mitigation And Adaptation Strategies

6.1 Mitigation Options

Mitigation involves reducing GHG emissions, or enhancing the capacity of carbon sinks to absorb GHGs from the atmosphere, or increasing the surface albedo. At the core of most strategies include the following:

i. Promoting land use acts that support afforestation and reforestation.

ii. Encouraging the development and use of clean, renewable energy.
iii. Geoengineering and carbon sequestration.
iv. Slowing gas flaring.
v. Enabling institutional framework (policies, legislation, strategies, programme of actions, coordinating mechanisms).
vi. Massive public awareness programmes backed by strong political will.
vii. Improved energy efficiency performance.
viii. Embark on vehicular and machinery emission monitoring programme.
ix. Making companies responsible for the consequences of their actions including payment of GHG emission taxes.

6.2 Adaptation

Adaptation in this context involves the adjustment in natural or human systems to a new or changing environment resulting from climate change with a view to moderating potential damages, taking advantage of opportunities or coping with consequences. Adaptation capacity of a region or nation relates closely to its vulnerability and resilience. Vulnerability varies by geographical location, extent to which economic activities depend on climate, and level of economic development. Resilience is the degree to which the system can withstand adverse effects. The level of preparedness relates closely to level of wealth, strength of educational institutions and access to technology. The following strategies can be insightful in building adaptation capacity:

i. Strengthening the educational system to make it more functional.
ii. Effective networking and information management.
iii. Environmental education programme in schools is crucial.
iv. Involving local actors and stakeholders in environmental management.
v. Paying sufficient attention to climate research and development to improve climate forecasting capacity.
vi. Having better equipped weather stations as against the scanty and ill-equipped ones.
vii. Improvement in building designs and use of roofing sheets with high reflection co-efficient.
viii. Introducing drought-resistant variety crops and heavy investment in irrigation farming rather than rain-fed agriculture. Enete and Amusa (2010) noted that the development of dynamic farming systems to adapt to climate change threats, backed by stable policy environment, is lacking in Nigeria.
ix. The use of treated mosquito nets and improved health care delivery systems.
x. Improvement of early warning systems.
xi. Development of a long-term strategy of investments to diversify the economy away from climate sensitive sectors, and strengthening institutional capacity to respond effectively to climate change. Ogbo et al (2013) observed that Nigeria has no known climate change policy and strategy to respond to climate change vulnerability.
xii. Studying the vulnerability and resilience to climate change of each city in Nigeria and designing appropriate coping mechanisms.
xiii. Population control is essential. As the increasing population puts more pressure on diminishing resources, escalating environmental problems further threaten food production and food security.

VII. Conclusion

This research work has provided evidence-based knowledge of the presence of climate change in Nigeria using temperature and rainfall data. The significant upward trends in minimum and maximum temperatures are accompanied by several risk challenges that have been highlighted in the work. The implication of shifting rainfall trends also portends grave consequences in the long-run. The recommended mitigation and adaptation mechanisms could provide good insights for governments, policy makers, environmental managers and other stakeholders in tackling the risk challenges of climate change. It is imperative that these potential risks are prioritized as we need to use present and recent events to chart a new course. The need for the development of dynamic farming systems that could adapt to the challenges of climate change requires a conducive and stable policy environment. Formulation of National Climate Change Policy and Strategy and the establishment of educational and institutional capacity to respond effectively to climate change are essential.All mitigation and adaptation mechanisms are necessary. Mitigation is essential but adaptation is inevitable, and both need to be pursued vigorously and in parallel.

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