Geospatial assessment of land use/cover, rainfall, and flood incidents in Eti–Osa, Lagos, Nigeria

Toka Sunday Onajomo

Department of Climate Change, Ministry of Environment and Water Resources, Lagos State, Nigeria tokasundayus@yahoo.com

DOI: http://dx.doi.org/10.4314/sajg.v11i2.3

Abstract

Flooding in Lagos State has been on the rise in the past two decades, especially in the Eti-Osa area of the state. This is largely due to the increased volume of rainfall associated with climate variability and sea level rise. Flooding incidents have led to loss of lives and properties. The objective of this study is to examine the dynamics of flood occurrences in the Eti-Osa area of Lagos metropolis. Rainfall data for the area covering a period of 30 years (1990 to 2019) were obtained from the Nigerian Meteorological Agency (NiMET) in Lagos, and analyzed using the basic descriptive statistical technique. The purpose was to evaluate rainfall characteristics that were influencing flooding events in the area. Furthermore, remotely sensed multi-date Landsat imageries of 1990, 1997, 2001, 2012, and 2017 were obtained, and analyzed to determine how land use and land cover characteristics have changed and have been affected by flooding over the study period. The data were subjected to digital image processing and supervised classification was carried out on the images of the various dates. Results showed that flooding became prevalent as more areas became built up and as vegetated areas declined. Also, flooding events appeared to be responsive to the climatic extremes. Moreover, poor drainage, increased population numbers, and non-compliance to building and current environmental regulations were key factors that exacerbated the increased prevalence of flooding in the area. The study recommended that flood control policies, including land-use planning for the area, need to be pursued urgently.

***Keywords**: Flooding, Climate variability, Geographical Information System, Land cover change.*

1. Introduction

In many parts of the world, floods are increasing in frequency and severity, especially in coastal areas. The increased prevalence of flooding in many countries has been linked to climate change or extreme climatic conditions, which in their turn have been exacerbated by rapid population growth and poor land-use planning in many areas (Tacoli, 2012). Flood-related disaster is a source of growing concern for the security of life and properties in a rapidly expanding metropolis such as Lagos, where the rainy season comes with worries to many (Nkwunonwo, et al., 2016). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (Alcamo et al., 2007) attributed increases in flood cases in settlements in coastal or riverine areas to natural and anthropogenically influenced conditions, including urbanization, extreme climate conditions and poor planning control. In the present study area, Lagos, coastal flooding has been associated with loss of life and destruction of property (see Figure 1).

Figure 1: Flood events in the study area; (a) submerged neighbourhoods during the 2012 flooding in Lekki, (b), submerged vehicles during the 2014 flooding in Ajah, (c), an inundated road in Ikate in 2016 (d), and inundated streets in Victoria Island, Lagos, Nigeria, in 2018.

The existing flood-related studies on parts of the Nigerian coastline, especially the Lagos area, have focused on land use /land cover change, as well as rainfall trends and patterns, and their impact on inundation (e.g. Rilwani and Ikhuoria 2006; Salami et al. 2006; Ikhuoria et al. 2006; Salami 2006; Nuga and Akinbola 2011). A review of studies in the southwestern part of Nigeria suggests an increase in the application of remote sensing in environmental monitoring, especially for the purposes of data collection and analysis, as the technology develops in the country (Oyinloye and Kufoniyi 2013; Eludoyin et al., 2019; Eludoyin and Iyanda, 2019). Many of these studies reveal a transition from the use of aerial photographs and topographical maps to satellite remote sensing data, such as SPOT and Landsat imageries, as they become available for exploration by researchers in the country. Remote sensing datasets provide adequate tools that can lead to an understanding of the past, present, and future state of land use and land cover change in an area. However, except for the Landsat (Satellite Programme of the National Aeronautics and Space Administration (NASA)) imageries that can be acquired from the NASA website at no cost, many of the high resolution remote sensing imageries are tooexpensive for most researchers and students in many developing countries, especially in Africa, to procure (Omodanisi et al. 2014; Eludoyin and Iyanda, 2019).

The present study aims at examining the factors influencing flood occurrences in the coastal area of Eti-Osa in southwestern Nigeria. A clearer understanding of the causes of flooding in the region will enhance and provide additional information for the improved decision-making process for minimising flood hazards in the study area. The specific objectives are to assess the land use /land cover changes, rainfall variability, as well as the potential for flood incidents in the study area, using the available records of data. The main hypothesis is that the increase in the built-up area, poor drainage, non-compliance to government regulations, and indiscriminate waste disposal are exacerbating flooding in the study area. This study is expected to contribute to the informed implementation of policies relating to adaptations to and the mitigation of the effects of climate change in the area.

2. Materials and method

2.1. The study area

The study area, the Eti-Osa local government area, is located approximately between 06º 25'N, 03º 24'E and 06º 26'N, 03º 25'E in southwestern Nigeria, and forms part of the commercial capital of Nigeria, Lagos State (Figure 2). The study area is surrounded by a lagoon and the Atlantic Ocean, which explains its vulnerability to flooding. The area is also characterised by dense residential settlements and commercial activities, such that over 40% of the Lagos State Government revenue is generated from its investments in real estate, tourism, commercial activities and quaternary industry, all of which are generated from the area (Olajuyigbe *et al*., 2012). Its low-lying topography (≤ 16 m above mean sea level) which makes it vulnerable to flooding and coastal erosion (Olajuyigbe, *et al*., 2012) has also contributed to its situation as a major sea-port route, including Tin Can, in the area (Omenai and Ayodele, 2014). Awosika *et al*. (2000) documented that the study area is known to experience flooding events as the surrounding water bodies are filled up during the rainy season. However, given the increasing population numbers and extent of the built-up areas, the level of impact of the human activities, as well as urban growth on the vulnerability of the residents, is not yet well-known.

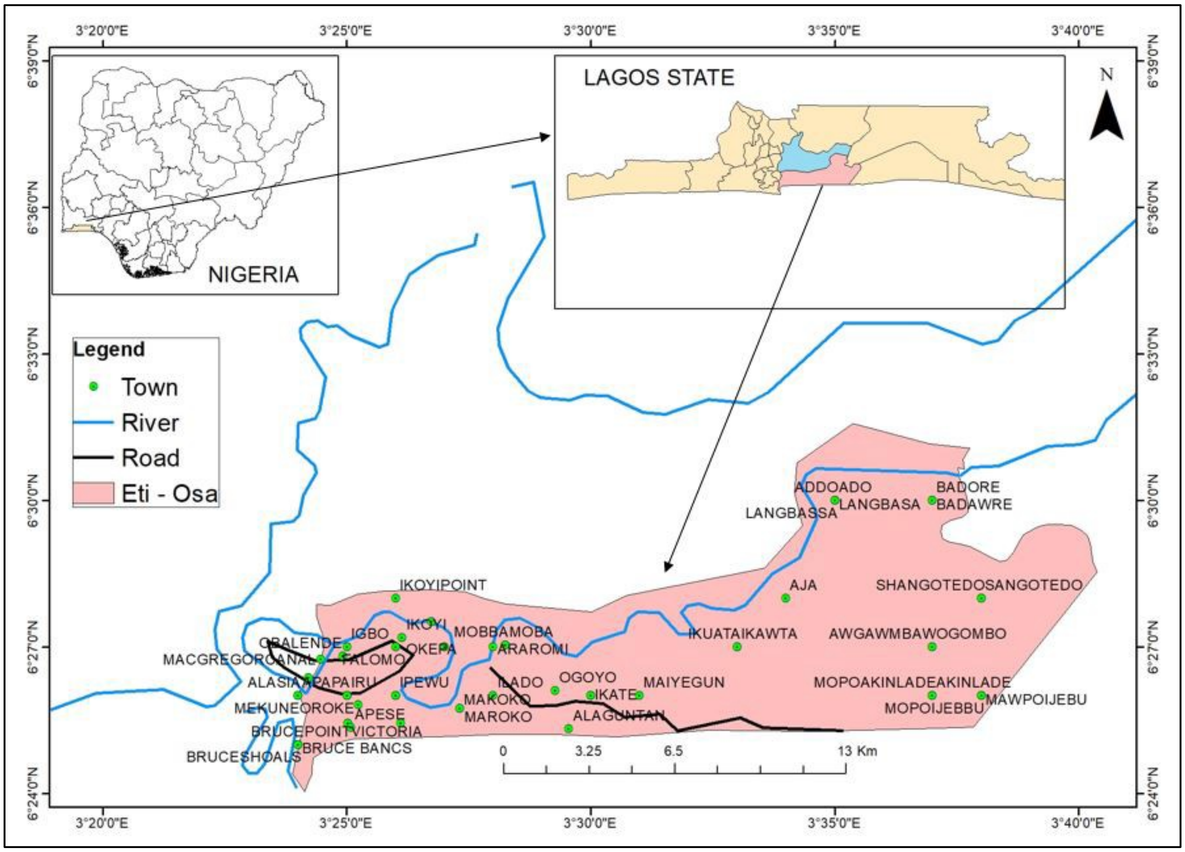

Figure 2: The study area, Eti Osa, in Lagos State, Nigeria

The relief of the area is shown in Figure 2. The elevation in the area varies from - 4.6m to 1.5m for water bodies, while the urban area, lying mostly between 1.7m and 16m, and a fair share as low as 2m 5m, with the highest locations capping 11 to 15m. The general impression of the area is that the water bodies are lower in elevation than the surrounding land. The wave height along the coast during any storm usually ranges from 0.9m to 2m and could exceed 4 metres, causing many offices and residential spaces to become flooded (Awosika, et al., 2000). With a total population of 283,791 persons (158,858 males and 124,933 females), the study area is rapidly urbanizing, with several economic activities such as banking, retail and wholesale trading, commercial transportation and monumental real estate development for both residential and commercial purposes going on within it (e.g., Omenai and Ayodele, 2014). The coastal communities live in a low-lying coastal environment with fragile coastal ecosystems and a high reliance on tourism, agriculture, and industries. All of the economic activities are vulnerable to the impacts of a changing climate.

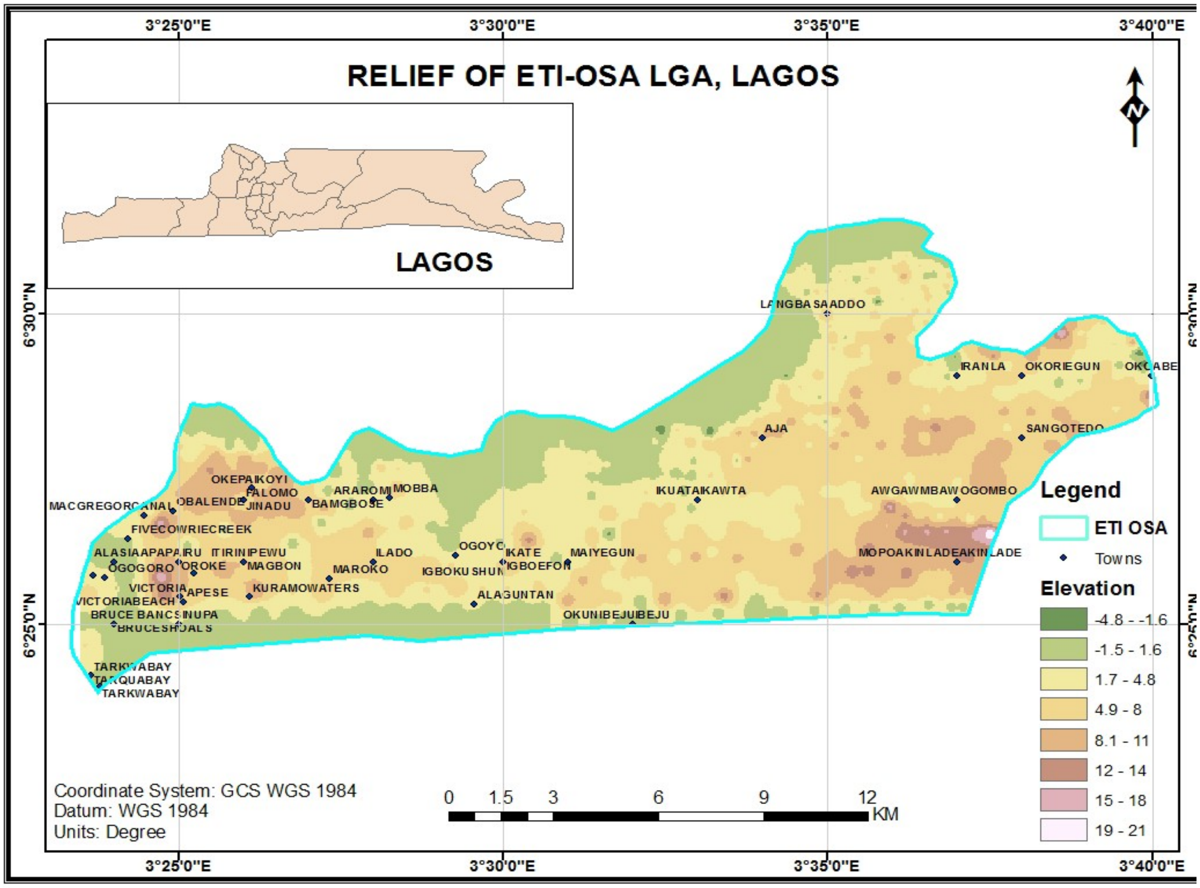

Figure 3: Elevation across the study area

2.2. Data collection

The data used were the 30 (1990-2019) years' monthly rainfall records of the Nigerian Meteorological Agency's station at Victoria Island (Lagos) in the study area and multi-date (1990, 1997, 2001, 2012 and 2017) Landsat imageries that covered the study area. Landsat imageries were preferred in this study because of their availability at different timeswithin the study period, and unlike other available image sensors, including SPOT and MODIS, which do not offer similar temporal coverage. Landsat is also a frequently used remotely-sensed data source across sub-Saharan Africa because it is freely available (Eludoyin et al, 2019; Eludoyin and Iyanda, 2019), technically suitable, and readily available (Chander *et al.,* 2009).

The choice of the years (1990, 1997, 2001, 2012 and 2017) covered was informed by data availability, quality, and the need for a relatively long time lag for noticeable change in the study area. Landsat imageries, based on their specific characteristics (Table 1), were downloaded from the archive of the United States' Geological Surveys, as described in Eludoyin and Iyanda (2019).

Table 1. Details of the satellite data used in the study.

Satellite Sensor	Path/row	Date acquired	LULC map naming	Spatial resolution
Landsat TM	191/55	04/01/1990	LULC 1990	30
Landsat TM	191/55	08/12/1997	LULC 1997	30
Landsat ETM+	191/55	06/10/2001	LULC 2001	30
Landsat ETM+	191/55	10/12/2012	LULC 2012	30
Landsat OLI_TIRS	191/55	10/12/2017	LULC 2017	30

2.3. Data analysis

Rainfall data were analysed for mean monthly, annual and long-term mean trends and variability, while the Landsat imageries were first corrected for line striping and later enhanced in remote sensing software (ENVI 4.5). Further correction of geometric and radiometric errors was achieved using ArcGIS software (version 10.5). After georeferencing, the study area was clipped out of the entire image scene using the 'Spatial Analyst' tool in ArcGIS, and then subjected to supervised classification. To achieve supervised classification, spectral signatures were obtained from specified locations (training areas) in the study area and linked with their appearance on the imageries. Supervised signature extraction, with the maximum likelihood classification algorithm, was used to classify the different training samples of the images of the study area as five land use classes were classified, following a modification of Anderson et al. (1976)'s recommendation. For this study, the identified land use/cover categories included water body, vegetation, sandbar, built-up and wetlands. The Kappa coefficients of the supervised classification for the selected years were at least 0.90, indicating strong agreement between the classified pixels and the field objects (Zeng et al, 2015). Consequently, the classified imageries were considered to be of the desired quality for interpretation in this study. Figure 4 presents the flowchart for the land use/land cover and change detection analysis in the study.

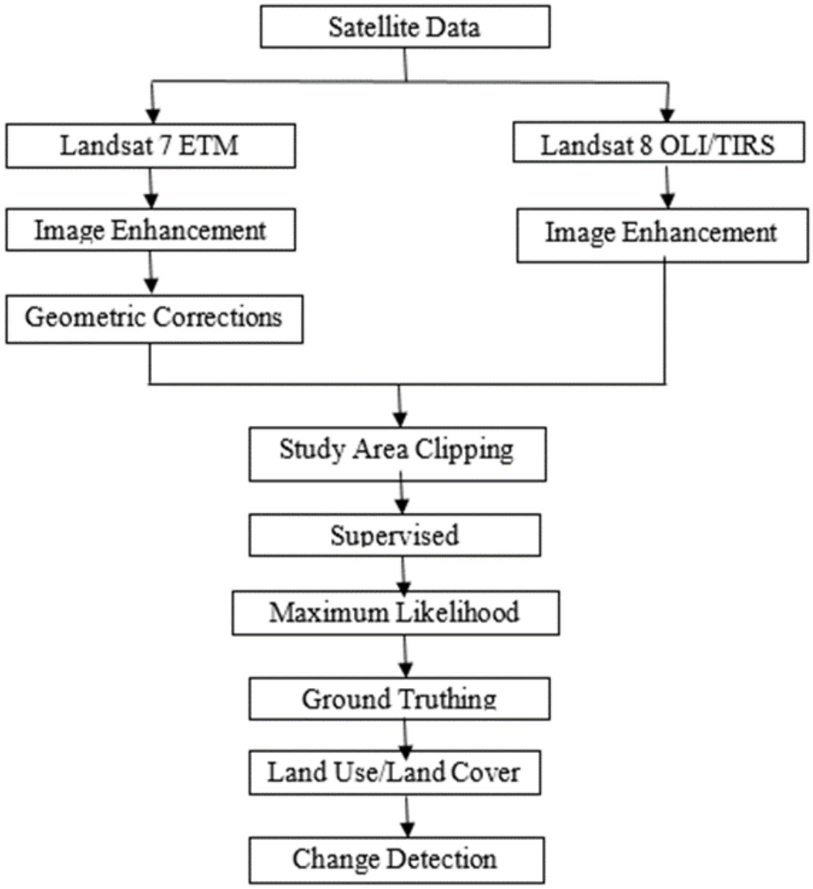

Figure 4: Flowchart for the land use/land cover and change detection analysis in the study.

3. Results and discussion

3.1. Rainfall variability

The study area, being located within the tropical rainforest region, is characterised by distinct wet and dry seasons. Figure 5, which shows mean variability and range for the 30-year rainfall average reveals peak temporal variability in June (69.5 mm – 720 mm). Mean rainfall generally increases slightly from January and peaks in June, before declining in July and August, to rise again in September, before declining through to the end of the year. The month of December generally record the lowest value for mean rainfall (e.g., 27.9 mm), with the dry season generally being experienced between December and March.

.

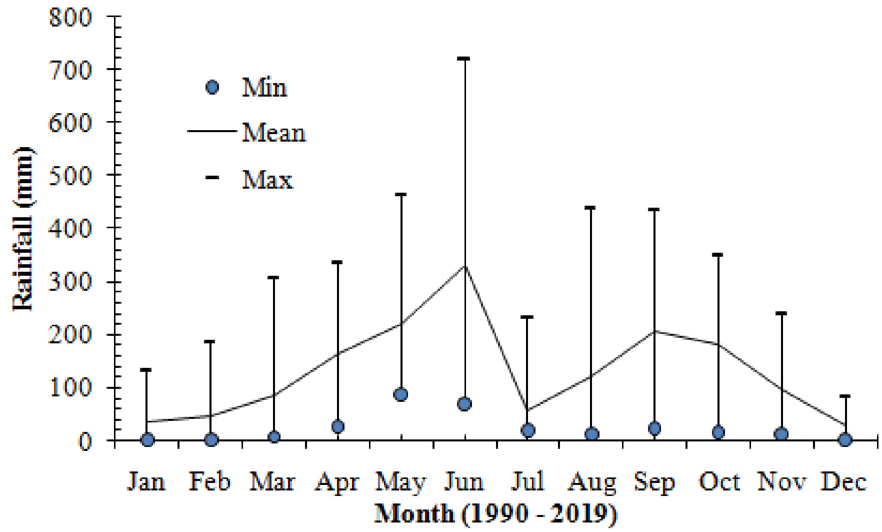

Figure 5: Thirty (1990 – 2019) years of average rainfall and rainfall range (min – max) at Eti-Osa local government area of Lagos State, Nigeria

The result of linear regression analysis conducted on the annual mean rainfall indicates a slight increase over the years (b = 0.27, R^2 = 0.05), although a cursory look at the annual pattern shows a relatively higher rainfall in 1993, 2010, and 2017 than for the other years (Figure 6). An evaluation of the flood pattern over the study area indicates that flooding events occur during both intense and slight rainfall periods, thus suggesting the dominance of the infiltration of excess runoff during non-intense rainfall or saturation excess runoff in the period of intense rainfall. The study area is largely covered by impervious surfaces, mainly due to the concretisation of the land surface and the high densities of building structures in the study area (Gholami *et al.*, 2010). Also, poor urban planning in respect of waste management has been linked to flood events that are induced by blockages in river channels and creeks.

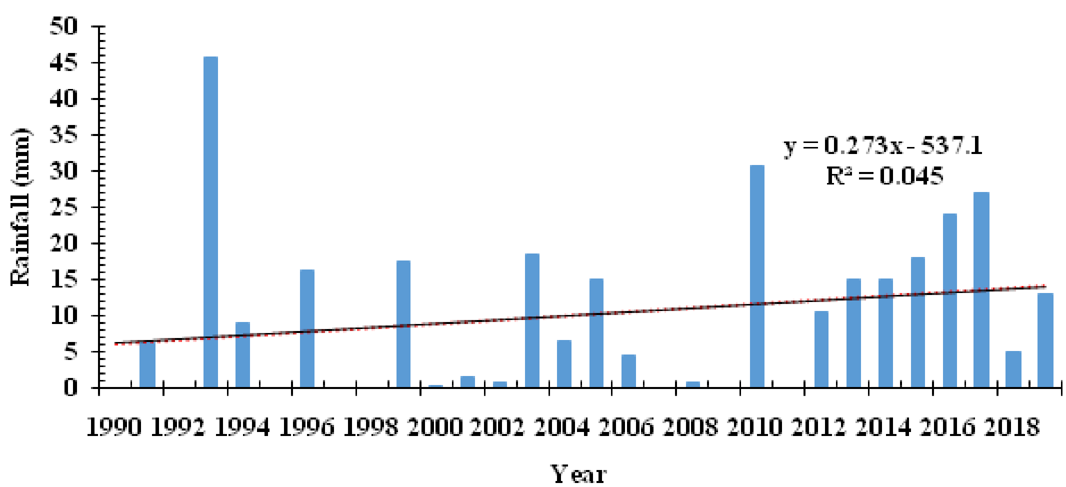

Figure 6: Changes and trends in mean annual rainfall patterns over Eti- Osa between 1990 and 2019

3.2. Land use/Land cover Distribution

The areas covered by the classified land use/cover, as well as the changes in land use/cover between 1990 and 2001, and between 2012 and 2017, are presented in Table 2. Out of the classified land uses/covers, only built-up areas, increased in area within the study period, while the areas occupied by vegetation, water bodies, sandbars and wetlands declined over the years. A recent study by Abiola-Oke *et al*. (2019) reveals that the study area has immensely benefited from urban development and programmes that have encouraged tourists and attracted investors into the area. Specific examples are given of, amongst others, the Lekki - Ikoyi Link bridge (a 1.36 km^2 cable-stayed bridge linking the fast growing Lekki with Ikoyi, an affluent part of Lagos), the Lekki Conservation Centre, the Eko Atlantic City Project, as well as the Eko Hotels and Suites. The development initiatives and programmes have encouraged urban growth, which is required to be planned sustainably into the future.

Table 2: Land use/Land cover changes – 1990 to 2017 in the Study Area.

Land use/cover	1990	1997	Year 2001	2012	2017	Δ 1990-2001	Δ 2012-2017
Water body	99.9	53.4	52.9	49.4	45.1	-47.0	-4.1
Built-up Area	11.4	44.3	49.1	56.6	104.9	37.7	48.3
Vegetation	53.6	91.4	83.3	75.3	41.3	-29.7	-34.0
Wetland	33.1	10.7	13.7	9.05	7.55	-19.4	-11.85
Sandbar	4.08	1.18	1.12	9.09	1.36	-2.96	-7.73

Furthermore, Figure 7 reveals the rapid decline in the waterbody category over the years despite the fact that the study area is surrounded by water (the lagoon and the Atlantic Ocean). The existing literature reveals cases of sand filling (Olanibi, 2015; Oyinloye et al., 2016) and the increased concretisation of the land for road construction/alterations, as well as the construction of buildings for residential, commercial, and religious purposes. However, the practice of sand filling has apparently declined as its impact has become more “unfriendly” (Oyinloye et al., 2016); hence, the relative stability of the area in terms of its coverage by water body since 1997. Vegetation, on the other hand, has been replaced by exotic flowering plants, while the wetlands have also declined (Figure 7).

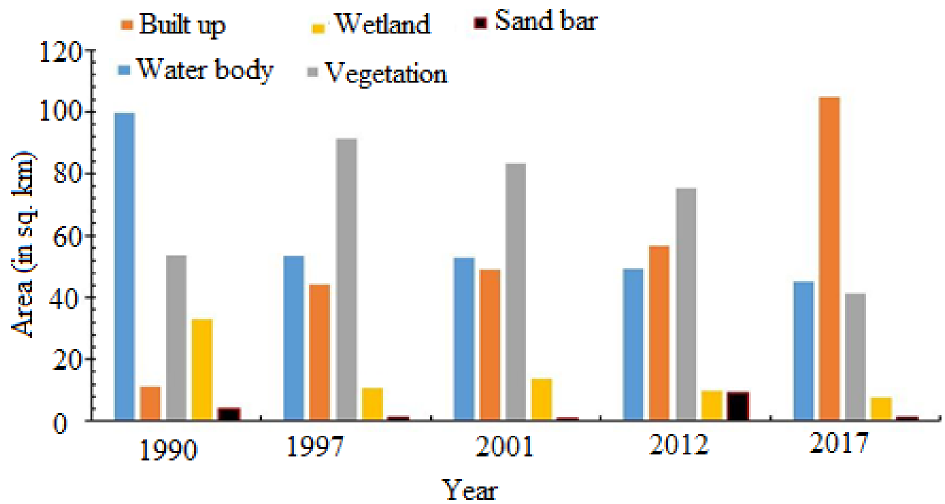

Figure 7: Variations in land use/cover for the study area over the study period

The vegetational cover, which previously formed an obstructivefeature against floods, recorded a decline from 53.6 km^2 in 1990 to 41.3 km^2 in 2017, while the area occupied by waterbodies declined by 100% in 1990 to 42% in 2017, and wetland from 33.1km^2 in 1990 to 119.4km^2 in 2017.

As indicated in Table 2, the land use /land cover classification reveals a great change of 48.3km^2 from 2012 to 2017 in terms of built-up area . The built-up area increased in area with a decline in the coverage of the vegetation, waterbody, wetland and sandbar categories. This is due to the increase in population growth linked with the high demand for land and urban supplies, which together could be responsible for the and use/ and cover changes. Table 2 also shows that the "waterbody" category in the study area did not undergo great changes during this period. A buffering operation carried out to assess the effect of flooding shows that houses should not be built less than 750 metres from the river banks. Furthermore, the land cover category, wetland, located along the margin of the waterways, and there to provide a barrier between the water body and the land, and which has up to the present time reduced the floodwater velocity, resulting in reduced downstream flooding, has been lost to infrastructural development.

From the land use classification carried out (Figure 7), the study area shows that in 1990, the Eti-Osa area was predominately covered by water, a relatively dense vegetation, and wetlands, with few built-up areas and few human settlements.

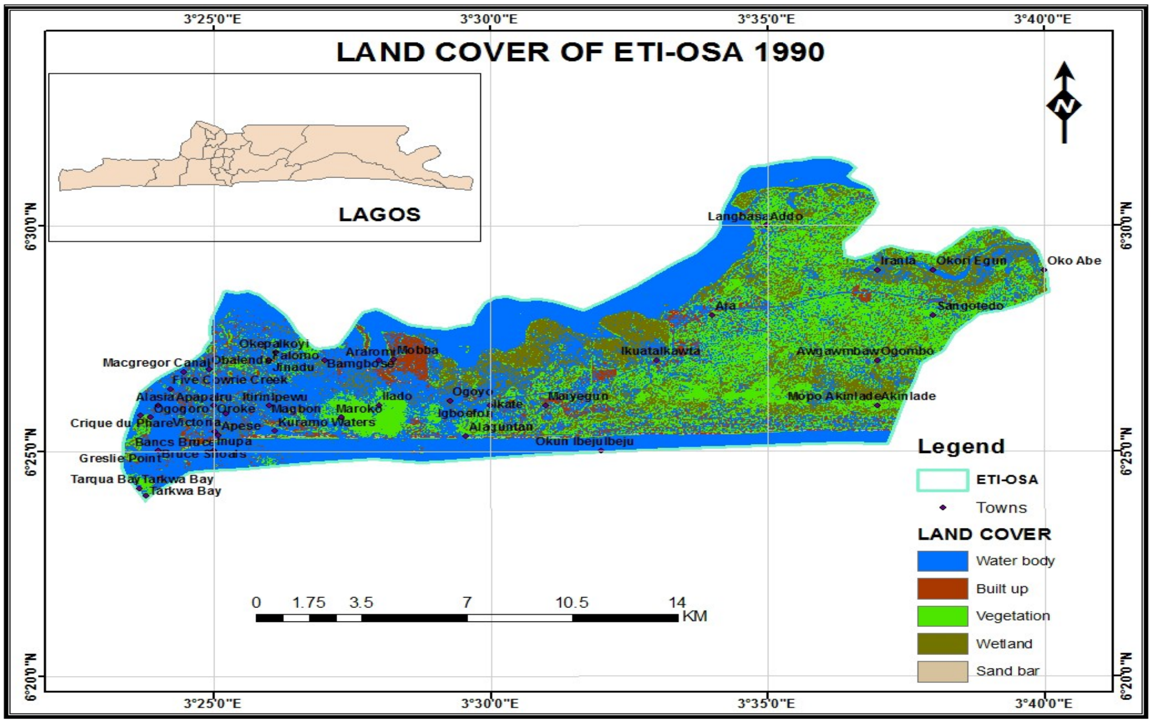

Figure 8: Classified Landsat image over the study area for the year 1990

As seen in Figure 9, the study area shows that by 1997, the area occupied by waterbodies had started to decrease with an increase in the built-up area as a result of the migration of people to the study area in a quest for land. This caused a decrease in the area occupied by wetlands and vegetation, and resulted in the waterbody in the area being filled up with sand.

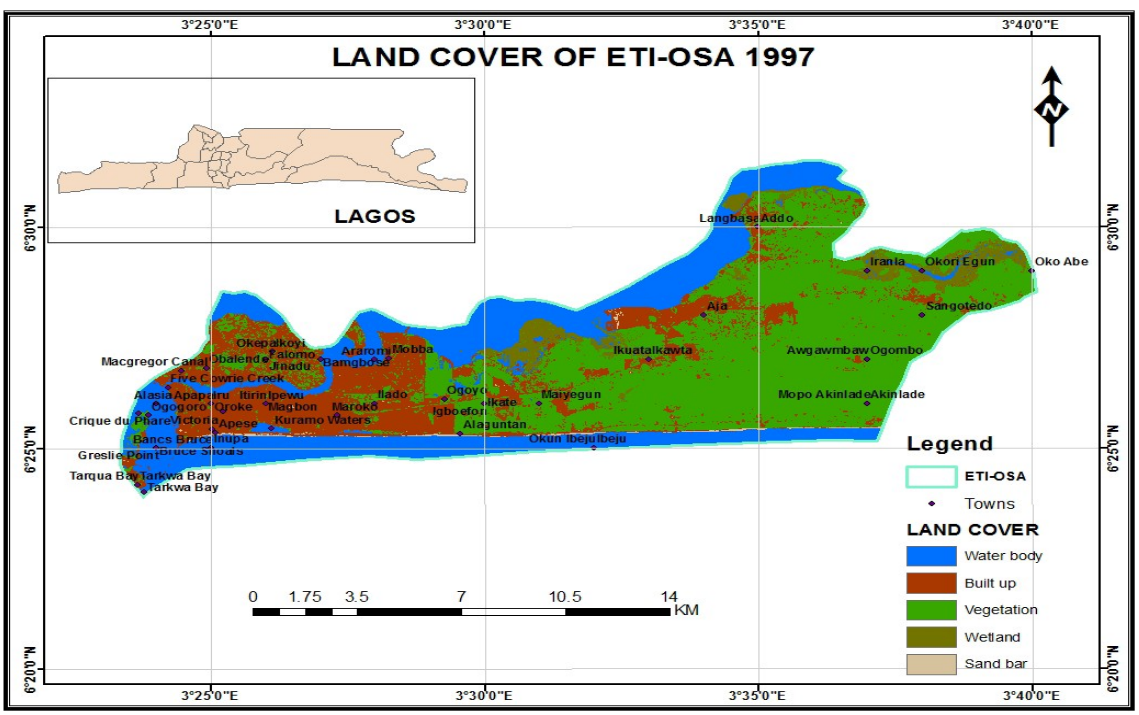

Figure 9: Classified Landsat image over the study area for the year 1997

Figure 10 shows that by 2001, as a result of the increasing population, the study area was continuing to experience an increase in its built-up area with a concomitant decrease in the areas occupied by water, wetlands and vegetation.

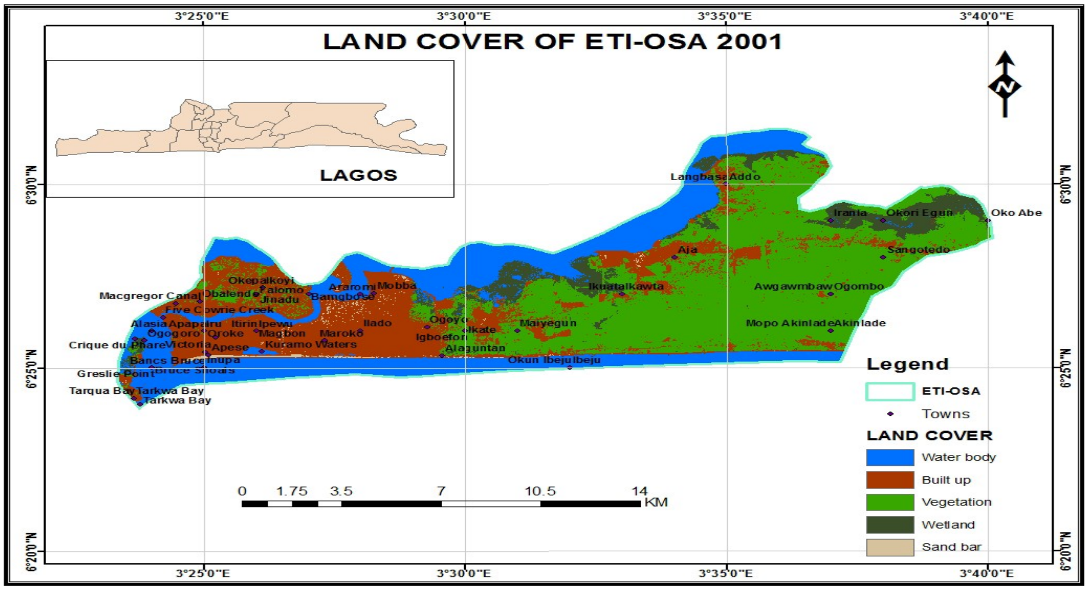

Figure 10: Classified Landsat image over the study area for the year 2001

As shown in Figure 11, by the year, 2012, the change in the built-up portion in the study area had continued to increase dramatically, which resulted in a decrease in the non-built-up area. This can be attributed to the rapid population increase, together with a high demand for land and urban supplies.

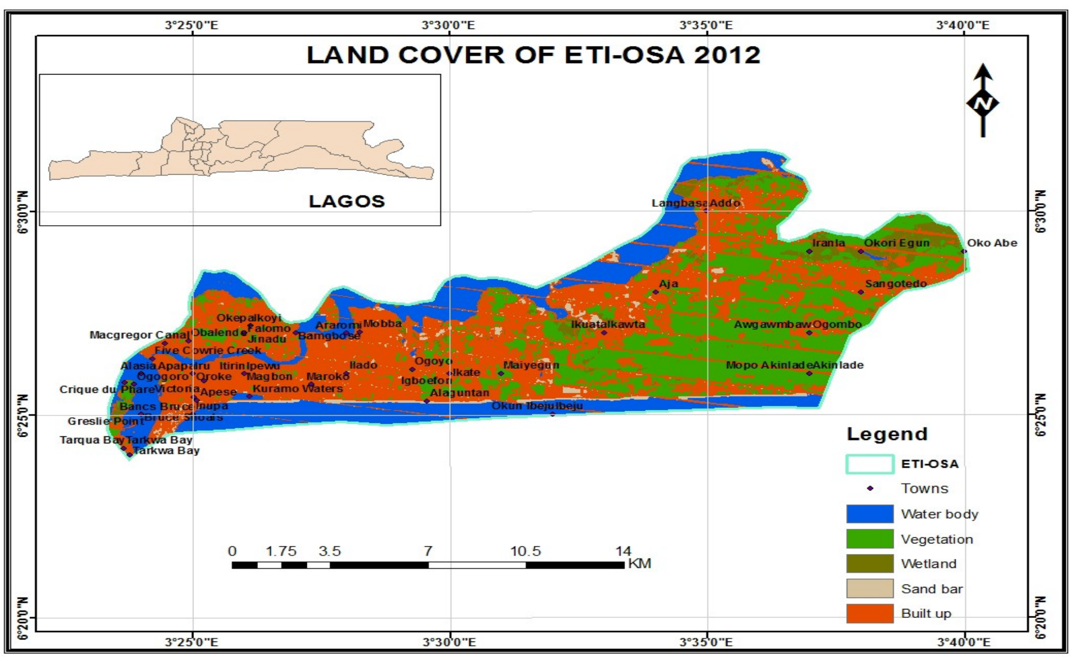

Figure 11: Classified Landsat image over the study area for the year 2012

Figure 12 shows that by 2012, over 100% of the land use/cover was categorized as built up, an indication of a potential flooding event after even the slightest rainshower. This dire situation can be attributed to the rapid population growth in the area that has in its turn led to, amongst others, ineffectual management systems, poor land-use practices, and inadequate drainage systems.

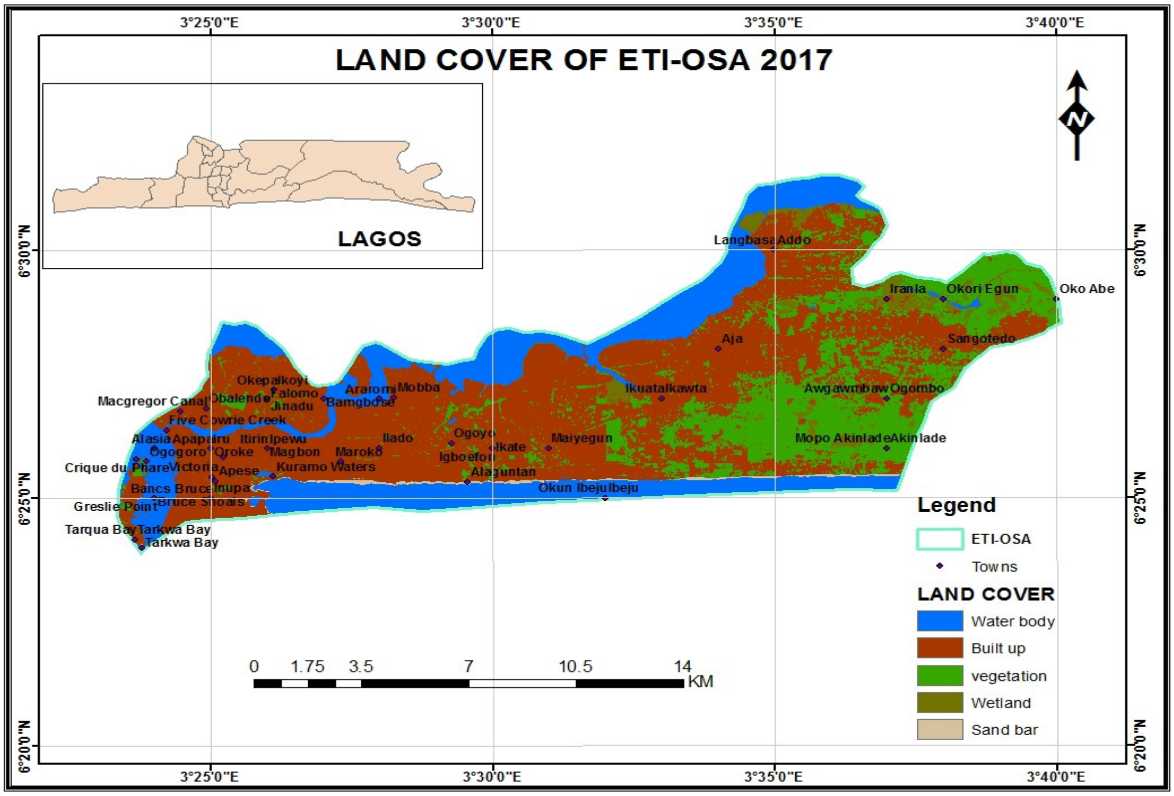

Figure 12: Classified Landsat image over the study area for the year 2017

From the land use classification carried out (Figure 12), the changes in the study area reflect an increase in the built-up area and therefore in impervious surfaces. Thus, it can be seen that apart from the climatic factors that are considered to be the cause of flooding in the study area, socioeconomic factors are also implicated. Rapid urbanisation is the dominant process in the study area (Offia, 2011) and the reason for the increased severity of the flooding. As observed by Adelekan (2010), the land use changes in the study area and the rising water levels leading to flooding are associated with the trend of rapid population growth in the study area, and the poor management of the urbanization process and all it entails.

Figure 13 depicts the blockage of the drainage system in the study area as a result of the continued dumping of waste in the drainage channels. This disrupts the flow of water, thereby resulting in significant flooding in the study area, which in itself is a commercial hub with the numerous activities that it conducts. The materials in the blocked channels include, among others, plastics, nylons, papers, and empty bottles.

The basic truth that has emerged from this study is that the rising water levels leading to flooding in this area are associated with the poorly managed urbanization process.

Topographical maps, if used to delineate the vulnerable areas in Lekki and Victoria Island, could assist in identifying the areas prone to flooding (Pradhan, 2009). The general impression about the area is that the water bodies are lower in elevation than the surrounding land. As such, , a closer look at the one-metre rise in the water level is likely to lead to insights that would reveal the causes of river or sea flooding. The topography also reveals that the reclaimed portions of the area are places that are highest at risk in the event of coastal flooding

Figure 13: Blocked drainage channels in the study area

4. Conclusion

With the combined approach of applying a remotely sensed GIS and a rainfall dataset, this study set out to reveal the change in land use/ land cover in Eti–Osa, Lago**s,** Nigeria, over the period from 1990 to 2017. To conduct the study, a rainfall dataset for 30 years, from 1990 to 2019, was obtained from the archives of the Nigeria Meteorological Agency, Victoria Island station. The dataset was analysed using simple statistical techniques to assess the conditions that could lead to a flood event. Supervised maximum likelihood classification methods were used to produce land use/land cover maps by using Landsat TM/ETM+/OLI satellite images for the years 1990, 1997, 2001, 2012 and 2017. The rainfall dataset and the geographical information system (GIS) approaches helped the researcher to identify the factors causing flooding in the study area, such as low-lying topography, climatic variability, rapid population growth, the poor drainage system, and real estate development. The study shows that the rainfall dataset and GIS, both of which revealed the flood- prone risk and vulnerability of the settlement and its infrastructures, proved to be effective and efficient tools in the study and mapping of the flooding in Eti-Osa. The challenges of flooding in this area of Lagos are significant issues within the context of environmental management and sustainable development. Available records indicate that flooding in the area affects the human population, destroys public assets, and disrupts economic activities. Unfortunately, these incidents are not likely to disappear any time soon and are likely to get worse.

Population growth is putting pressure on the land for housing, in particular, and as such, the risk of flooding will continue to grow. However, if well managed with the available geospatial techniques, and in conjunction with proper urban planning policies, and by establishing a sea wall fortification, the impacts of flooding can be reduced. The appropriate agencies of government need to pay particular attention to this area and to minimize flooding. One of the responses will be, as previously mentioned the construction of of a sea-wall fortification to reduce the force of the water from the waves and tides and thus to protect the reclaimed areas. Without this and other possible engineering feats, the area will succumb to the pressures of persistent flooding and global climate change.

5. References

Adedeji, O. H., Odufuwa, B. O., & Adebayo, O. H. 2012. Building capabilities for flood disaster and hazard preparedness and risk reduction in Nigeria: need for spatial planning and land management. Journal of Sustainable Development in Africa, 14, 45-58

Adelekan, I. O. 2011.Vulnerability assessment of an urban flood in Nigeria: Abeokuta flood 2007. *Natural Hazards,* 56, 215-231.

Adelekan, I. O. 2009**.** Vulnerability of poor urban coastal communities to climate change in Lagos, Nigeria. In Fifth Urban Research Symposium. 28-30.

Adelekan, I. O., & Asiyanbi, A. P. (2016). Flood risk perception in flood-affected communities in Lagos, Nigeria. Natural Hazards, 80(1), 445-469.

Aderogba, K. A. 2012.Global warming and challenges of floods in Lagos Metropolis, Nigeria. *Academic Research International,* 2, 448-468.

Ajibade, I., Mcbean, G. & Bezner-Kerr, R. 2013.Urban flooding in Lagos, Nigeria: Patterns of vulnerability and resilience among women. *Global Environmental Change,* 23, 1714-1725.

Ajibola, M., Awodiran, O. & Salu-Kosoko, O. 2013**.** Effects of infrastructure on property values in Unity Estate, Lagos, Nigeria. *International Journal of Economy, Management and Social Sciences,* 2, 195-201.

Anderson JR, Hardy EE, Roach JT, and Witmer E (1976) A Land Use and Land Cover Classification System for Use with Remote Sensor Data. Geological Survey Professional Paper 964. Washington, DC: US Government Printing Office

Awosika, L., Dublin-Green, C., Folorunsho, R., Adekoya, E., Adekanmbi, M. & Jim-Saiki, J. 2000. Study of main drainage channels of Victoria and Ikoyi Islands in Lagos Nigeria and their response to tidal and sea level changes. *CSI-UNESCO Special Report*.

French, G. T., Awosika, L. F., & Ibe, C. E. 1995. Sea-level rise and Nigeria: potential impacts and consequences. Journal of Coastal Research, 224-242.

Gholami, V., & Mohseni Saravi, M. 2010. Effects of impervious surfaces and urban development on runoff generation and flood hazard in the Hajighoshan watershed. *Caspian Journal of Environmental Sciences*, *8*(1), 1-12. Chicago.

Gobo, A. & Abam, T. 2006. Return period analysis as a tool for urban flood prediction in the Niger Delta: a case study of Port Harcourt City, Nigeria. *Journal of Environmental Hydrology,* 14, 1-9.

Ibe, A. C. 1988. *Coastline erosion in Nigeria*, Nigerian Institute for Oceanography and Marine Research. Ilesanmi, A. O. 2010. Urban sustainability in the context of Lagos mega-city. *Journal of Geography and Regional Planning*, 3, 10, 240-252.

Isong, M. A. (1999). Analysis of Flooding in Calabar Polytechnic and Environs. *International Journal of Tropical Environment,* 1, 28-37.

Montz, B. E., & Evans, T. A. 2001. GIS and social vulnerability analysis. In Coping with flash floods. 37-48. Springer, Netherlands

Nicholls, R. J., & Leatherman, S. P. 1995 . 4. Global Sea-level Rise. As climate changes: International Impacts and Implications, 92.

Nkwunonwo, U., Whitworth, M., & Baily, B. (2016). A review and critical analysis of the efforts towards urban flood risk management in the Lagos region of Nigeria. Natural Hazards and Earth System Sciences, 16(2), 349-369.

Nwilo, P. C. (1997). Managing the impacts of storm surges on Victoria Island, Lagos, Nigeria. IAHS Publications-Series of Proceedings and Reports - Internal Association of Hydrological Sciences, 239, 325-330.

Nzeribe-George, G., Nwokoye, E., Uwajumogu, N. & Ezenekwe, U. What Implications does 2012 Flood Disaster have on the Nigerian Economy?

Obiefuna, J. N., Nwilo, P. C., Atagbaza, A. O., & Okolie, C. J. 2013. Spatial changes in the wetlands of Lagos/Lekki Lagoons of Lagos, Nigeria. Journal of Sustainable Development, 6 , p123.

Odunuga, S., Oyebande, L. & Omojola, A. 2012. Socio-economic indicators and public perception on urban flooding in Lagos. Hydrology for Disaster Management. Ibadan, Oxford University Press.

Offia I.E., 2011. Challenges of disaster vulnerability reduction in Lagos Megacity Area, Nigeria. *Disaster Prevention and Management: an International Journal*, 20(1), 27-40.

Ojinnaka, O. C., Baywood, C. N., & Gift, U. A. 2015. Flood Hazard Analysis and Damage Assessment of 2012 Flood in Anambra State using GIS and Remote Sensing Approach. American Journal of Geographic Information System, 4, 38-51.

Ojo, O. (1977) The Climates of West Africa. Heinemann, Ibadan.

Olajuyigbe, A. E., Rotowa, O. O., & Durojaye, E. 2012 . An assessment of flood hazard in Nigeria: The case of Mile 12, Lagos. *Mediterranean Journal of Social Sciences*, 3, 367-375.

Onwuemele, A. 2014. Socio-economic and Environmental Impacts of Urbanization in Lagos, Nigeria: A Review of Grey Literature. Urbanization and Migration as Factors affecting Global Economic Development, 210.

Oyebande, L. & Oyebande, B. 1983. Rainfall intensity-duration-frequency curves and maps for Nigeria, Department, Univ.

Pradhan, B. (2009) Flood Susceptible Mapping and Risk Area Delineation Using Logistic Regression, GIS and Remote Sensing. *Journal of Spatial Hydrology*, 9, 1-18.

Reid, R. S., Kruska, R. L., Muthui, N., Taye, A., Wotton, S., Wilson, C. J., & Mulatu, W. 2000. Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: the case of southwestern Ethiopia. *Landscape Ecology*, 15, 339-355.

Roesner, L. A. 1966. Mathematical models for time series of monthly precipitation and monthly runoff

Simpson, A. 2006, "Sustainable strategies for combating the problem of floods in Lagos: pointer from a Csi-UNESCO culture-based project", in Okewole, I.A., Daramola, S.A., Ajayi, C.A., Ogunba, O.A. and Odusami, K.T. (Eds), International Conference Proceedings on the Built Environment: Innovation Policy and Sustainable Development, Department of Architecture, Covenant University, Ota, Nigeria, 24-26 January, 2006, 165-72.

Slingo, J. & Palmer, T. 2011. Uncertainty in weather and climate prediction. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences,* 369, 4751-4767.

Small, C., & Nicholls, R. J. 2003. A global analysis of human settlement in coastal zones. *Journal of Coastal Research*, 584-599.

Soneye, A. 2014. An overview of humanitarian relief supply chains for victims of perennial flood disasters in Lagos, Nigeria (2010-2012). *Journal of Humanitarian Logistics and Supply Chain Management,* 4, 179-197.

Tacoli, C. (2012). Urbanization, gender and urban poverty: paid work and unpaid carework in the city (p. 48). Human Settlements Group, International Institute for Environment and Development.

Vyas, V., Kumar, A., Wani, S. G., & Parashar, V. 2012. Status of riparian buffer zone and floodplain areas ofRiver Narmada, India. *International Journal of Environmental Sciences*, 3, 659-674.