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Effects of Rainfall and Temperature on Coastal Flooding in Victoria Island, Lagos State Nigeria

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Abstract
Coastal flooding has been and will continue to be a major problem for many coastal cities and settlements in Nigeria. One of the key factors in the design of flood forecasting models for the institution of a robust flood early warning system and towards the amelioration and effect of this flood is a good knowledge of rainfall and temperature trends as well as extremes. This study assessed the effect of rainfall and temperature on coastal flooding in Victoria Island, Lagos state, Nigeria. Data for this study was obtained from both primary and secondary sources. The primary data was from field survey on the causes and effects of flooding in the study area, while the secondary data which includes temperature, rainfall, and actual flood data were collected from the archives of the Nigerian Meteorological Agency (NiMet) and National Emergency Management Agency (NEMA) respectively. Results were presented by the use of mean, departures, regression, and correlation. To determine the annual trend in the meteorological parameters, a statistical Z-test was carried out at the 5% level of significance. An increasing trend in rainfall and temperature was observed though rainfall was not statistically significant. A further test on the rainfall data using a simple regression on the Extreme Daily Rainfall (EDR) with a threshold of 129.1mm revealed that extreme rainfall events have increased at the rate of 0.3mm per decade in the study area. Also, subjecting the actual flood data and extreme daily rainfall to a correlation analysis produced a correlation coefficient (R) of 94% indicating that there is a strong linear relationship between the number of EDR and the number of flood cases. Similarly, the coefficient of determination of 89% existing between the EDR and the flood cases means that 89% of the flood cases can be predicted by changes in EDR. For one-unit increase in EDR, flood increased by 0.34 in the study area between 2012 – 2017ges adequate monitoring. This study encourages adequate monitoring and study of rainfall and temperature characteristics as well as proper record of flood data towards the institution of a robust flood early warning system and to aid research. This will form a strong decision support system to policy makers.

Keywords: Coastal Flooding, Rainfall, Victoria Island, NiMet, Lagos.

Introduction
The increasing incidences of flooding across the globe in recent times and the attendant devastating impact has heightened anxiety among the people, investors, investment advisers, policy makers and prompted media attention (Okoye & Ojeh, 2015). Flood has been identified as one of the most frequently occurring and devastating natural disasters, occasioned by changes in climate (Potschin & Young, 2009). Nelson (2001) views flood as a natural consequence of stream flow in a continually changing environment; while Sada and Odemerho (1998) define it as unusually high rates of discharging, often leading to inundation of land adjacent to streams, which is usually caused by intense or prolonged rainfall. Flood, simply put, refers to a flow of water over areas which are habitually dry.

Sources of flood water can rise from the sea (in the form of storm surge or coastal degradation), and from glacier melt, snowmelt, rainfall and/or from failure of manmade water containment systems, such as dams, reservoirs and pumping system. It is noteworthy to

mention that excess of water in and of itself is not a problem; rather it is when excess water interacts with natural and man-modified environments in a negative sense, causing damage, death and disruption to the ecosystem, that problem results. Commenting on the impacts of floods on national development, Action Aid (2006) reported that floods are a major natural disaster that prevent Africa's growing population of city dwellers from escaping poverty and stand in the way of United Nations 2020 goals of achieving significant improvements in the lives of urban slum dwellers. Climate change and or variability is a serious threat to the environment and has become a major topical issue in most scientific discourse in recent times following observed changes in global temperature and rainfall patterns in the past three decades. Variability in the climate of an area is born out of interactions between systems that define the earth's climate. It is an interactive system consisting of a teleconnection between the atmosphere, oceans, cryosphere, lithosphere and the biosphere (Le Treut, H. Somerville, R. Cubash, Y. Ding, C. Mauritzen, A. & Prather, 2007). Amongst climatic parameters, rainfall and temperature are the first to respond to any change in climate. It is mostly manifested in the form of changing rainfall patterns, distribution, amount and intensity.

Climate variability has been shown to have significant impact on the environment, causing flood, and sometimes drought conditions. Flood conditions can have profound impact on food security, inundate the roads, causing undesirable effects to economic and social infrastructure. Furthermore, flood conditions have the capacity to cause modification in the environment, affecting, agriculture (Obot and Onyeukwu, 2010), structures, health, and could lead to significant losses (Ayanlade and Babatimehin (2009). Currently, more than half of the world's population live in cities, especially in vulnerable coastal cities. It is estimated that many of the world's large cities are vulnerable to rising sea levels and climate change, with millions of people being exposed to extreme floods and storms (Aerts et al, 2009). It is also expected that in many regions in the world, the frequency, intensity and duration of extreme precipitation events will increase as a result of climate change. At the same time, many coastal cities suffer from severe land subsidence. As a consequence of these, urban development and projected land subsidence and Climate change, the vulnerability of our coastal cities is expected to increase in decades to come (Nicholls et al, 2008; Rozenzweig et al, (2010).

Statement of the Problem

From a historical perspective, Lagos has always been susceptible to various types of flooding which are well documented from the 1960s onwards (Odunuga, 2008; Oyebande, 1974; Etuonovbe, 2011). This may have resulted from a change in climate which has proven to be real and existential and presents real developmental problem and challenges that demand national response. Although many societies have taken approaches to deal with extreme weather events, new and more intense events have the potential to overwhelm existing structures and systems put in place to mitigate their impacts. It is also creating some effects with impacts due for quantification, analysis and assessment in order for adaptation to be effective. A key form of adaption strategy is the ability to take proactive approach which is only possible through evaluation and assessment of climate change and variability, manifested as extreme rainfall storms.

Increased flood occurrence in Nigeria have disrupted socio-economic activities affecting all facets of life, displacing people and resulting in death. Adeoye, Ayanlade and Babatimehin (2009), in their study observed that flood brings misery to affected persons. Of particular concern is the Nigerian situation where in most parts of the country communities have been displaced with no access to portable drinking water, decent housing, and electricity supply leaving communities at the mercy of water- borne diseases. Roads have been clogged affecting people's means of livelihood. The consequent effect of flood menace is damage to social infrastructure, environmental modification, price increases, modification to demographic structures, fiscal and foreign sector imbalances, changes in development priorities as a result of having to replace lost or damaged assets with an overall effect on the economy, Adeoye, Ayanlade and Babatimehin, (2009). What is more disturbing is that it is the poorest of the society that are often more affected because of their low or poor coping capacity.

Research Questions

This study addressed the following questions:

i. What are the areas affected by flood in the study area?
ii. What are the causes of flood in Victoria Island?
iii. What is the trend in temperature and rainfall over Lagos State?
iv. What is the effect of change in temperature and rainfall on flooding in Victoria Island?

Objectives of the Study

The aim of this study is to assess the effects of temperature and rainfall variation on coastal flooding in Victoria Island, Lagos Nigeria. To achieve this aim, the specific objectives are to:

i. Determine the trend in rainfall and temperature in the past 30 years over the study area;
ii. Evaluate the effect of temperature and rainfall in the study area;
iii. Identify areas affected by flood in the study area;
iv. Determine the causes of flooding in the study area;
v. Determine the relationship between rainfall and actual flood cases in the study area;

Significance of the Study

One of the most frequently occurring and devastating natural disasters, occasioned by climate change, is flood (Potschin, 2009). Nelson (2001) views flood as a natural consequence of stream flood in a continually changing environment; while Sada and Odemerho (1998) define it as unusually high rates of discharging, often leading to inundation of land adjacent to streams, which is usually caused by intense or prolonged rainfall. Flood, simply put, refers to a flow of water over areas which are habitually dry. Sources of flood water can rise from the sea (in the form of storm surge or coastal degradation), and from glacier melt, snowmelt, rainfall and/or from failure of manmade water containment systems, such as dams, reservoirs and pumping system. It is noteworthy to mention that excess of water in and of itself is not a problem; rather it is when excess water interacts with natural and man-modified environments in a negative sense, causing damage, death and disruption to the ecosystem, that problem results. Commenting on the impacts of floods on national development, Action Aid (2006) reported that floods are a major natural disaster that prevent Africa's growing population of city dwellers from escaping poverty and stand in the way of United Nations 2020 goals of achieving significant improvements in the lives of urban slum dwellers. Rainfall is a climate parameter that affects the way and manner man lives. It affects every facet of the ecological system, flora and fauna inclusive. Hence the study of rainfall is imperative (Obot and Onyeukwu, 2010). Apart from the beneficial aspect, rainfall can also be destructive in nature; natural disasters like floods and landslides are caused by rain (Ratnayake U. and Hareth S., 2005). Issues relating to changing rainfall and temperature patterns have unarguably dominated scientific discuss in recent years. Reports of soaring temperatures and predictions that have not allayed the fears of more years, coupled with increasing cases of devastating flood events makes this research unarguably an instructive one that will contribute to the knowledge of science and sustainable development of the Nigerian society and the Lagos coast in particular.

Conceptual Framework

The conceptual model presented in figure 1. forms the basis upon which this study is hinged and depicts the hydrologic cycle which describes the continuous movement of water on, above and below the surface of the Earth.

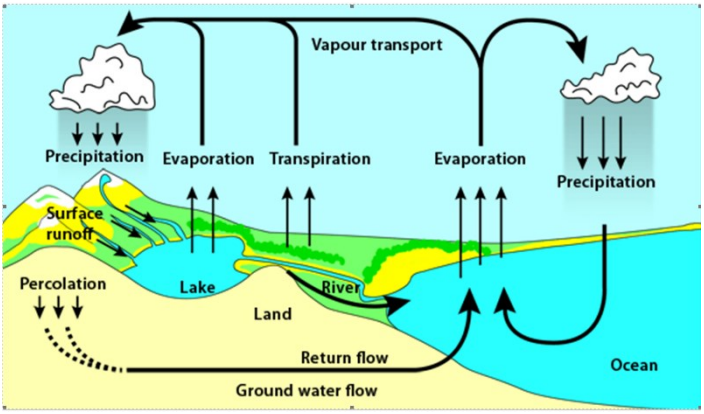


Fig 1: The Hydrologic cycle. Source: ResearchGate.net

The mass of water on Earth remains fairly constant over time but the partitioning of the water into the major reservoirs of ice, fresh water, saline water and atmospheric water is variable depending on a wide range of climatic variables. The water moves from one reservoir to another, such as from river to ocean, or from the ocean to the atmosphere, by the physical processes of evaporation, condensation, precipitation, infiltration, surface runoff, and subsurface flow.

Evaporation

The hydrologic cycle begins with the evaporation of water from the surface of the ocean. As moist air is lifted, it cools and water vapour condenses to form clouds. Moisture is transported around the globe until it returns to the surface as precipitation. Once the water reaches the ground, one of two processes may occur; i) some of the water may evaporate back into the atmosphere or ii) the water may penetrate the surface and become groundwater. Groundwater either seeps its way to into the oceans, rivers, and streams, or is released back into the atmosphere through transpiration. The balance of water that remains on the earth's surface is runoff, which empties into lakes, rivers and streams and is carried back to the oceans, where the cycle begins again. Flooding may occur as an

overflow of water from water bodies, such as a river, lake, or ocean, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries (Glossary of Meteorology (June 2000) Flood Archived 2007-08-24 at the Wayback Machine, Retrieved on 2009-01-09) or it may occur due to an accumulation of rainwater on saturated ground in an areal flood.

Precipitation

Precipitation is water released from clouds in the form of rain, freezing rain, sleet, snow, or hail. It is the primary connection in the water cycle that provides for the delivery of atmospheric water to the Earth. Most *precipitation* falls as rain.

Transpiration

Transpiration is the process of water movement through a plant and its evaporation from aerial parts, such as leaves, stems and flowers. Water is necessary for plants but only a small amount of water taken up by the roots is used for growth and metabolism. The remaining 97–99.5% is lost by transpiration and guttation.

Surface Runoff

Surface runoff is water, from rain, snowmelt, or other sources, that flows over the land surface, and is a major component of the water cycle. Runoff that occurs on surfaces before reaching a channel is also called overland flow. A land area which produces runoff draining to a common point is called a watershed.

Lake, River and Ocean

A lake is a large body of water within a body of land. Lakes do not flow like rivers, but many have rivers flowing into and out of them. A *river* is a natural flowing watercourse, usually freshwater, flowing towards an ocean, sea, lake or another *river.* An ocean on the other hand is a body of water that composes much of a planet's hydrosphere. There are five major oceans on Earth namely; the Pacific, Atlantic, Indian, Southern (Antarctic), and Arctic Ocean.

Return Flow

Return flow is surface and subsurface water that leaves the field following application of irrigation water.

Ground Water Flow

In hydrogeology, groundwater flow is defined as the "part of stream flow that has infiltrated the ground through percolation, has entered the phreatic zone, and has been discharged into a stream channel, or springs and seepage water." It is governed by the groundwater flow equation.

Climate Variability

Climate variability refers to variations in the mean state and other statistics (such as standard deviation, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Research has shown that climate change/variability touches on every aspect of the Earth's ecosystem including the hydrologic cycle. Because the processes involved are highly dependent on temperature, changes in one have consequences on the other. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (IPCC, 2014). Climate change intensifies the water cycle because as air temperatures rises, more water evaporates into the air. Warmer air can hold more water vapour, which can lead to more intense rainstorms, causing major problems like extreme flooding in coastal communities around the world. Extreme climatic events refer to any dangerous climate phenomena that has the capacity to cause damage, serious disruption to social activities, or loss of human life. It can also refer to any aspect of weather that poses risks to life and property and requires the intervention of authorities. Types of severe weather phenomena vary depending on altitude, latitude, topography and atmospheric conditions of the place. Some of the effects of severe weather include excessive precipitation, wildfires, thunderstorms, windstorms, and tropical cyclones. In Nigeria, the most predominant effects are the windstorms to the northern parts and excessive precipitation to the southern part and especially around the coastal areas of the country.

Empirical Review/Review of Previous Studies

Seasonal Variability and Trend in Rainfall and Temperature

Climate has changed across the globe with these changes experienced especially in the form of increasing rainfall and temperature. Increasing levels of extreme events has become a topical issue across the globe with more recent

incidences of rainfall related disasters such as flood. This phenomenon often referred to as climate change or variability has become a source of concern to individuals and researchers as well. Furthermore, Nigeria has witnessed in recent times weather extremes in different parts of the country, causing significant socio-economic impacts.

In 2013, the Intergovernmental Panel on Climate Change (IPCC) concluded in its authoritative fifth assessment report (AR5, 2014) that "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased".

Olajuyigbe et al in their assessment of flood hazard in Nigeria identified that floods in Nigeria usually results from high river levels, concentration of overland flow following heavy rainfall, limited capacity of drainage systems and blockage of waterways and drainage channels (Olajuyigbe et al 2012). Similarly, in their critical analysis of the efforts towards urban flood risk management in the Lagos region of Nigeria, Nkwunonwo et al. identified heavy rainfall events as the major cause of floods in Lagos metropolis of Nigeria from 1968 to 2012 (Nkwunonwo et al 2016). The major worry lies in the fact that the solution to this problem seems not in sight as Nicholls et al. has also identified Nigeria as one of the top 20 countries ranked in terms of population exposed to coastal flooding in the 2070s (Nicholls et al., 2008). There is therefore the need to understand the effect of rainfall and temperature variability on coastal flooding in the Lagos coast of Victoria Island for necessary adaptation and or mitigation measures to be effective.

On the other hand, while natural variability continues to play a key role in rainfall and temperature extremes, it is believed that climate change and variability has increased the odds and intensity of rainfall and high temperature events surpassing the historically expected limits. Although many societies have taken measures to cope with historical weather extremes, new and more intense rainfall has the potential to overwhelm existing structures and systems, hence the need for both reliable and current information on the pattern of rainfall across the country cannot be overemphasized.

One of the adaptation strategies is the ability to continually evolve proactive mechanisms which is only possible through quantification or trend analysis, evaluation, and assessment of rainfall. Quite a number of researches and studies have, at various times for different regions, been dedicated to understanding the variability and trend of rainfall; and based on the character of the trend, some studies have gone as far as quantifying the amount by which this key climatic parameter has either decreased or increased over the years depending on the region (McCarthy et al., 2005; Niasse, 2005; Uduak C., 2012). An instance of this is the study by Afiesimama et al. (2014) who showed that rainfall amount has increased by 15-20% in many parts of the country leading to increase in rainfall intensity by 10-15% causing flooding in recent years. Others include studies by Ifabiyi and Ojoye (2012) who demonstrated that there has been an increase of 5% in annual rainfall from 1960 to 2009 over the Sudano-Sahelian region. Furthermore, other researchers have also analysed rainfall trends over entire or part of Nigeria with a view to understanding its implication on flooding. For example, Adefolalu (1986) in his study examined trends in rainfall pattern using 70-year period (1911–1980) for 28 meteorological stations. Bello (1998) went further to compare seasonality of rainfall distribution in Nigeria for two climate periods, 1930–1961 and 1962–1993. Also, Ati et al., (2009) posited that there has been significant increase in rainfall over nine stations in northern Nigeria between 1953 and 2002 with significant effect on flooding. Folland et al, (1986), Odekunle (2001), and Ologunorisa (2004) also examined the issue of rainfall trend and flood occurrence. (Olaniran, 1983, Ologunorisa, 2001) in their studies identified the characteristics of extreme rainfall associated with flood frequency to include duration, intensity, frequency, seasonality, variability, trend and fluctuation. Eludoyin et al., (2009) studied monthly rainfall distribution in Nigeria between 1985-1994 and 1995-2004 and observed some inter annual variation. Ayansina et al., (2009) also investigated the seasonal rainfall variability in Guinea savannah ecological zone of Nigeria and established that there was variability in rainfall and that such variability was on the increase. Some of the devastating effect of changing rainfall and temperature patterns include increased incidences of flood and heat waves.

Theoretical Framework

The Concept of Climate Change as a Cause of Changing Rainfall and Temperature Patterns

Climate change according to United Nations Framework Convention on Climate Change (UNFCCC, 1992) refers to a change of climate which is 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 time periods. This implies that although distinct from natural climate variability, climate change occurs over a time-scale that

has to be reasonably comparable to natural climate variability, and both of these are mutually exclusive. The indicators of this change are mostly rainfall and temperature.

The variations between climate changes attributable to human activities was made by the UNFCCC which brought about the alteration of the composition of the atmosphere as well as the climatic variability and its attributes to natural causes. A statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer); climate change may be due to natural internal processes or external forces, or due to persistent anthropogenic changes in the composition of the atmosphere or in land use is referred to as Climate change.

Some of these activities including industrialization have led to the issue of global warming.

De Chavez and Tauli-Corpus (2008) views global warming as the average increase of the earth's surface temperature and oceans as compared to previous centuries. They posited that the increased quantity of greenhouse gases was as a result of the continuous trapping of heat within the earth's atmosphere. Global warming is one of the key aspect of climate change. Global warming could result in an increase in sea level, melting of glaciers and ocean warms, hence posing threats on human habitats and agricultural products. Other adverse effects may include; storms, drought and floods, variation in rainfall patterns and increased soil erosion. Ultimately, the by-product may be decrease in energy and general environmental breakdown worldwide as well as food crisis and worsening weather.

There are a number of factors that are responsible for climate change as summarized by the Intergovernmental Panel on Climate Change (IPPC) 4th assessment report (IPPC, 2007), man's activities are very likely the cause of global warming; in other words, about 90% or more is attributed to man's action. Certain activities of man that could lead to climate change which are of great significance includes the burning of fossil fuels (coal, oil, and natural gas) and cutting down.

Study Area

This study focuses on a naturally dynamic area in Lagos state; Victoria Island. Lagos Island is an adjoining LGA sharing boundaries on the North with the largest coastal lagoon in Western Africa; Lagos Lagoon. It is a densely-populated area with land area of approximately 4.996 square kilometers.

Location

Victoria Island is located within Latitude 6°26' 34" N and Longitude 3°24' 30" E on the left and Latitude 6°27' 8" N and Longitude 3°22' 42" E on the right. The study area can be described as a place with a variety of land uses. It is notably a commercial area with a mixture of residential and institutional land uses. Figure 3.1 shows the location of the study area. The Figure vividly describes the water surrounding nature of the study area (Hudson *et al*. 2018). Lagos city on the whole is a coastal city situated within latitudes $6^0$23'N and $6^0$41'N and longitudes $2^0$42'E and $3^0$42'E on the narrow plain of the Bight of Benin. It is bounded on the North and East by Ogun State of Nigeria, on the West by Republic of Benin. Its coastline stretches 180kilometers along the Guinea coast of the Bight of Benin on the Atlantic Ocean. Lagos is the economic nerve centre of Nigeria and also one of the most populous cities in Africa (https://lagosstate.gov.ng/about-lagos/). The city has the largest concentration of multinationals and commercial institutions and is home to about 60% of Nigeria's non-oil economy (Adelekan, 2010). It is bordered in the south by the Atlantic Ocean, with a dense network of roads and buildings, and several inland waterways including the Lagos Lagoon which empties into the Atlantic, the conurbation serves as a major hub for transportation, tourism, and economic activities in Nigeria. With a population of over 20 million people (LSG, 2012).

The Island is a loose geographical term that is used to define the area of Lagos that is separated from the "mainland" by the main channel draining the lagoon into the Atlantic Ocean, which forms Lagos Harbour. The Island is mainly a collection of islands that are separated from each other by creeks of varying sizes and are connected together by bridges. The smaller sections of some creeks have been dredged and built over. This part of Lagos is the area where most business activities and entertainment events in Lagos takes place. It also houses most of the upscale residential areas in Lagos. The Local Government Areas (LGAs) that are considered to be in the Island include Lagos Island, Amuwo-Odofin, Apapa (sometimes also regarded as being on the mainland), and Eti-Osa. The major upscale island neighbourhoods within the Lagos Island LGA include Ikoyi and Victoria Island. Three major bridges join the island to the mainland. They are the Carter Bridge, which starts from Iddo; the Eko Bridge (formerly called the Second Mainland Bridge); and the Third Mainland Bridge, which passes through densely populated mainland suburbs to the Lagos Lagoon.

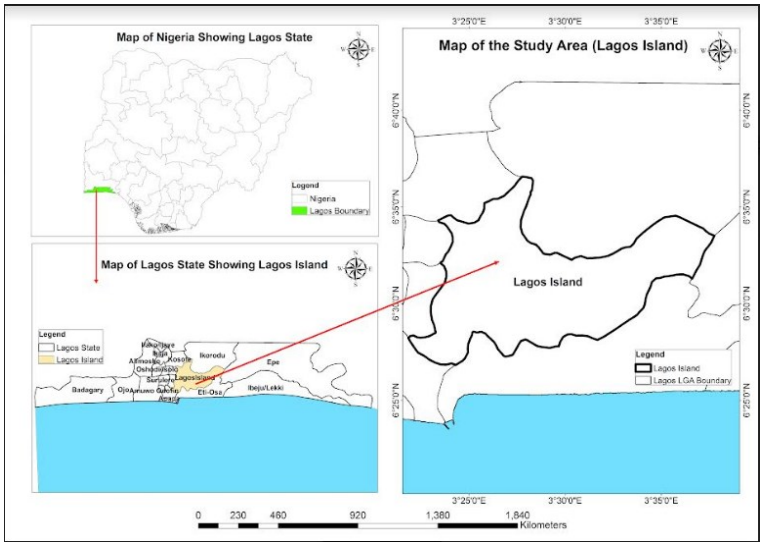


Figure 2: Maps of Lagos State showing Victoria Island in Eti-Osa LGA.
Source: Office of the Surveyor General of the Federation (OSGOF)

Methodology

Type and Sources of Data

Primary data on causes and effects of flood on the study area was obtained through a field survey carried out on Victoria Island, Lagos. Daily rainfall and temperature data was obtained from the archive of the Nigerian Meteorological Agency for the period 2000-2017. Additionally, flood risk map showing areas that are most vulnerable to flood events for the period 2013, 2015 to 2019 (six years) was obtained from the Nigerian Hydrological Services Agency (NIHSA).

Methods of Data Collection

The study was restricted to Victoria Island, Lagos State because it is the most important coastal community in Nigeria that is well known for coastal flooding. The primary data was obtained through the use of questionnaires which was administered to residents of Victoria Island. I delineated the study area into three major communities namely; Ibeju Lekki to the south, Awoyaya to the east, and Magbon to the central part of the study area before administering the questionnaires through face to face interactions. I was joined by four of my colleagues who work at the Victoria Island office of the Nigerian Meteorological Agency in the administration of the questionnaires. A total of 300 questionnaires were administered, 100 for each part and 100% of all the questionnaires were retrieved with answers. Additionally, daily rainfall and temperature data was obtained from Nigerian Meteorological Agency covering Victoria Island for the period 1981-2017. Also, data on the probable flood risk areas in Nigeria as well as actual flood data covering a period of 6 years were obtained from the Nigerian Hydrological Services Agency (NIHSA) and the National Emergency Management Agency (NEMA) respectively. The study did not take other areas within the Lagos Island into consideration but concentrated only on Victoria Island hence both the questionnaire and secondary data concentrated only on Victoria Island, Lagos.

Technique for Data Analysis and Model Specification

Data for the research comprising of daily rainfall values from the weather station in Victoria Island spanning a time interval of thirty (37) years (1981-2017) was obtained from the archives of the Nigerian Meteorological Agency (NIMET). Additionally, data spanning 6 years on areas in Nigeria that are most liable to flood events was obtained from the Nigerian Hydrological Services Agency, NIHSA. Using software in Microsoft Excel, the rainfall data points was then aggregated into their annual values in order to investigate the trends therein. Furthermore, daily rainfall data that can potentially induce flooding over the region was generated by collecting daily rainfall data above a given threshold. Year 2012 was acknowledged as a year of widespread flooding across the country (Afiesimama, 2013) and as such, the maximum rainfall recorded in one day in this year was used as the threshold for extreme rainfall, i.e. the threshold is given by $\max(dRR2012)$. … … … … … … … … … … … 1

Where dRR2012 is actual daily rainfall for the whole of year 2012.

This was, for some years, validated with actual flooding data based on available data. Trend analysis test was then carried on the rainfall data in order to ascertain the significance or otherwise of the trend therein at the 1% level. Similarly, a corresponding trend analysis test was also carried out on the of extreme rainfall events based on the defined threshold. A detailed description would be provided on how the flood database would be generated in the subsequent section.

Test of trend in annual rainfall

As earlier stated, in order to ascertain the nature of trend in rainfall, annual rainfall data was obtained by summing up the collected daily rainfall was subjected to statistical trend test at the 15% and 10% levels of significance.

A trend is a significant change over time exhibited by a random variable, detectable by statistical parametric and non-parametric procedures.

The trend test was conducted using parametric (the Z test) and non-parametric (the Mann Kendall Test) procedures. In the case of the Z test, which is appropriate when the data to be tested conforms to the normal distribution with a sample size of at least 30 (n ≥30), it was tested to ascertain whether the slope (trend) of the regression to which the data points were fitted is significantly different from zero at the chosen level of significance. In this case the null hypothesis, H_0, would state that the slope of the regression of the fitted data is zero, while the alternative hypothesis would state that the slope is significantly different from zero i.e.

$H0: the\ slope\ =\ 0$ ……2

H_1: the slope ≠0……3

As a further illustration, the null hypothesis is based on the assumption that the mean of the slope of the regression lines computed from all the data samples that can be drawn from an identically distributed population of rainfall data is zero i.e.

$$H0: \beta\ =\ 0\,,\quad H1: \beta\ \neq\ 0\ ;\ where\ \beta\ represents\ the\ slope\ \ldots\ldots\ldots 4$$

This test is associated with the fact that the various slopes of regression lines computed from all the possible data samples that can be randomly drawn from an identically distributed data (the population) are normally distributed around the mean of all the slopes, or the slope of the regression obtained from the data of the entire population.

With X as the random variable representing rainfall values, $\overline{X}$ the mean, and δ the standard deviation, the normal distribution is given by*:*

$$F\ (X \leq x) = \frac{1}{\delta\sqrt{(2\pi)}} \int_{-\infty}^{x} e^{-\left(\frac{1}{2}\right)\left(\frac{X-\bar{X}}{\delta}\right)^2}\ dx \ldots\ldots\ldots\ldots 5$$

Generally, in hypothesis testing involving a set of normally distributed set of data, the Z statistic is given by $Z = \frac{X-\bar{X}}{\delta}$ ……6; and is computed and compared with its critical value at a given confidence interval.

With regards to this study, with a sample size of 37, the Z statistic was computed and compared to the critical Z value and is given by $Z = \frac{X-\bar{X}}{S_b}$, with the standard deviation in the previous equation replaced by the standard error of the slope, S_b. This adjustment is usually necessary when dealing with samples. Given that the regression here are the rainfall values as function defined on time t ($t = 1,2,..35\ years$), with SE as the standard error of the regression, the standard error of the slope is given by

$$SE/SQRT(\Sigma t^2 - ((\Sigma t)\text{^}2)/n) \ldots\ldots\ldots\ldots 7$$

The standard error of the regression , SE, is given by $SQRT(\Sigma\overline{X} - \Sigma X)\text{^}2)/(n-2))$ where $\overline{X}$ *are* the rainfall values obtained from the regression line.

If the absolute value of the computed Z statistic, which would be normally distributed, is greater than its critical value at a given confidence level (here the confidence levels 95% and 99% were considered) the null hypothesis is rejected in favour of the alternative hypothesis and we conclude or accept that the slope is significantly different from zero at the chosen confidence or significant level; the null hypothesis was accepted otherwise. Alternatively, to investigate the significance or otherwise of trend in annual rainfall, an approach involving p-value under the proposed hypothesis (4) would be employed. In this case if the computed p-value is less than the chosen level of significance (which would be 1%, 5% and 10%), it would be concluded that the trend is significant in relation to the significant level, otherwise the null hypothesis would not be rejected and it would be concluded that the trend is not significant. Since the size of data used in the computations is more than 30, the p value was computed using normal distribution or standardized normal distribution using Microsoft Excel. To further access or aid visual inspection of the behaviour of rainfall over the years in the location, standardized annual precipitation index (SPI) was computed using the equation

$$spi(R_k) = \frac{R_k - \bar{R}}{\partial(R_k)} \ldots\ldots\ldots\ldots 8$$

where R_k *is the annual rainfall,* $\bar{R}$ *and* $\partial(\ R_k)$ *are the mean annual rainfall and standard deviation respectively and are given by* :

$$\bar{R} = 1/n \sum_{k=1}^{n} R_k\,, \quad and\ \partial(R_k) = \sqrt{\frac{1}{n \sum_{k=1}^{n} \frac{(R_k - \bar{R})^2}{\partial(R_k)}}} \quad with\ k = 1999,2000. \ldots 2016.$$

Results and Discussion

Rainfall and Temperature Trend over Victoria Island (1981 – 2017)

Figures 3a and 4.1b below show the annual distribution of rainfall and the corresponding standardized precipitation index (SPI) over Victoria Island in the last 37 years (1981-2017) respectively. Highest annual rainfall recorded over the location was 2442.5mm (in 1988) while the lowest recorded was 939.2mm (in 2008); the mean annual rainfall is 1680mm. With an average maximum daily rainfall of 140mm, the highest one-day rainfall of 280mm was recorded in year 2000. Based on the z-test method outlined in section 3.4.1 the linear regression of annual rainfall over time was computed as: $\tilde{y} = 0.68x + 326.8$……14

Where, $\tilde{y}\ represents\ annual\ rainfall, and\ x\ time\ in\ years\ i.e\ 1981 - 2017$. The trend or slope of the regression is 0.68 with a corresponding z-score of 0.11973. At the 5% level of significance, the critical level of significance is 1.96. With $z = 0.11973 < 1.96$, it was therefore concluded that the trend/slope of the regression is not significant at the 5% level. In other words, annual rainfall has not made any significant increase at the 5% level over Victoria Island from 1981 to 2017. This conclusion aligns with Olarenwaju et al who in 2017 posited that from 1986 to 2007, rainfall in Warri metropolis decreased though with a trend that is not statistically significant at the 95% confidence level. This observation can also be confirmed by mere looking at the corresponding standardized precipitation index. Given this observation, is it also possible that the number of Extreme Daily Rainfall (EDR) based on a given threshold as defined in section 3.4.1 has not increased over the years? To test this hypothesis, the potential flood-inducing rainfall data was generated and the result of the test is presented in the next section.

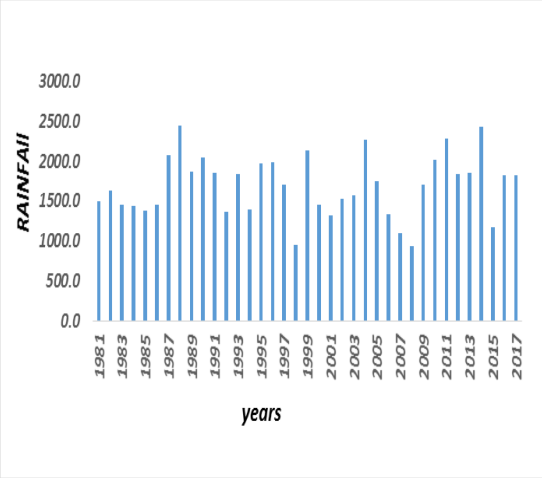


Figure 4: Annual rainfall distribution over Victoria Island from 1981-2017

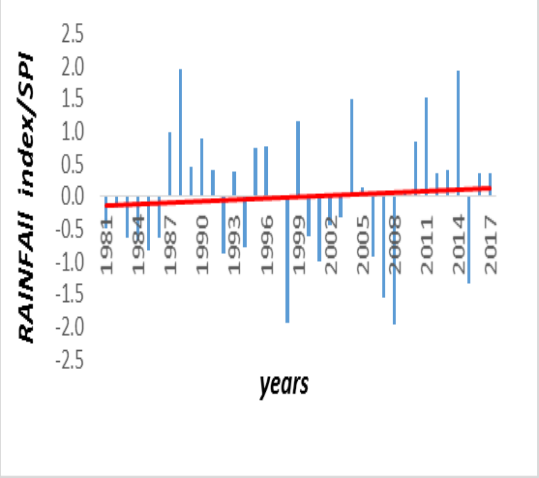


Figure 5: Standardised precipitation index over Victoria Island from 1981-2017.

The nearly horizontal trend line (in red) shows that there has been no significant increase in rainfall amount over the years.

Evaluation of the Effect of Temperature and Rainfall in the Study Area

Five Year Temperature Trend

In order to closely examine and detect patterns in temperature and rainfall over the study area, the five-yearly evolution in temperature and rainfall were generated and plotted (fig. 4.2a-h and 4.3a-h). Specifically, the standardized rainfall and temperature values were computed and plotted using approaches detailed in chapter three. The essence of this procedure is to enable the detection of temperature changes, as changes in temperature through time has been observed to be very small. This is the situation in the tropics where throughout the year, temperature change is gradual and very small; unlike in the polar region where temperature can change rapidly owing to the advection of frontal systems. Based on its formulation, the standardized index procedure is very effective in detecting changes, even when such changes are very minimal, and as such it was considered as a tool for the detection in this case.

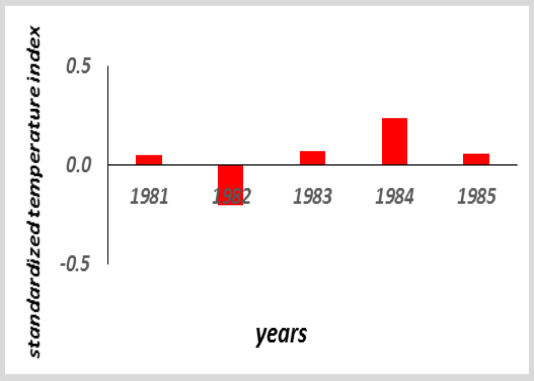


Figure 6: Five-year temperature plots over Victoria Island (VI), Lagos from 1981-1985

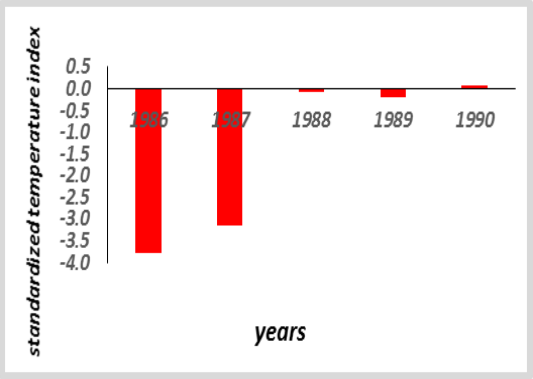


Figure 7: Five- year temperature plots over Victoria Island (VI), Lagos from 1986-1990

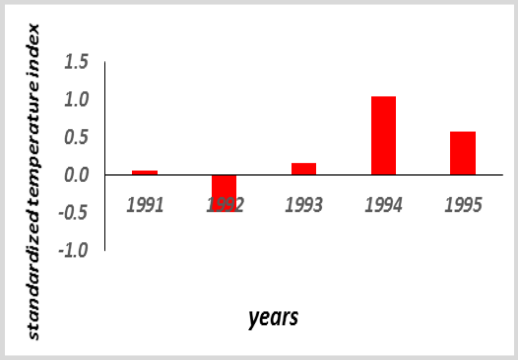


Figure 8: Five-year temperature plots over Victoria Island (VI), Lagos from 1991-1995

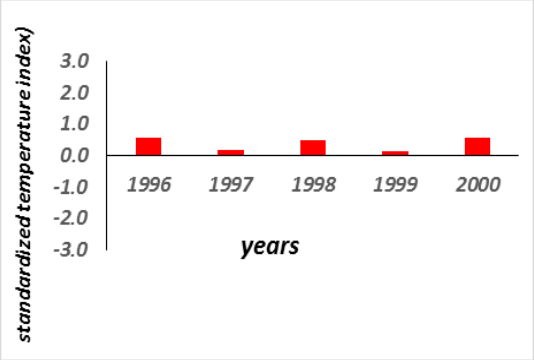


Figure 9: Five -year temperature plots over Victoria Island (VI), Lagos from 1996-2000

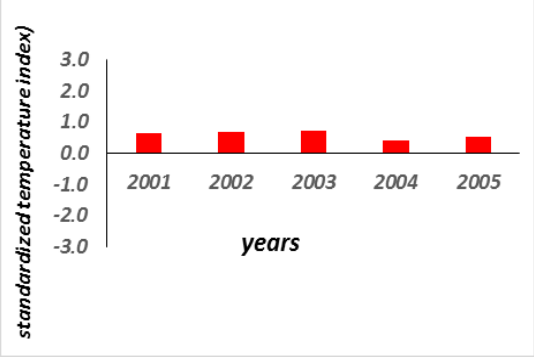


Figure 10: Five-year temperature plots over Victoria Island (VI), Lagos from 2001-2005

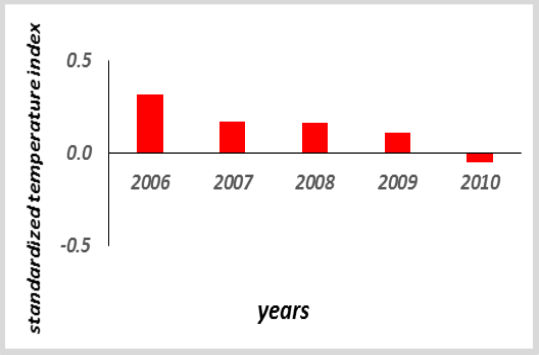


Figure 11: Five-year temperature plots over Victoria Island (VI), Lagos from 2006-2010

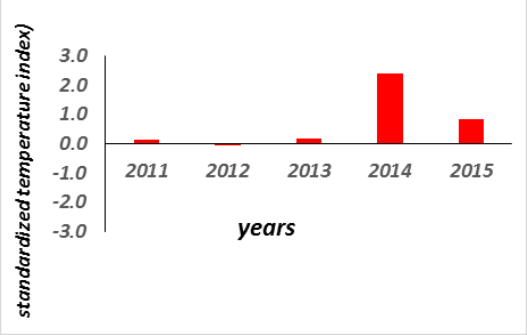


Figure 13: Five- year temperature plots over Victoria Island (VI), Lagos from 2011-2015

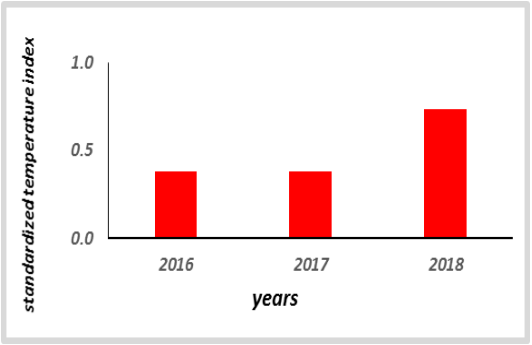


Figure 14: Five- year temperature plots over Victoria Island (VI), Lagos from 2016-2018

The results of the analysis indicated that in the earlier periods (fig. 13 and 14), i.e. 1981-1985 and 1986-1990, the temperature indexes were very low particularly in the period 1986-1990, where the indexes were negative (<-0.35 to -0.3) showing below normal temperatures for the years. In simple terms, the standardized temperature index

indicates the ratio of actual temperature change (which could be an increase or decrease) at a given time (in this case year) to the expected change; the expected change being the standard deviation. Based on this definition, it can be seen that through the years: 1994, 1996, 1998, 2000, 2001-2005, the indexes revealed that temperature values experienced at least half the expected increase. Though increases were observed in the period 2006-2010, they were lower compared to the previous five years. Similarly, increases were also noticed in the last periods especially in the years 2014 and 2015, with the index indicating that about three times the expected increase occurred in 2014; thus being the highest so far. Based on these observations, it was very clear that over the years, temperatures have experienced significant increases in the study area.

Five Year Rainfall Trend Analysis

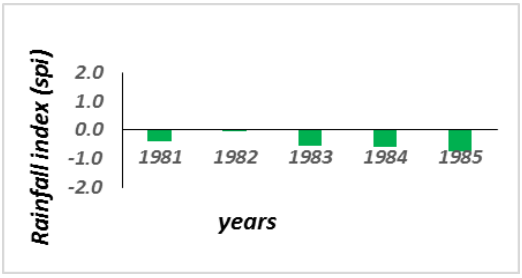


Figure 15: Five-year Rainfall plots over Victoria Island (VI), Lagos from 1981-1985

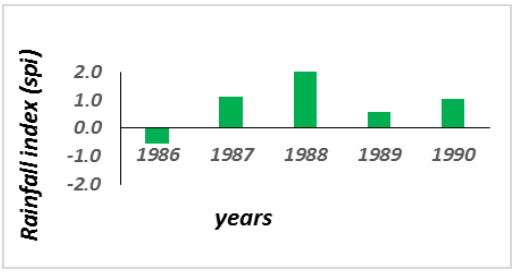


Figure 16: Five- year rainfall plots over Victoria Island (VI), Lagos from 1986-1990

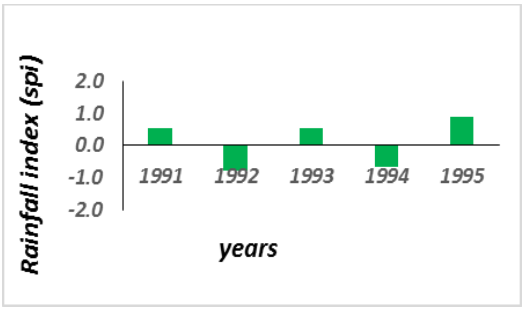


Figure 17: Five- year rainfall plots over Victoria Island (VI), Lagos from 1991-1995

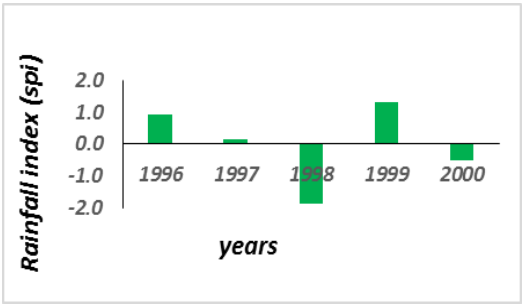


Figure 18: Five- year rainfall plots over Victoria Island (VI), Lagos from 1996-2000

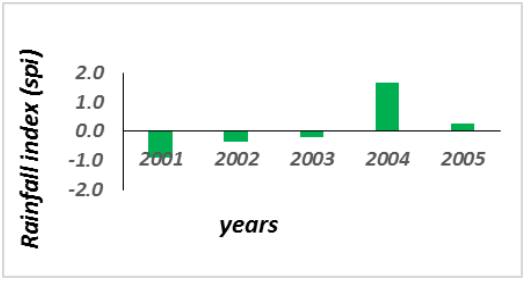


Figure 19: Five- year temperature plots over Victoria Island (VI), Lagos from 2001-2005

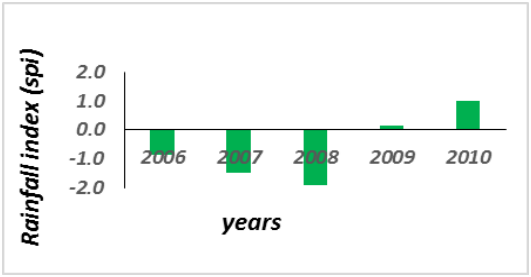


Figure 20: Five -year rainfall plots over Victoria Island (VI), Lagos from 2006-2010

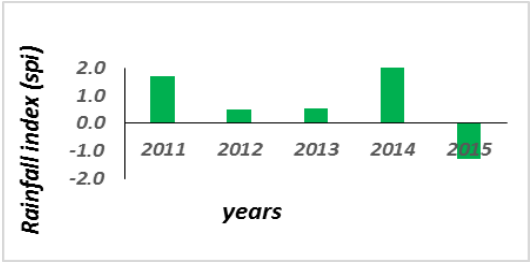


Figure 21: Five -year rainfall plots over Victoria Island (VI), Lagos from 2011-2015

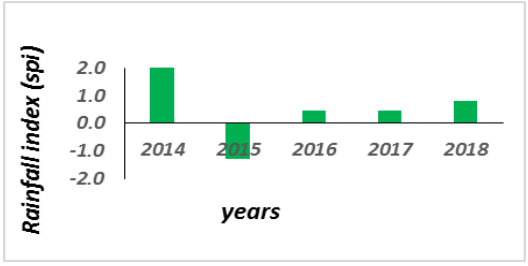


Figure 21h: Five- year rainfall plots over Victoria Island (VI), Lagos from 2014-2018

A similar analysis of the rainfall data shows that in the period between 1981- 2007, rainfall has also experienced increases although interspersed with some cases of decreases (fig.4.3a-h). During the earliest of the periods, 1981-

1985, negative rainfall indexes were observed. In the proceeding period however, positive rainfall trends were observed particularly in the years: 1987-1990, 2011-2014, 2016 and 2017. The indexes also indicated that some of the years experienced extremely high rainfall increases. These include the years, 1988, 2004, 2011 and 2014. Though, a few cases of negative indexes were recorded, the increase has been consistent since 2016. Based on these observations, therefore, it can be reasonably concluded that annual rainfall has experienced some significant increases through the years/periods.

An observation was made in the year 2014, which is the year in which the highest temperature index coincided with the highest rainfall index in the series. Could these occurrences therefore imply a possible correlation between temperature and rainfall? In other words, did the increase in temperature result also in the rainfall increase? Research have indicated that higher temperatures can increase the moisture capacity of an air parcel which could ultimately result into increased cloudiness and higher precipitation as was observed in 2014. Otherwise the observation could just be a mere coincidence especially when such an occurrence was not noticed in the other years.

Nevertheless, higher temperature values could result into rise in sea level (by causing a melting of the glaciers in the arctic region) as much as rainfall increase can raise the prospect of run-off, and both of these could be responsible for the increasing number of flood cases over the study area. In this scenario, other factors such as hydrological factors and human influences are held constant.

Areas Affected by Flood in Victoria Island

Most residents of the Victoria Island think that the effects of flooding generally cuts across every part of the study area and in particular the following communities within the zones:

Table 1: Areas affected by floods in Victoria Island

Zones	Communities affected by floods
Ibeju Lekki	Eputu, Badore, Elegusi, Aja, Sangotedo, Lakowe,
Awoyaya	Ogidan, Abijo, Okun, Orimedu, Eleko, Tiye, Omu, Bogije,
Magbon	Kajola, Igbojia, Elemoro, Ayeteju, Iwerekun, Kuramo

Causes of Flood in the Study Area

Responses received from the 300 questionnaires and oral interviews conducted at the study area is shown in table 2 below.

Table 2: causes of flood in Victoria Island

		Ibeju-Lekki		Awoyaya		Magbon		Total	
SN	**Causes**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
1.	Extreme Rainfall	33	33	38	38	34	34	105	35
2.	Sea Level Rise	25	25	18	18	23	23	66	22
3.	Low level Terrain	15	15	16	16	11	11	42	14
4	PoorEnv.behavior	27	27	28	28	32	32	87	29

The results indicate that 105 persons representing 35% of the total respondents think that floods in Victoria Island is due to extreme rainfall events while 66 persons representing 22% said it is due to sea level rise. 42 persons or 14% of the respondents said it is due to the low level nature of the terrain while the remaining 87 persons (29%) think it is as a result of poor environmental practices within the community.

Potential Flood-Inducing Rainfall Data

Based on the approach detailed in section 3.4.1 a threshold of $129.1mm$was used to generate the potential flood-inducing rainfall data vis-à-vis number of EDR above $129.1mm$ over the location. This value ($129.1mm$) was the second highest daily or one-day rainfall in Victoria Island in 2012, and thus all values above this were considered EDR. It was based on this idea that, the values in table 3 and analysed in fig.4.4, showing the number of EDR recoded each year from 1981-2017 were generated. The generated data was then subjected to statistical test in a bid to ascertain if the number of EDR has, over the years, experienced any significant increase at the 5% level.

Result of Test of Significance of Trend in the Number of EDR

Table 3: Number of EDR from 1981-2017 in Lagos (Victoria Island)

Year	Number of EDR
1981	0
1982	0
1983	0
1984	0
1985	0
1986	0
1987	0
1988	4
1989	0
1990	1
1991	0
1992	0
1993	0
1994	0
1995	0
1996	0
1997	0
1998	1
1999	1
2000	1
2001	0
2002	1
2003	1
2004	3
2005	2
2006	0
2007	1
2008	0
2009	0
2010	1
2011	2
2012	2
2013	1
2014	1
2015	0
2016	2
2017	1

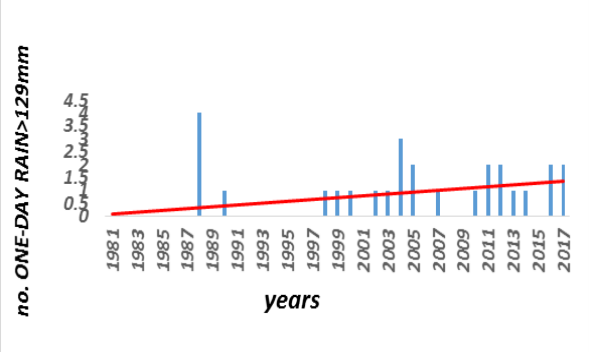


Figure 22: Number of Extreme Daily Rainfall (EDR) over Victoria Island from 1981-2017. The trend line shows that the number of EDR has been on the increase.

A linear regression was fitted to the generated data, with time as the independent variable and number EDR as dependent variable. The regression obtained was;

$\tilde{y} = 0.031x + 0.1126$

$\tilde{y}$ *represents the number of EDR and* x *representing time*$(years)$.

The slope/trend of the regression, 0.031, was tested to ascertain its significance at the 5% level using the hypothesis and the approach involving p-value already stated in chapter three. A p-value of 2.8% was obtained showing that

the trend was significant at the 5% level. In other words, the number of extreme events or EDR has over the years increased significantly at the 5% level. Given that the trend is significant, it could be argued that since 1981 number of daily rainfall of the EDR magnitude has been increasing at a rate of 0.3mm per decade. Given this situation, is it possible that the number of EDR events translated into actual flood cases experienced over the years in Victoria Island, Lagos? In other words, is there a correlation between the number of EDR and actual flood cases in Victoria Island, Lagos?

Relationship between the Number of EDR and Actual Flood Cases in Victoria Island

Table 4: Actual flood cases in Victoria Island (2012 – 2017)

Years	Number of flood cases
2012	2
2013	1
2014	1
2015	0
2016	2
2017	1

Actual flood data (table 3) was only available for six years (2012-2017), consequently the strength of relationship between the number of flood cases and the number of EDR could only be assessed within the period 2012-2017. Thus the correlation coefficient and the coefficient of determination was computed using equations (13) and (14) but within the period 2012-2017. The correlation coefficient and coefficient of determination were $r = 94\%$ and R^2=89% respectively. The $r = 94\%$ indicated that there is a strong linear relationship between the number of EDR and the number of flood cases within the period 2012-2017, while R^2=89% indicated that 89% of the actual variability in the number of flood cases can be predicted by changes in the number of EDR values. The linear regression between the number of flood cases and number of EDR was found to be;

$$\tilde{y} = 0.34x + 0.437, where\ \tilde{y}\ is\ number\ of\ flood\ cases\ and\ x\ is\ number\ of\ EDR$$

The trend or slope of the regression is significant given a p-value of 0.24%, and based on this observation coupled with strength of the indexes, the number of flood cases could be predicted using the number of EDR as predictors. Furthermore, the trend 0.34 indicates the rate of increase in flood cases compared to the number of EDR i.e. for every unit increase in the number of EDR, number of flood cases are expected to increase by 0.34; if the number EDR were to increase by 10, number of flood cases would also increase by 3.4.

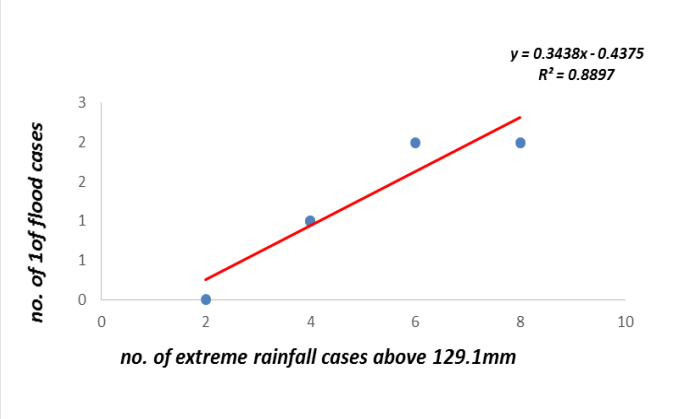


Figure 23: Number of actual flood cases against number Extreme Daily Rainfall (EDR) in Victoria Island from 2012-2017

Conclusion

The study concludes that there has been an increasing trend in rainfall and temperature in Victoria Island in the past 37 years which has led to the observed increase in flood incidences. Rainfall amount ranged between lowest value of 939.2mm in 2008 and highest value of 2442.5mm in 1988.The significance of trend for EDR reveals a significant upward trend at 5% levels (2.8%) showing that the number of extreme rainfall events or EDR has over the years experienced significant increase at the 5% level. The results also show that temperature and rainfall variations have strong effects on coastal flooding in the study area.

Recommendations

The purpose of this research work is to assess the effect of rainfall and temperature variability on coastal flooding in Victoria Island Lagos. From the results of the analysis carried out, it is clear that Victoria Island area is prone to flooding and this is mainly attributable to rainfall and temperature variations. Also there are contributions from other factors mentioned in the paper. If serious measures are not taken soon, taking the increasing extreme daily

rainfall into consideration, the area is under the threat of being submerged by floods with lives and properties in danger of being destroyed. Since Lagos in general and Victoria Island in particular is of immense importance to the economy of Nigeria, Therefore, it is important that the federal government collaborate with the Lagos State government and the private sector to put in place measures to mitigate flooding in Victoria Island. Measures such as:

- Instituting a Flood forecasting and flood early warning services using relevant government agencies such as the Nigerian Meteorological Agency in collaboration with NIHSA.
- Careful planning of development in potentially flood prone areas. Using appropriate legislation, public information and education programmes (to ensure that residents understand the flood risk), and flood early warning systems (to reduce the impact of floods).
- Construct roads with proper drainage channels and dumping of refuse in drainage channels should be prohibited and proper enforcement of laws prohibiting such acts should be instituted.

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