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Effects of Climate Change on Built Environment in Lagos, Nigeria

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ABSTRACT

Climate change has become one of the most exigent concerns of human race today. The effect of climate changes connected to human activities has become alarming since our ecosystem is not naturally adapting quickly to this phenomenon that depends on natural and human causes. As the key climate change indicators such as increasing temperature and intensity of rainfall are being verified in Nigeria, the consequent impacts of climate change connected to these symptoms are to be expected in Nigeria. With the increasing incidence of climate change related hazards and disasters, considerable damage to buildings and infrastructure is expected. Lagos being one of the largest/fastest growing cities in the world and the foremost manufacturing port city in West African sub region is chosen for this study. Its importance as the economic hub of Nigeria, its coastal position, the peculiarity of building development makes it an ideal State for the study of the impact of global climate change on Nigerian built environment.

This research uses statistical methods to analyze rainfall, temperature and structural failure data of Lagos State and postulates their impacts on constructed facilities in Lagos Cosmopolitan urban area. The results confirm the vulnerability of Lagos environment to climate change and the trend of the impacts of flooding on Lagos built environment.

Key Words: Climate Change, Built Environment, Building Collapse, Mitigation Approach

INTRODUCTION:

In the recent times, climate change has become one of the most challenging global issues facing human race. Earth's climate has fluctuated for millions of years but the rate of changes verified since industrial revolution is very alarming. These changes are linked to some natural phenomenon and human activities such as the combustion of fossil fuels, large-scale industrial pollution, deforestation and land-use change connected to urbanization and human settlement around the world [1]. Many disasters experienced in the recent times are manifestations of the degradation processes caused by climate change. Three indicators commonly used to describe global climate change trends are: concentrations of greenhouse gases in the atmosphere, rising temperatures, and sea level rise. Globally, all these factors are on the rise. Uncertainties exist on the way the climate change data are interpreted but a growing consensus is emerging that human activity is a significant cause of the global climate change [2]. Until recently, the effects of man's activities on climate variation was assumed to be negligible, but as impacts of climate and environmental change threatens the very existence of human race, the world is now very anxious to know more about this unpredictable phenomena. Nigeria as a country is not left out in this trend of world climate change as different parts of the country is being faced with increases in the frequency and intensity of heavy rainfall, flooding, sea level rise, droughts, heat-waves and other extreme weather events. Climate change is already having an impact in Nigeria. Weather-related disasters have become more frequent in the past four decades and the trend continues to rise. Lagos is particularly vulnerable to the impact of climate change in many fronts considering its geography, climate, vegetation, soils, economic structure, poor physical infrastructure, population and settlement, energy demands and agricultural activities [3].

Lagos is currently one of the largest/fastest growing cities in the world and is the foremost manufacturing and port city in West African sub region and also the hub of business and economic development in Nigeria. Lagos, the home to about 10% of the estimated population of Nigeria, is the major industrial center of the nation with a large concentration of industries and motor vehicles emitting CO_2 and other greenhouse gases into the atmosphere. The

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City is located close to the ocean with about 22% of the total surface area made up of water and is surrounded by water bodies or lagoons. Lagos has very inadequate provision of basic infrastructure to cope with flooding resulting from normal rainfalls and this leads to frequent flooding of numerous areas of the State, largely as a result of the inadequacies drains. Increase in the intensity of storms and storm-surges as a result of climate change is likely to increase flooding problems seeing that much of the land within Lagos State is below sea level. In many parts of the State, roads have been built without complementary drainage and where drainage system exists; it is often not properly constructed and maintained. The lack of functional solid-waste collection methods compounds the problem as wastes block the drainage system. In addition, many low-income buildings are erected in ways that block storm-water routes thereby heightening the risk of flooding. The importance of Lagos as the economic hub for Nigeria, its coastal position, the peculiarity of infrastructural development makes it ideal state for the study of the impact of global climate change on Nigerian built environment.

Based on the Intergovernmental Panel on Climate Change projections [4], Nigeria is expected, to be characterized by increase in both temperature and precipitation, and this will impact negatively on the built environment thereby compromising the current inadequate state of Nigerian buildings and infrastructure. Flooding will be more intense due to heavy rainfall and therefore, buildings and infrastructures close to coastal areas will be exposed to a great risk of being destroyed by the flood. Global climate change will also lead to sea-level rise with its attendant consequences especially in the low stretch out areas of Lagos.

Global warming induced changes in temperature and rainfall are already evident in many parts of the world and in many parts Nigeria [5]. Severity of hazards like floods, droughts, cyclones and others aggravated by climate change are on the increase in Nigeria than ever before. In 2010, the National Emergency Management Agency (NEMA) reported that over 250,000 Nigerians were displaced by flood disasters that ravaged many communities across the country. The flood of July 2011 overwhelmed residents of Lagos as all the drainage systems could not cope with the intensity of a two hours severe rain. In August 2012, the whole nation of Nigeria was brought to a standstill as the Lokoja Bridge and many parts of the nation were submerged and the country cut into two parts, thereby creating the worst emergency scenario ever for Nigerians in the recent times.

In view of these foregoing facts, it has become imperative for Nigeria to respond more adequately to climate change. Thus studying the effects of climate change on our buildings and infrastructures is a bold step towards finding ways of mitigating this menace threatening our built environment. Climate change is a wide-ranging phenomenon bordering and affecting many areas of human endeavor with complicated and conflicting methods of studies and analysis. For these reasons, this study will be concentrated on finding the impacts of flooding (a natural disaster aggravated by climate change) on buildings and infrastructures in Lagos and proffering a sustainable means of mitigating and adapting to these effects. This research will analyze data on rainfall and temperature from the Nigerian Metrological Agency (NIMET) and the National Emergency Management Agency (NEMA) to determine how the changes in these confirm the vulnerability of our environment to climate change, the trend of flooding and the impacts of flooding on buildings and infrastructure in the Lagos Cosmopolitan urban area.

CLIMATE CHANGE

Climate change is defined as a change in the state of the climate that can be identified by changes in the mean and or the variability of its properties and that persists for an extended period typically decades or longer. The key to understanding global climate change is to first understand what global climate system is and how it operates [6]. The global climate system is made up of the atmosphere, the oceans, the ice sheets (cryosphere), living organisms (biosphere) and the soils, sediments and rocks (geosphere), with all of them affecting, to a greater or lesser extent, the movement of heat around the Earth's surface. The global climate is regulated by how much energy the Earth receives from the Sun and by other flows of energy which take place within the climate system itself. Flows of energy within the climate system are principally between the atmosphere and the world's oceans. Therefore, a drastic change in the flows of energy between the oceans and the atmosphere can have dramatic effects on the global climate. The current climate change effects being experienced by the world is due to a combination of natural forces and the unsustainable human activities connected to urbanization and industrialization and the advanced nations are the most responsible [7].

Causes of climate change

Climate change is caused by two broadly distinct procedures: natural (biogeographical) processes and human (anthropogenic) activities [8]. The natural processes or the biogeographical processes include the plate tectonics, orbital variations, volcanism, ocean variability and solar radiation. Over the course of millions of years,

the motion of the tectonic plates reconfigured global land and ocean areas and generated topography. This affected both global and local patterns of climate and atmosphere-ocean circulation [9]. The position of the continents determines the geometry of the oceans and therefore influences patterns of ocean circulation. The locations of the seas are important in controlling the transfer of heat and moisture across the globe, and therefore, in determining global climate. The ocean is a major component of the climate system and covers about 71% of the Earth. It absorbs much of the sun's radiation on the earth. Much of the heat that escapes from the oceans is in the form of water vapor, the most abundant greenhouse gas on Earth. The sun is the predominant source of energy input to the Earth. Both long and short term variations in solar intensity are known to affect global climate. Short-wave radiation from the Sun, including visible light, penetrates the atmosphere and is absorbed by the surface, warming the Earth. Earth's surface in turn releases some of this heat as long-wave infrared radiation. Much of this long-wave infrared radiation makes it back to the space, but a small portion remains trapped in Earth's atmosphere, held in by certain atmospheric gases, composed mainly of water vapor, carbon dioxide, and methane (greenhouse gases).

The anthropogenic factor in climate change involves human activities that either emit large amount of greenhouse gases into the atmosphere that depletes the ozone layer or activities that reduce the amount of CO_2 absorbed from the atmosphere [10], [11]. The human factors that emit large amounts of greenhouse gases include industrialization, burning of fossil fuel, gas flaring, urbanization and agriculture. On the other hand, human activities that reduce the amount of carbon sinks are deforestation, alterations in land use, water pollution and agricultural practices.

Various human activities result in the production of greenhouse gases. Evaporations arising from irrigation and combustion processes contribute to the presence of water vapor, the most abundant greenhouse gas in the atmosphere.

Evaporations arising from irrigation and combustion processes contribute to the presence of water vapor, the most abundant greenhouse gas in the atmosphere. Since warmer climate increases evaporation and allows the atmosphere to hold more moisture, the surface warming caused by the increase in other greenhouse gases leads to an increase in atmospheric water vapor, thereby creating an amplifying "feedback loop," that leads to more warming. The four most important types of greenhouse gas produced by human activities are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro fluorocarbons and other fluorinated gases [1]. These greenhouse gases are produced from various sources, but can also be removed from the atmosphere by various processes or activities, referred to as 'sinks'. These gases do not all have the same impacts upon climatic change, they are often described using their CO_2 equivalent values. Carbon dioxide (CO_2) is the most important anthropogenic greenhouse gas responsible for climate change. The burning of fossil fuels used in transportation, heating, cooling of buildings, manufacture of cement and other substantial industrial activities in urban areas, is responsible for more than 75 per cent of the increase in atmospheric CO_2. Land-use changes of deforestation and changing agricultural practices account for the remaining 25 per cent of CO_2 emissions. Deforestation also reduces an important sink for the gas, as plants absorb CO_2 in the process of photosynthesis. Other gases include methane (CH_4), Nitrous oxide (N_2O), Halocarbons including chlorofluorocarbons (CFC_s) and hydro chlorofluorocarbons (HCFC) al produced through a variety of human activities, including energy production from coal and natural gas, waste disposal in landfills, raising ruminant animals, rice cultivation and the burning of biomass, fertilizers and the burning of fossil fuels and natural processes in soils and oceans. Nitrogen oxides and volatile organic gases emitted by automobiles and industrial sources combine with ozone to form the ozone layer. This greenhouse gas contributes about a fourth as much as carbon dioxide to global warming and damages vegetation. Unlike the other greenhouse gases discussed above, which are well-mixed throughout the atmosphere, ozone in the lower atmosphere tends to be limited to industrialized regions.

For the building and construction industries worldwide, impacts of human activities on environment are being addressed by the careful choice of building materials [12]. The need for new ecological equilibrium has led the world into researches for embracing of materials that are more environmentally friendly and for that, the choice of 'greener' building material is becoming prominent in relation to other conventional ones[13], [14].

Proofs of Global warming and Climate Change in Nigeria

As the effects of the climate change are being made manifest around the world, it is now known that no nation including Nigeria is immune from its effects. Developing nations such as Nigeria are least prepared for the effects of climate change and global warming. Although the nation has been lucky not to have experienced devastating climate-change-induced disasters, the effects of climate change abound nationwide and are evidenced in the rise of

sea level, erosions, change of weather pattern, rise in temperature and intense precipitations that overwhelms the existing drainage systems thereby flooding crops and destroying buildings and infrastructures. The increase in the rate and intensity of extreme weather events and the effects already evidenced in different parts of Nigeria include but not limited to desert encroachment in the northern part of Nigeria, drying up of rivers, gully erosion in the south eastern part of the country, rising sea level and flooding in various parts of the of the coastal areas of the country. Within the Gulf of Benin in which Nigerian coastal boundaries lie, it has been estimated that the yearly mean sea level rise is about 3 mm/year, which will translate to about 50 m coastline retreat in the next 50 years. The people living in the low lying coastal areas of Southern Nigeria, particularly in Lagos are under severe threat as about half of the population of Lagos residents living mainly in slums are exposed to this danger. All these will lead to damages to the few existing buildings and infrastructures and affect the safety and health of the populace. For these frightening facts, more efforts need to be made to drastically reduce the risks of the unpredictable challenges that might emerge from the effects of climate change.

Influence of climate change on flooding

It has been predicted that in the next 100 years, the average near-surface temperatures across the globe will be risen, thereby causing an increase in flood hazard in some areas due to sea level rise and changes in seasonal precipitation [15]. As the temperature of the earth increases, the oceans absorbs more heat leading to thermal expansion and increase in volume of ocean water which results in sea-level rise. Sea-level rise is a serious concern for coastal cities such as Lagos as rising water levels and storm surges can lead to flooding which can cause property damage, displacement of residents, disruption of transportation and wetland loss. Similarly, higher surface temperature which influences precipitation will cause floods in some places, and droughts in others. As the temperature of the earth surface increases, more water evaporates during the hydrologic circle as a warmer atmosphere can hold more water vapor which condenses and precipitates. Therefore there will be more water available to fall back to the Earth when it rains and the rain is more likely to be with greater intensity within the coastal areas. As a result, extreme precipitation events would become more frequent and intense, leading to more severe flooding.

The effects of climate change on built environment

With the increasing occurrence of climate change related hazards and disasters, substantial damage to residential and commercial structures is expected. In this regard, flooding is one of the most costly and destructive natural Hazard. Flood inundation causes water to sink inside building foundations and this can lead to foundation settlement and softening which could sooner or later result in building collapse. A building may remain intact and stable on the outer surface, while the foundation materials are gradually and severely damaged. The velocity of flood may erode the building's foundation or the soils under the foundation. This leads to total collapse. Buildings can be washed away due to forceful impact of the water under high velocity. This occurs when light weight houses are not securely anchored or braced. Damages caused by debris can be very scaring as massive floating objects like trees and materials from other collapsed houses may have impact significant enough to cause severe damage to standing buildings. As the effects of climate change increases, intense wind trust will bow off roofs and building roofing sheets will deteriorate faster due to the effect of intense sun and rainfall acting on them. This will require more maintenance and repairs as a result of damages. In higher temperatures concrete durability will deteriorate as cement sets more quickly concrete is weaker if it dries too quickly and it will lacks durability to corrosion, frost damage, sulphate attack and alkali-silica reaction. Therefore, increasing temperature rise is likely to exacerbate concrete durability problems. Additionally, when concrete reacts with atmospheric CO_2, cracking ensures. This process will be accelerated with the increasing CO_2 concentrations in the atmosphere [16]. Subsidence poses a great risk to residential and commercial structures in cities. Subsidence can be caused or exacerbated by overexploitation of groundwater resources during hot, dry periods which are likely to occur more frequently with climate change. Subsidence can result to significant damages to pipelines, building foundations and other infrastructure.

As the key climate change indicators (increasing temperature, changes in amount, intensity, and pattern of rainfall, sea surge, drought and sea level rise) are being verified in Nigeria, these challenges will most likely manifest themselves in Nigeria. In fact, the terrible flood of July 2011 will not easily be forgotten by residents of Lagos as the State was pushed to a standstill for over 5 hours. In July/August 2012, the whole nation of Nigeria was brought to a standstill as the Lokoja Bridge and many parts of the nation were submerged and the nation cut into two parts thereby creating the worst emergency scenario for Nigerians in the recent times.

MATERIAL AND METHOD

This research analyzes the impacts of flooding on buildings in Lagos State based on a previous work by Adeyemi [17]. It starts by comparing the temperature and rainfall variation over a period of 10 years to determine if the rate of flooding is increasing or decreasing as temperature and rainfall intensity increase. The data used were the mean annual and monthly rainfall depth (mm) for a period of ten years and the maximum and minimum temperature (^{0}C) data collected from the Nigerian Metrology Agency (NIMET), the agency responsible for the measurement, control, and storage of the hydro-meteorological data in Nigeria. Data were also collected from the National Emergency Management Agency (NEMA) and the Lagos State Emergency Management Agency LASEMA. These data include the frequency of flooding/rainstorm in Lagos State from 2002 – 2011. List of collapsed buildings in Lagos State was also collected from the Lagos State ministry of regional planning. These data were complemented with published papers and journals from reputable scholars.

The mean annual rainfall and mean annual temperature for Lagos was computed for a period of 10 years (2002-2011). The 10 years was further divided into 2 climatic periods of 5 years each, first climatic period (2002-2006) and second climatic period (2007-2011). In order to compare the changes between these periods, the average of each of the climatic period was determined. Subtraction of the values of the first climatic period from the second climatic period gives the change in temperature for the period of study:

$$x = \sum C_2/n - \sum C_1/n \qquad (1)$$

where

C_2 =2nd climatic period

C_1 =1st climatic period

x = Change in temperature

n = number of years

Simple linear regression analysis was used for the analysis of the data as to hypothesize a probabilistic relationship between the mean temperatures within the interval of years considered. This calculation was done with Microsoft excel with the equation displayed in the form:

$$y = mx + c \qquad (2)$$

where

m = the slope of the line and

c = the y-axis interception.

The regression analysis is to confirm if the data is statistically significant.

The impact of climate change on flooding was determined by comparing the temperature increase and the maximum rain intensity increase (signs of climate change) to the trend in flooding. In examining the linkages between these parameters, graphs where plotted using Microsoft excel to correlate the increasing incidence of flooding with the increasing trend of rising temperature/rain intensity increase. After establishing the relationship between climate change and flooding, the flood frequency is compared with the rate of building collapse for each of the ten years to determine the trend in collapse.

RESULT AND DISSCUSION:

The analysis of the temperature shows an increasing trend in temperature and this is a pointer to the fact that Lagos is getting warmer. The average temperature in the first climatic period (2001-2007) was 31.482^{0}C as compared to 31.86^{0}C in the second climatic period; this shows an increase of 0.387^{0}C in the temperature of the study area within the ten year period, this is a strong indicator of a warming climate. The R^2 =0.690 value gotten indicates that the temperature data is statically significant. Figure 1 shows the trend of maximum temperatures within the ten year period of study. The analysis of the rainfall data obtained from NIMET shows a decreasing trend in annual rainfall. These finding corroborates a previous work on rainfall trend (Odjugo, 2007), which concluded that rainfall trend in Nigeria between 1901 and 2005 showed a general decline within the 105 years of his study as the rainfall amount in Nigeria dropped by 81mm.

Figure 2 shows the annual rainfall data for Lagos. From the result obtained, a strong indicator emerged that the rainfall in the more recent years is much more intense than the previous period as the fewer rainy days of the recent 5 years period produced almost as much rainfall as the 5 year period with more raining days. This intensive rainfall translates to the risk of more hazardous floods. According to The data gotten from the Lagos State Emergency Agency (LASEMA), there has been four major incidence of flooding in the last three years of the study period (2009-2011). The flooding 2009 destroyed 4 buildings, the flooding of 2010 destroyed a total of 6 buildings and that of 2011 destroyed a total of 12 buildings. This scenario is further confirmed by the rainfall event of July 10 2011 which lasted for 17 hours and resulted in the flooding of most parts of Lagos state as all the drainage system resulted insufficient.

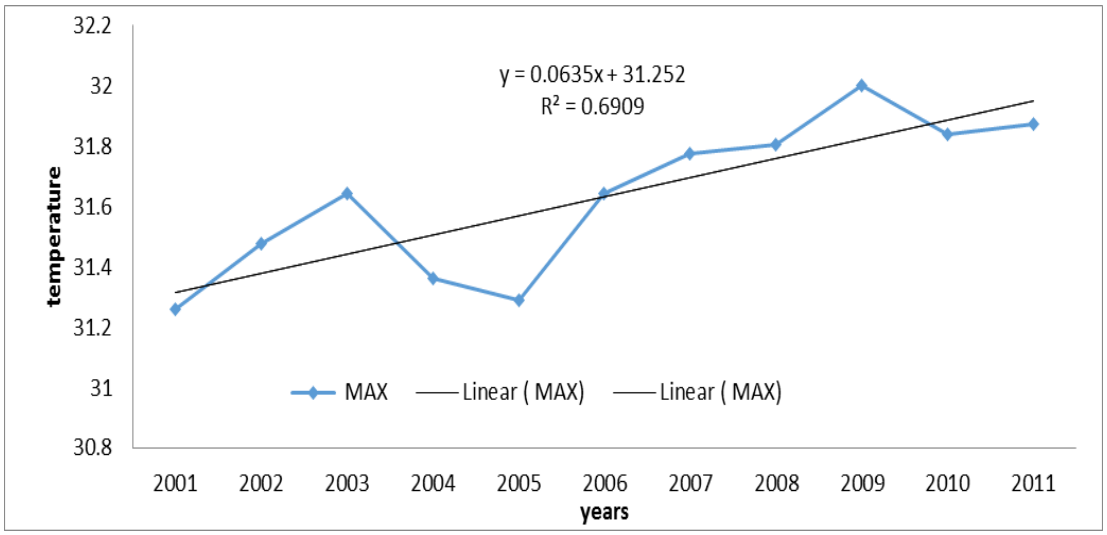

Figure 1: Trend of maximum temperature in Lagos for the period of 2002-2011

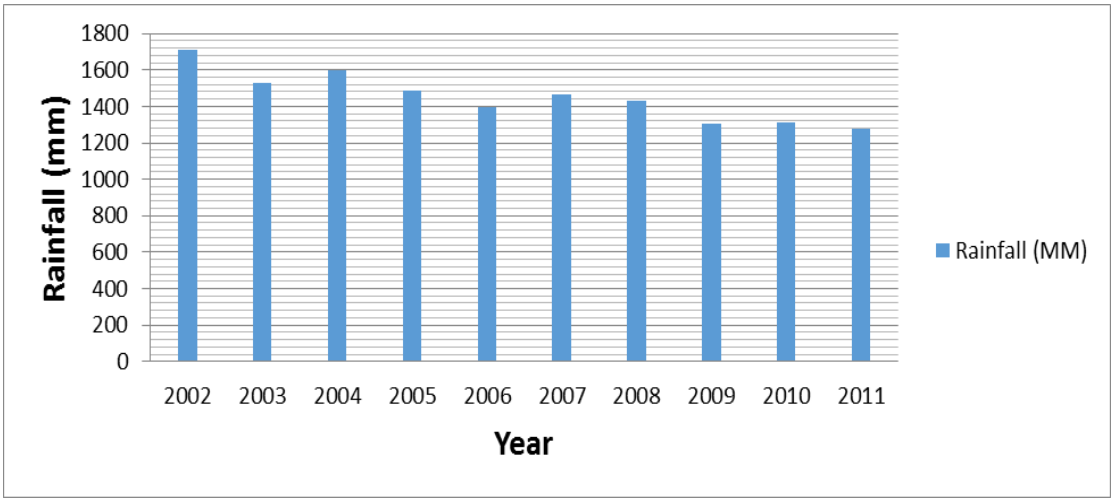

Figure 2: Recorded annual rainfall (2002- 2011)

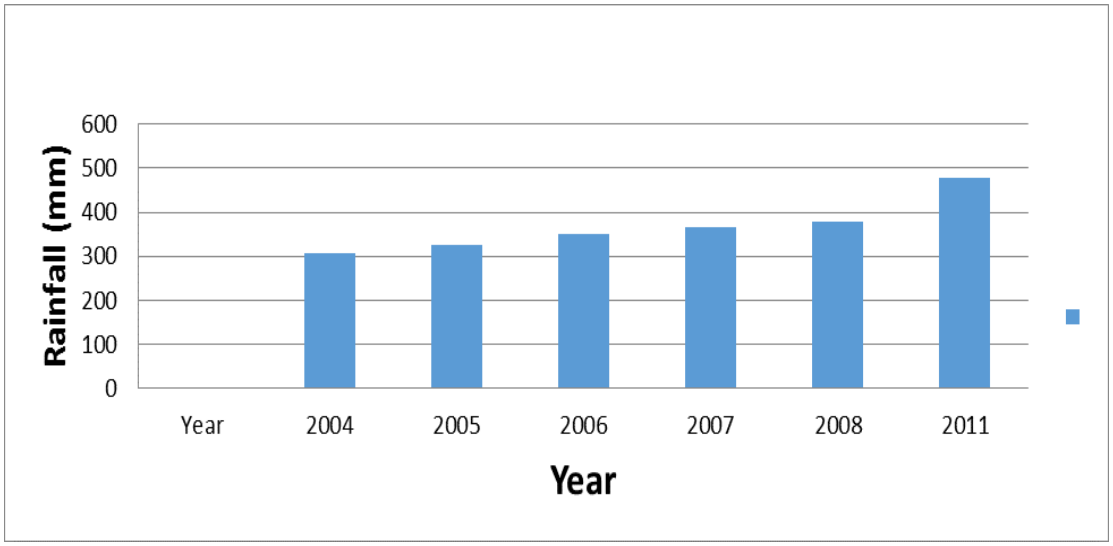

Figure 3: Maximum rainfall intensity for 2004-2011 period

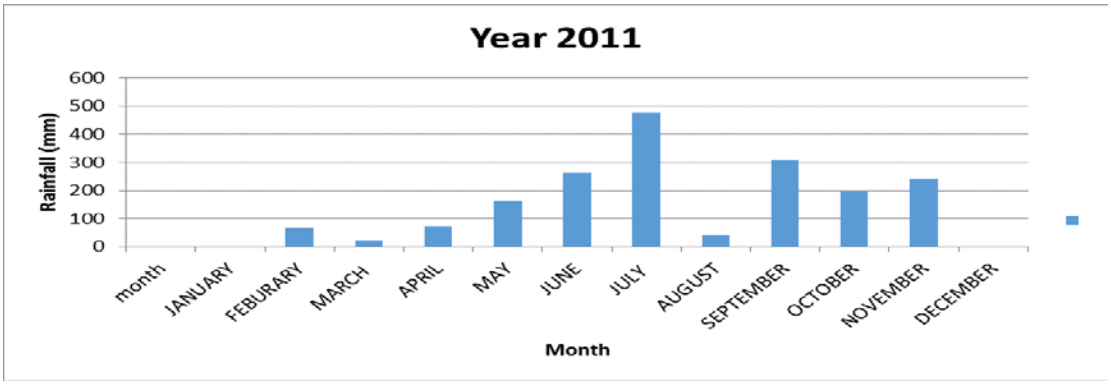

Figure 4: Monthly maximum rainfall intensity of the year 2011.

Figures 3 and 4 show the recorded maximum rainfall intensity for 2004-2011 period and the monthly rainfall intensity for the year 2011. Figure 5 captured the monthly building collapse pattern in Lagos State for 2011. It can be seen that the pattern of monthly collapse marched very well the pattern of monthly rainfall intensity.

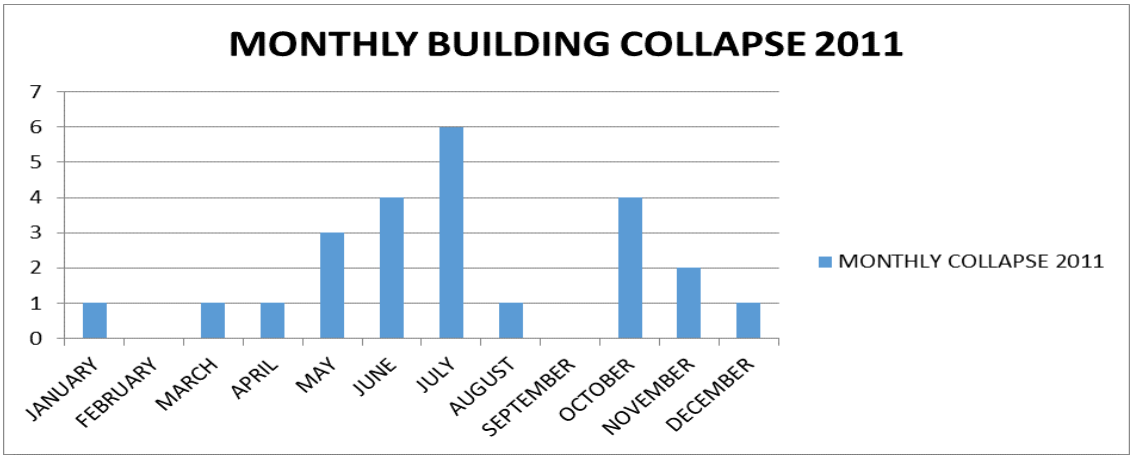

Figure 5: Monthly building collapse pattern of the year 2011.

From the data obtained from the Lagos State Ministry of Environment on the major cause of building collapse, it is worth noting that a good percentage of the collapse was caused by flooding and rainstorm. The pie chart of figure 6 shows the major causes of building collapse in Lagos State with flooding/rainstorm contributing directly to about 27%. The percentage is definitely far higher because damages caused by flooding can be cumulative in nature as causes attributed to other factors actually came from the derivative effects of flooding.

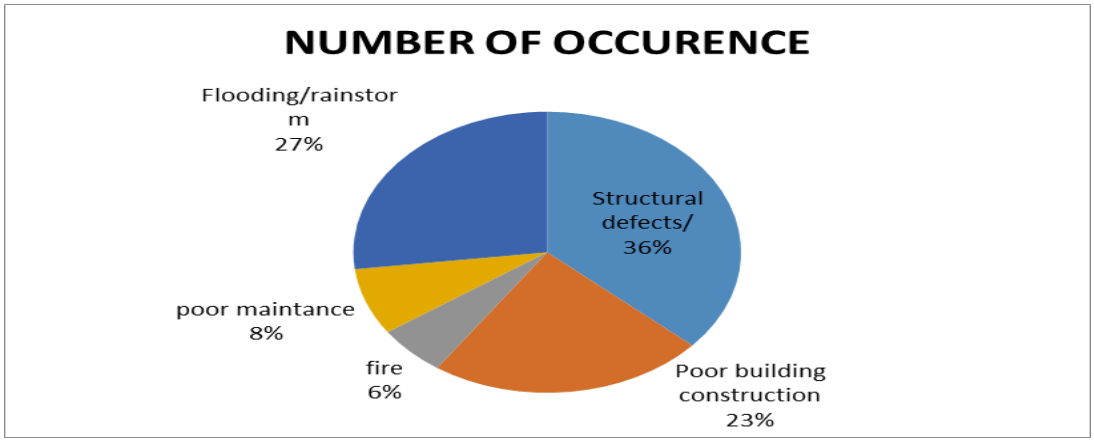

Figure 6: Major causes of building collapse in Lagos State

From this analysis it can be seen that flooding/rainstorm is a major cause of building collapse in Lagos State and this issue must not be taken lightly. It's therefore very important to note that as the population of Lagos State is increasing, human activities will be increasing, stress on the environment will be increasing, risk of higher temperature and consequent intensive rain and more hazardous flooding around Lagos State will be much higher than the current level.

CONCLUSION

The study reveals increasing temperature and decreasing annual rainy days in Lagos State. Also it is noticed that while the number of rainy days are decreasing, rainfall intensity is increasing, this is a strong indicator of a changing climate in the study area. An increase of 0.387^0C in the temperature of the study area was observed between the ten year's period of study. The change in climatic condition has impacted negatively on buildings and infrastructures in Lagos state. Flooding in Lagos shows an increasing trend as the number of times flooding occur in Lagos state was gradually increasing within the last 5 year period of study (2007-2011). This is accompanied by the increasing number of buildings affected/destroyed by flooding in the same period. The statistically significant change observed in both temperature and rainfall explicitly confirms that climate change is taking place.

To stem this increasing menace to our buildings and infrastructures, Government and all stake holders should come up with concrete and substantial policies and planning measures capable mitigating the effects. Irrespective of the measures being adopted to checkmate the impacts of climate change in Lagos and Nigerian environment, results of this research suggest the following mitigation approaches.

Issues of climate change cannot be managed as a standalone problem but must the confronted together with all the factors that affect it especially the anthropogenic causes. The intense human activities around Lagos State must be considered if we are to put under control the growing symptoms of climate change verified in Lagos State. The measures will include long term National/Regional planning programs that will stem the tide of uncontrollable rural-urban migration and take off the stress from Lagos State. The current growth rate of the State population far surpasses the capacity of the State to handle and if this growth rate is not halted, issues related to climate change will definitely get out of control. New industries should be strongly encouraged to establish outside Lagos State. This will enable the State to plan better and easily cope with the evolving climatic conditions. Another measure to be considered is the investment in innovative technologies and human resources that will be capable of predicting future challenges and be able to handle them as they emerge. Adoption of these measures will reduce the hazards of climate change in Lagos State and preserve the built environment, human lives and save investments.

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