Impact of Climate and Land Use Changes on the Livelihood of Residents in Calabar River Basin, South-eastern Nigeria

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Abstract: Human activities such as deforestation, urbanization, and fuel combustion have caused climatic and land use changes, affecting the livelihood of residents negatively in Calabar River Basin, South-eastern Nigeria. In the region, there has been a constant and prolonged rise in temperature. To determine the status of climatic change, data sets spanning 43 years (1971-2014) were obtained from the Nigerian Meteorological Agency (NIMET) and compared to NIMET's historical meteorological data maps of Nigeria between 1941-1970 and 1971-2000, commonly known as the base period. In contrast, utilizing imageries from several satellites (Landsat), multi-temporal dates (MSS 1980, TM 1990, ETM 2000, and ETM+2010) and ArcGIS, researchers were able to determine the Land Use Changes / Land Covers (LULC) that have occurred in the Calabar river basin through time (1980-2020). Climate data revealed a historical sequence of temperature rises, as evidenced by late beginning and early cessation of rainfall, which had a negative influence on agriculture. Similarly, the investigation found that the environment has been warmer as temperatures have risen significantly, and that the harmattan dust haze has also increased in recent years. The investigation for LULC came up with six broad classifications: urban (built-up), water bodies, forest, farm, grass, and bare areas. Built-up area and farmland land uses have increased dramatically (3.19%-20.73%) and (10.20% -23.79%), respectively; forest (35.85%- 24.84%), water bodies (8.77%- 5.27%), Grassland (24.68%- 12.67%), and bare land uses have decreased dramatically (17.31%-12.69%). Since 1941 through 2020, temperatures have risen at a pace of 0.14° F (0.08° C) every decade, and the rate of warming is more than twice that: 0.32° F (0.18° C) per decade. The shortening of the rainy season has been forced by the late start and early cessation of rains. This has had a negative impact on the region's farming activities. The study recommends reforestation and the formation of forest reserves, greater energy efficiency, a shift to renewable resources / cleaner sources of energy (solar and wind), and reduced deforestation to mitigate the risks connected with climate and land use changes.

Keywords: *Climate, Deforestation, Global warming, Land use, Rainfall, River basin, Tropics*

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1. Introduction

Sustainability and environmental management entail using sustainability concepts to manage the oceans, freshwater systems, land, and atmosphere. Because changes in the relative quantities of land committed to urbanization, agriculture, forest, woodland, grassland, and pasture have a significant impact on the global water, carbon, and nitrogen biogeochemical cycles. Because of the possible catastrophic impacts on biodiversity and human communities, managing the Earth's atmosphere entails assessing all elements of the carbon cycle in order to identify chances to solve human-induced climate change, which has become a significant focus of scientific research. Ocean circulation patterns have a significant impact on temperature and weather, as well as human and other organisms' food supplies.

Significant climate and land use changes had happened in Nigeria in general and Calabar in particular. According to Ayoade (1988), tropical areas experienced the majority of changes in vegetation and rural land use. Because of the

Calabar River, the Great Kwa River estuary, and the wetlands of the Cross River estuary, Efiong (2011) saw a significant shift in land development from the city's eastern and southern sections to the state's northern regions. The National Integrated Power Project (NIPP), for example, is located in the study area along the Calabar–Itu highway and utilizes large swaths of land at Ikot – Nyong in Odukpani, Pamol Rubber Plantation in Odukpani, and Tinapa Leisure Resort in Odukpani, respectively. In these territories, humans have continued to conduct commercial operations, which has had an impact on the land. Despite these efforts, there is little indication that the government is concerned about the region's ecosystem. In Nigeria, Okude (2006) noted a scarcity of literature as well as a lack of awareness of the ecological aspects of land use studies.

Cross River State in Nigeria is home to more than 40% of Nigeria's remaining Tropical High Forests (THFs) (Balogun, 1994). The forest resource base includes mangrove swamps and tropical rainforest in the south, central Guinea savanna in the middle, and derived Guinea savanna in the north (Ogar, 2006). As a result, Cross River has become Nigeria's most heavily forested state, with at least 75% of the population residing in rural areas. According to Ogbonaya (1996), forest loss in Nigeria is expected to be over 4,000 km2 each year. If the current rate of deforestation continues, Nigeria would have no natural forest left in less than fourteen years, according to the researcher. However, 5% of the forest remains, with 4% of that in the Cross River Region (NEST, 1991). At the moment, forests encompass 34% of Cross River State (Dunn, 1994). The tendency has been reflected in the extent of exploitation in the Calabar river watershed forest reserves for agriculture, fuel generation, construction, urbanization, and other activities.

Despite the fact that the Cross River National Park (CRNP), which includes approximately 4,000 square kilometers of forested terrain, was established in 1994, the loss of rainforests within and outside its specified bounds due to commercial logging is rapidly increasing. Multinational logging and wood processing companies like Hanseatic Nigeria Limited (Germany), Kisari Investment Company Limited (Belgian), and, most recently, Wempco Agro-Forestry Company Limited (Hong Kong/China) have gradually turned their attention to this valuable vegetation, according to Akintoye (2002). According to Egbai et al. (2011), there is no link between Calabar's metropolis status and the apparent lack of vegetation cover, sandy soil, and high temperature regimes. They feel that the city's position has minimal bearing on the soil's susceptibility to rain wash.

Similarly, rapid deforestation is accompanied by urban expansion in the region due to a range of human activities. The pattern depicts the major changes in land use in the research region throughout time. According to Jackson et al., the expansion of an urban / residential area in any coastal location encroaches on other land uses such as farming, water bodies, swamp/mangrove, grassland, bare ground, and forest over time (2012). Within the study area, urban and farmland land uses have increased dramatically (3.19% -20.73%) and (10.20% - 23.79%), respectively, whereas forest (35.85% -24.84%), water body (8.77% - 5.27%), Grassland (24.68% - 12.67%), and bare land uses have decreased dramatically (17.31% - 12.69%).

As a result, urban center in Nigeria is linked to rapid urbanization. Severe erosion and flooding, as well as other environmental concerns, play a role if there is a lack of simultaneous provision for an adequate urban runoff disposal system, as in the study area. Continuous flooding in Calabar, according to the United Nations Development Programme (1995), has harmed socio-economic activity, culminating in the collapse of residential structures and fences. Severe, moderate, and low floods have been reported in the Calabar region (Adefolalu, 1978). According to the World Health Organization (WHO), climate change is the greatest threat to global health in the twenty-first century.

From the foregoing, various studies had been done to address land use change and climatic trends in the Calabar region without regard for sustainability and environmental management. There is a missing link on the sustainability and management of land use and climate changes.

2. Materials and methods

Calabar river basin is located in south - eastern Nigeria, lies between Latitudes 40451N and 50101 N and Longitudes 80051 and 80451 E, with an estimated area of 460km2 (Fig. 1). It is a lowland (plain), underlain by coastal plain sands of Benin formation. The mean annual temperature remains about 27oC throughout the year and, with a total rainfall of about 2,900 mm. The relative humidity is estimated to reach about 90%. It is located within the Hydrological boundary of the Calabar river system, with distinct vegetation and soil characterized by tropical rainforest and lateritic grained sand respectively. The population is estimated to be over 399,761 persons (2010 Population Census). The main occupations of the people include farming, hunting, extraction and gathering of timber and non-timber forest products.

Data on land use changes/land cover in the study area was gathered using a 1:500,000 scale topographical map and aerial images. This was utilized as a basis for interpreting and comparing the changes in different land use types in the research area. The research area was interpreted using images from four epochs: 1980, 1990, 2000, and 2010. The study also included a topographical map of the study area at a scale of 1:160,000 that was available. The study employed data from a variety of sources, as well as various methods and approaches, to examine long-term land use/cover changes and trends over the course of four decades in the studied area. Using ArcGIS, the researchers used satellite images from various satellites (Landsat), as well as multi-temporal dates (MSS 1980, TM 1990, ETM 2000, and ETMS+ 2010 & 2020).

The climatic (rainfall) data documentation of the Nigerian Meteorological Agency (NIMET), Calabar Station between 1971 and 2014, as well as the monthly annual temperature and rainfall documentation of the Nigerian Meteorological Agency (NIMET), Calabar station, were used as the primary source of data for climate variability and change in this study. As a result, the research data prioritized the key climatic factors, which were directly employed to generate line graphs. NIMET's historical meteorological data maps from 1941 to 1970 and 1971 to 2000 were compared to the 43-year trend of rainfall and temperature in Calabar as documented by NIMET between 1971 and 2014. The computation was based on meteorological parameters that reflect climate status, such as temperature, rainfall, and extreme weather events, such as flooding, drought, dust storms, and heat waves, among others. The evaluation was also based on scientific and trustworthy data from the Agency's decades-long archive.

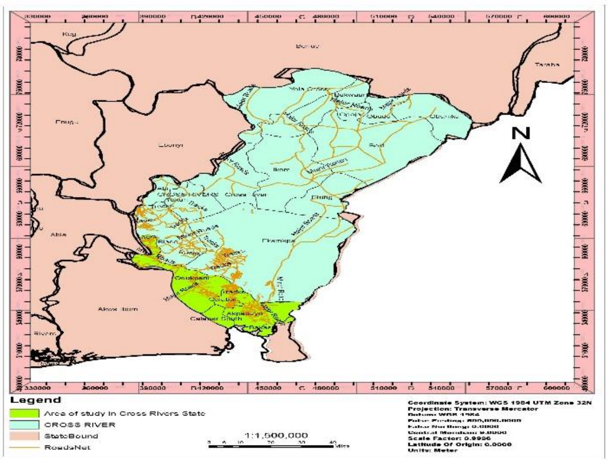


Figure 1: Map of the study site

3. Results and discussion

3.1. Land use changes/land covers

Water bodies occupied 8.77% of total land area in 1980, according to the earliest statistics on land use changes/covers, followed by urban areas (3.19%), grassland (24.68%), farmland (10.20%), forest (35.85%), and bare ground (17.31%). The most common land use, according to the summary result, was forest. Urban land use was the least recorded at the time (Figure 8).

By 1990, urban land usage had increased by 4.23%, encroaching on farms, bare areas, water bodies, and the adjacent secondary forest. Over this time span, mangrove swamps, woods, barren places, and farmlands have all shrunk substantially (Figure 9).

Urban land use had expanded by 8.41% by the year 2000, encroaching on farms, bare surfaces, water bodies, and the secondary forest that surrounding them. Mangroves, bare surfaces, and woods all suffered at this time (Figure 10).

Urban land use has expanded by 17.54% by 2010, intruding on farmlands, bare surfaces, water bodies, and the secondary forest that surrounding them. Over this time span, the amount of mangrove and woodland cover has substantially decreased (Figure 11).

By 2020, urban land usage had increased by 23.99%, encroaching on farmlands, bare surfaces, water bodies, and the secondary forest surrounding them. Mangrove and woodland cover has drastically decreased over this time period (Figure 12).

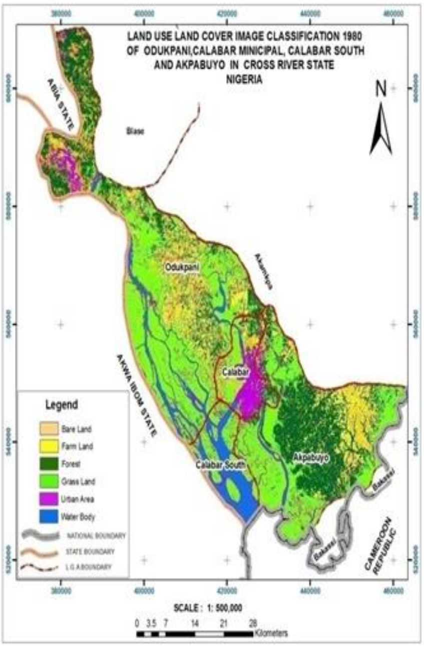


Figure 2: Land use land cover 1980

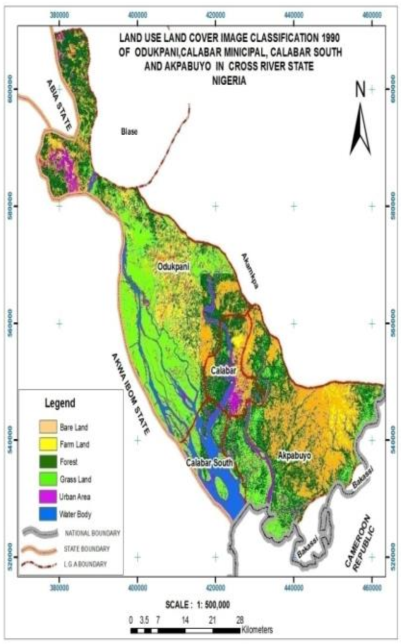


Figure 3: Land use land cover 1990

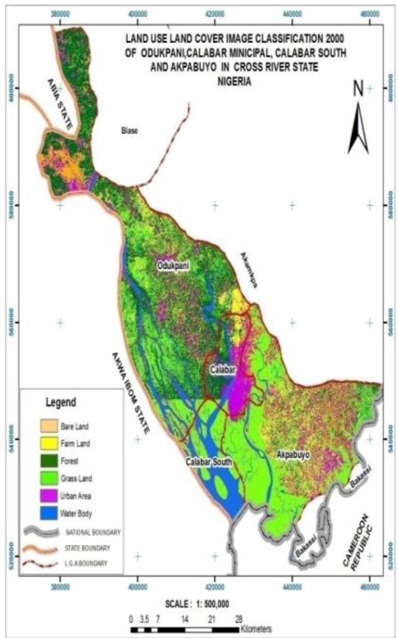


Figure 4: Land use land cover 2000

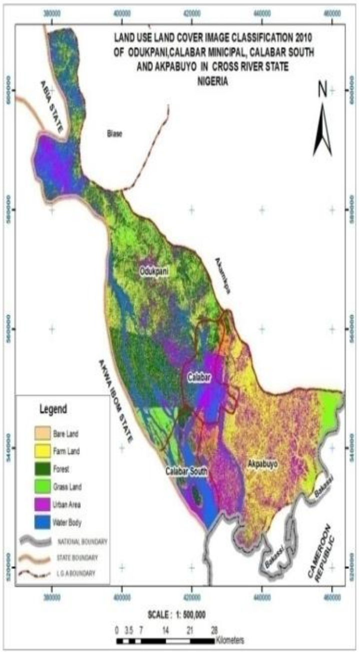


Figure 5: Land use land cover 2010

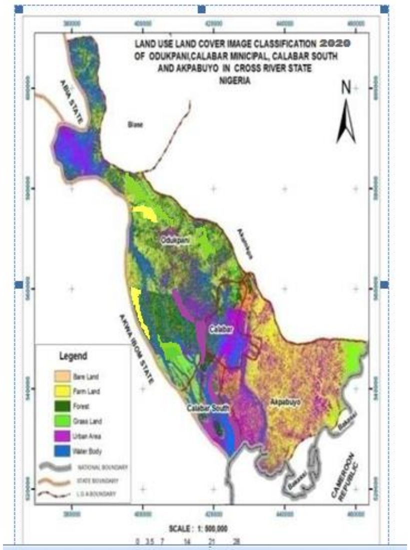


Figure 6: Land use land cover 2020

Figure 7: Urbanized (concretized) surface, bare, grass, farm and forest surfaces side by side along Calabar – Itu highway of the study area

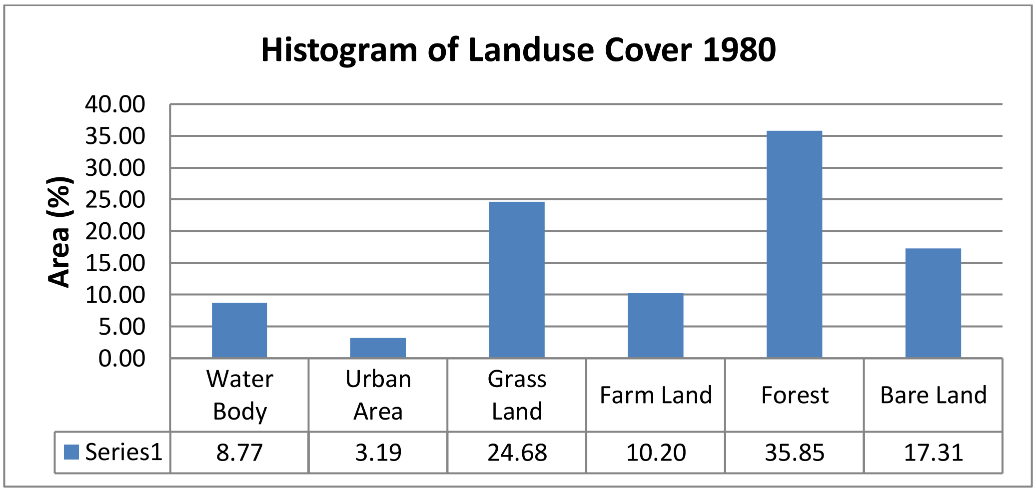


Figure 8: Histogram of land use cover (1980) of the study area

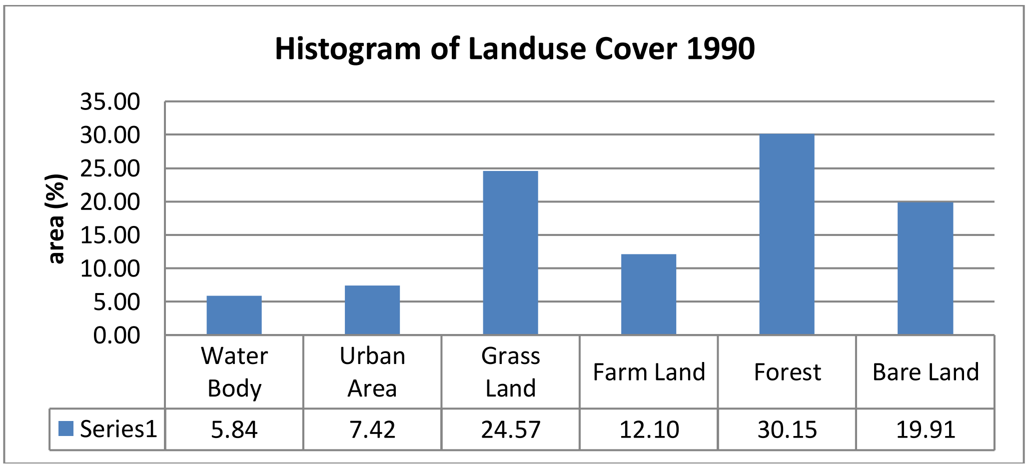


Figure 9: Histogram of land use cover (1990) of the study area

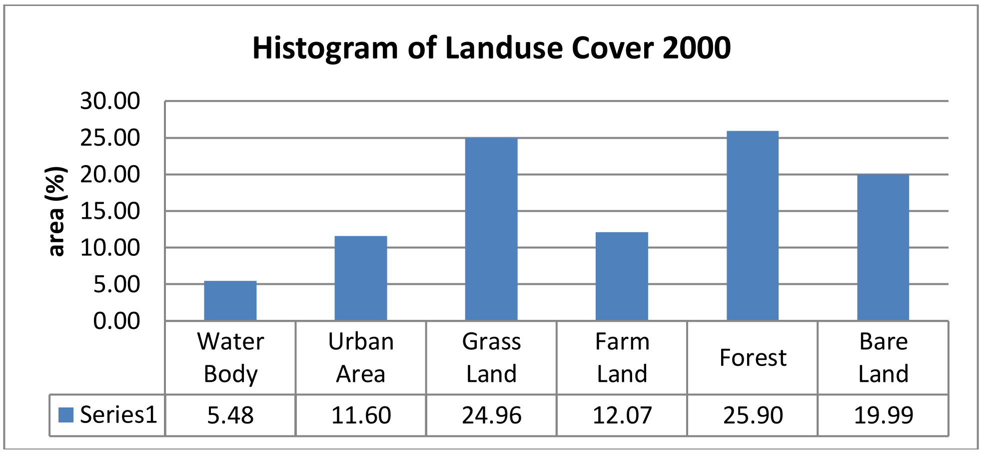


Figure 10: Histogram of land use Cover (2000) of the study area

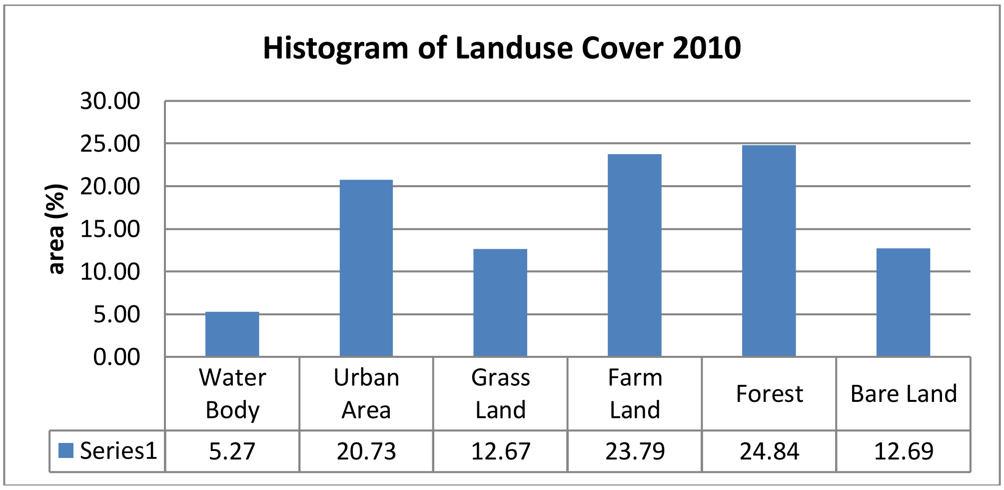


Figure 11: Histogram of land use Cover (2010) of the study area

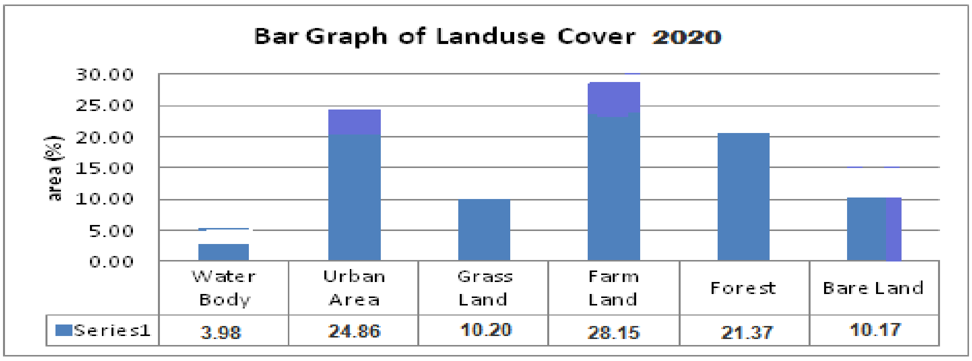


Figure 12: Histogram of land use cover (2020) of the study area

Table 3: Summary of land use change category at different epochs (1980 - 2020) in the study area

Landuse Change Category	***1980***		***1990***		***2000***		***2010***		***2020***	
	Area (m^2)	*(%)*	**Area (m^2)**	*(%)*	**Area (m^2)**	*(%)*	**Area (m^2)**	*(%)*	**Area (m^2)**	*(%)*
Water bodies	205098300	8.77	136590300	5.84	128119500	5.48	123402600	5.27	4.98	1196038620

Urban	74699100	3.19	173699100	7.42	271471500	11.60	485040600	20.73	23.99	5753254310
Grass	577357200	24.68	574892100	24.57	583918200	24.96	296449200	12.67	11.48	2752264560
Farm	238747500	10.20	283138200	12.10	282449700	12.07	556709400	23.79	25.12	6025165400
Forest	838700100	35.85	705433500	30.15	606020400	25.90	581134500	24.84	23.06	5532260170
Bare	405070200	17.31	465919200	19.91	467693100	19.99	296936100	12.69	11.36	2724395340
Total	**2339672400**	**100.0**	**2339672400**	**100.0**	**2339672400**	**100.0**	**2339672400**	**100.0**		**23983378400**

3.2. Climate variability and change

The 43 years trend (1971-2014) of rainfall and temperature in Calabar as recorded by NIMET was compared against NIMET's historical meteorological data maps between 1941-1970 and 1971 – 2000 (Figure 13 – 27). The computation was predicated on meteorological parameters that indicate status of the climate such as temperature, rainfall and extreme weather events like flooding, drought, dust storm and heat wave. The assessment was also based on scientific and credible data from the Agency's archive that spans many decades.

The mean annual temperature is 270C with two periods of high temperature recorded (double maxima) in the months of July and September. The annual range of temperature is a characteristic of equatorial climate. The difference between the temperature of the hottest month and the coldest month is as low as 5.00C. The mean monthly rainfall of 242 mm and mean monthly annual rainfall is over 2,900 mm. The average annual relative humidity is about 90% and the evaporation rate is above 1.7 mm (Table 4).

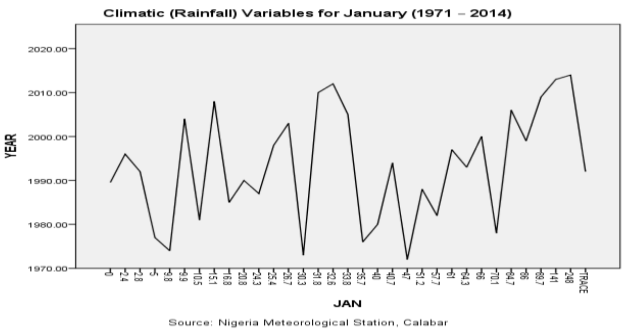
From the graphs, one can deduce that there is significant variability of rainfall in Calabar. Iloeje (1979) classified areas into three temperature zones: hottest areas - over 270C, moderately low areas (240C-270C) and cool areas-less than 240C. Calabar falls under the hottest areas with mean annual temperature of 270C. The region is accompanied by anthropogenic activities that produce greenhouse gases (mostly carbon dioxide) in the environment and this constitutes abnormal global warming in the area. Unless high temperatures are accompanied by high humidity, the weather is not as comfortable as it would appear to be. It is much more uncomfortable under the sticky heat of Calabar where the air is always charged with water vapour. The high temperatures with high humidity are more oppressive than hot but dry conditions (Iloeje, 1979). The above trend depicts significant climate change in Calabar, evidenced by late onset and early cessations. The late onset and early cessation of rains has revealed the contraction of the length of the rainy season. This has impacted negatively on farming practices in the region, which has also changed in line with this observed pattern. There is also evidence of significant changes in known weather patterns in the region. For example, the little dry season, then commonly August Break has become less significant in the region. Similarly, analysis has revealed that the environment has become warmer as temperatures have risen considerably and harmattan dust haze has also become more pronounced in recent years.

The average annual temperature is 270°C (Abali, 2016), with two periods of exceptionally high temperatures (double maximum) in July and September. The annual temperature range is a feature of equatorial climate. The variation in temperature between the hottest and coldest months might be as small as 5.00C. The average monthly rainfall is 242 mm, with a yearly average of approximately 2,900 mm. The yearly relative humidity averages above 90%, with an evaporation rate of over 1.7 mm. One may deduce from the graphs that rainfall in Calabar is quite variable. Iloeje (1979) divided the world into three temperature zones: hot (above 270°C), moderately low (240°C-270°C), and cold (less than 240°C).

Calabar is one of the hottest places on the planet, with an average yearly temperature of 270°C. Anthropogenic activities in the region release greenhouse gases (mainly carbon dioxide) in the environment, resulting in anomalous global warming in the area. The weather is not as pleasant as it appears unless high temperatures are accompanied with excessive humidity. The sticky heat of Calabar, where the air is always charged with water vapour, makes it considerably more uncomfortable. High humidity and high temperatures are more oppressive than hot but dry situations (Iloeje, 1979). Calabar is experiencing considerable climate change, as demonstrated by late onset and early cessations in the graph above. The shortening of the rainy season has been revealed by the late onset and early cessation of showers. This has had a negative impact on the region's farming techniques, which have likewise shifted in line with the observed pattern. There is also evidence of significant alterations in the region's recognized weather patterns. For example, in the region, the short dry season, then generally known as August Break, has become less important. Similarly, investigation has found that the environment has become warmer as temperatures have risen significantly, and that the harmattan dust cloud has also increased in recent years.

Table 4: Monthly annual temperature and rainfall for the study area

Month	Temperature (^{o}C)	Rainfall (mm)
January	23.70	32.30
February	28.70	26.70
March	28.40	165.80
April	27.90	199.10
May	27.30	287.60
June	26.30	404.40
July	25.40	456.10
August	25.20	407.20
September	25.80	404.60
October	26.10	343.30
November	26.90	145.50
December	27.10	28.10
	Summary	
Maximum	28.70	456.10
Minimum	23.70	26.70
Mean	26.60	242.00
Total	**318.80**	**2,900.70**



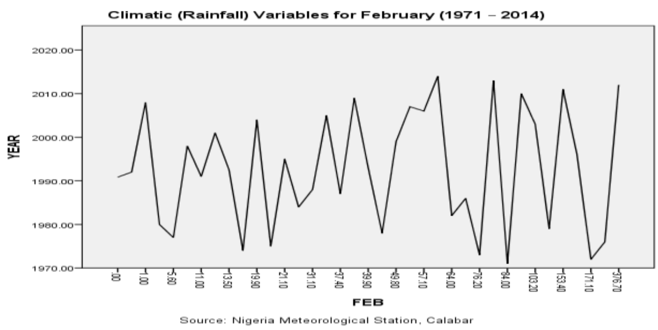


Figure 13: Climatic (rainfall) variables for January (1971-2014) **Figure 14:** February (1971-2014)

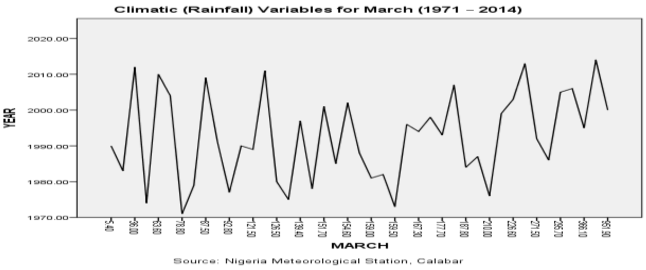


Figure 15: February (1971-2014)

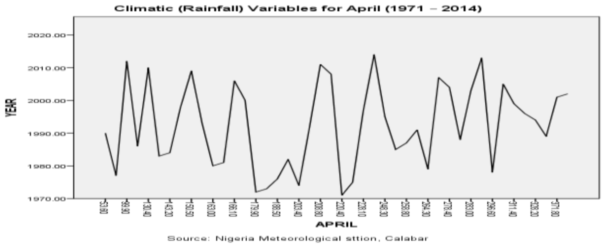


Figure 16: February (1971-2014)

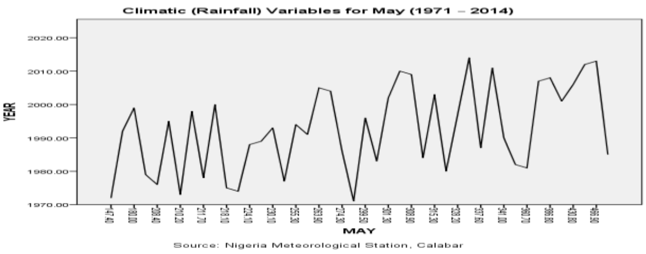


Figure 17: February (1971-2014)

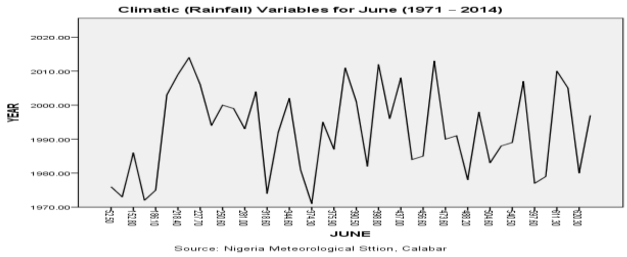


Figure 18: February (1971-2014)

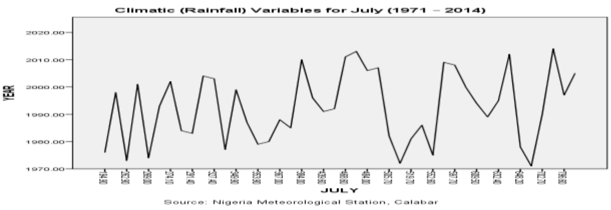


Figure 19: February (1971-2014)

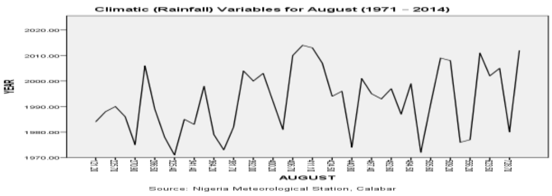


Figure 20: February (1971-2014)

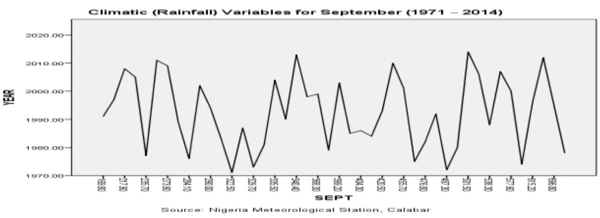


Figure 21: February (1971-2014)

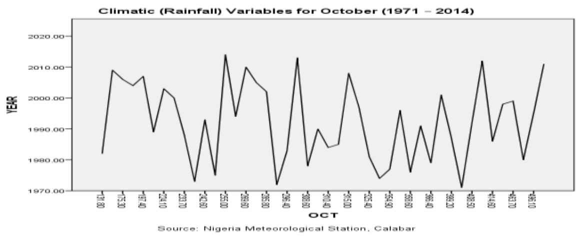


Figure 22: February (1971-2014)

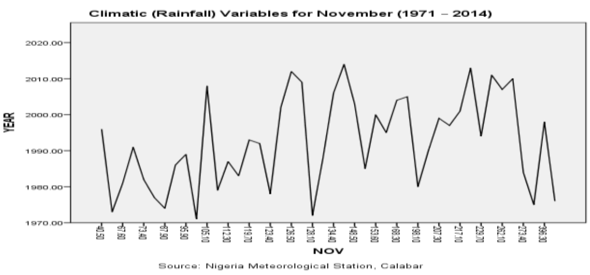


Figure 23: February (1971-2014)

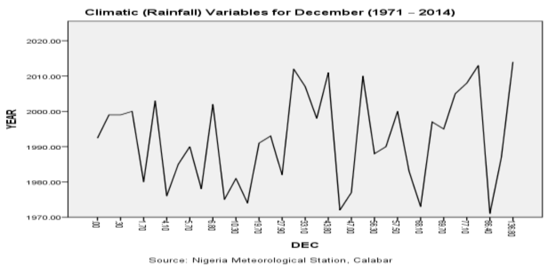


Figure 24: February (1971-2014)

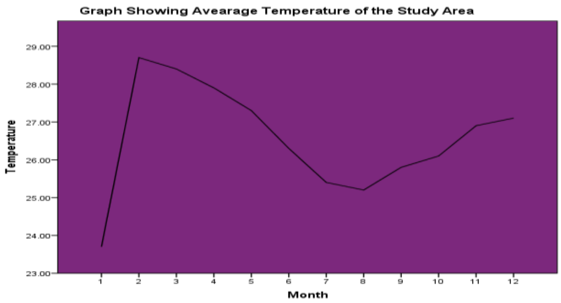


Figure 25: Graph showing average temperature of study area

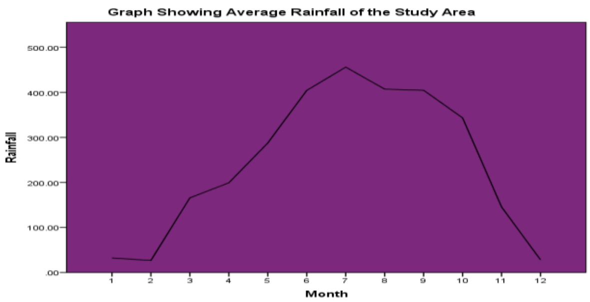


Figure 26: Graph showing average rainfall of study area

4. Conclusion

Human activities such as deforestation and the burning of fuel (in machinery and automobiles) into the atmosphere have contributed to climate change in Calabar, Nigeria. A consistent and sustained rise in temperature has been recorded in the region. To avoid future hazards, recommendations are offered on how to limit the greenhouse effect. Increased urbanization has been related to the dynamics of land use and land cover in the Calabar River catchment. The land use change trend in the region is dominated by urban land types. This means that the Calabar river watershed is becoming increasingly urbanized, yet residents continue to engage in agriculture as a main source of income. The result of land use changes in the research area over a 40-year period (1980-2020) revealed that urban land use types encroached on farming, grassland, bare land, and water bodies. Land use has been identified as the transformation of natural or wilderness areas into constructed environments like settlements and semi-natural habitats like arable fields, pastures, and managed woodlands.

The study recommends, among other things, reforestation and the creation of forest reserves, improved energy efficiency, a shift to renewable resources / cleaner sources of energy (solar and wind), and reduced deforestation to mitigate the hazards associated with the effects of climate and land use changes. The Montreal Protocol of 1987, the 1979 convention on long-range transboundary air pollution, the Kyoto Protocol of 1997, the Clean Air Act of 1990, UNCED (1992), the United States Congress (2008), and other international organizations' action plans to combat global warming should all be strictly followed.

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