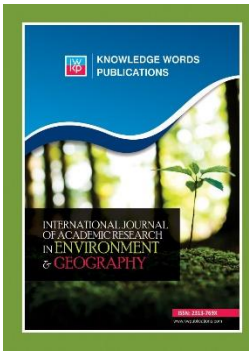

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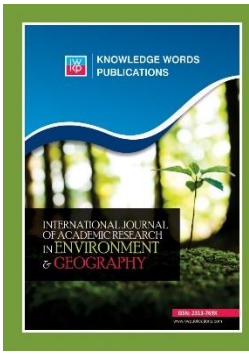

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Mapping and Geo - Visualisation of Flood Susceptible Administrative States in Nigeria: A Terrain Modeling Approach

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Abstract

This study considered morphological characteristics such as plateau, highland, lowland, simple slope, and/or flatland as major determinants aside from other elements such as soil, land cover, and human activities. This study utilized spatial query and Digital Elevation Modeling developed from Shuttle Radar Topographic Mission to identify administrative states in Nigeria that are most vulnerable to flood. This study revealed that Ekiti State is the only administrative state that is far less susceptible to flood in the southwest. Also, Jos in the plateau state in the north center was found to be far less vulnerable, with similar observation for Gembu in Sardauna Local Government Area in Taraba. Toungo, Ganye, Madagali, and Michika Local Government Areas of Adamawa State are also far less vulnerable to flood. This study also revealed that all the administrative states in the south-south geo-political zone and areas along Niger – Benue Syncline were observed to be highly vulnerable to flood while most of the administrative states in North East and North West are only prone to flood in the case of extreme rainfall events. This study recommends that a buffer dam should be constructed along the Benue River to absorb excessive water coming from any source. Also, dredging of River Niger and Benue's tributaries should be considered to accommodate a large volume of water, and adequate standard setbacks along all the rivers in Nigeria should be implemented to discourage erecting structures along the floodplain.

Keywords: Terrain Modeling, Morphology, GIS, Flooding and Spatial Query

Introduction

Flood in Nigeria affects buildings, human activities, infrastructure, and inhabitants across the country. The ongoing urbanization process in Nigeria, most especially the development of structures in the flood susceptible areas are opening up more areas to flood and consequently flood hazard. Flood incidences in Nigeria often result from high rainfall, river and ocean upsurge, the opening of dams and canal overflow, and topography which include high elevation (crest), slope, and depression. The rate of damage depends on the susceptibility of the affected people,

infrastructure, and facilities. Flood incidences have been on the rise particularly in the last 20 years, with significant growth in the number of lives and property lost (United Nations, 2011). Although flood severity in Nigeria generally cannot be compared to those in some developed countries, the aftermath of flooding in Nigeria can be severe and is now of great concern to Nigerians and a challenging issue for the Nigerian government (Egbinola et al., 2015). Flood events in the country have become typical and recurrent events, having devastating effects on human livelihoods and infrastructural development. Unfortunately, the effect is felt more in some areas than others which may be a result of geomorphological factors.

The present trend and future events of flooding demand precise spatiotemporal information on their potential risks and hazards, particularly in developing countries such as Nigeria. Spatial information about landforms is crucial, for instance, through studies of landscape evaluation and assessment of potential erosion, natural hazards, and risk prediction, as well as for regional planning landscapes. Terrain analysis includes topography studies such as elevation, slope, aspect, the pattern of groundwater flow, and the physical structure of landforms that possess greater advantages in determining areas that are naturally susceptible to flood (Butler, 2001). Terrain analysis in environmental assessments of the landscape was quite rare until the last decade, while terrain topography is a key indicator in a wide range of environmental processes (Bates et al., 1998; Butler, 2001).

Terrain analysis is a set of activities that leads to the compilation of terrain characteristics or terrain qualities (Townshend, 1981). Terrain analysis from the Digital Elevation Models (DEM) has become widely used in geomorphological research and landform classifications in recent years (Iwahashi and Pike, 2007).

Niyongabire et al, (2016) studied DEM for flood susceptibility mapping in the city of Bujumbura. A weighted overlay analysis was carried out to distinguish areas according to their susceptibility to flooding through DEM which was integrated with a Geographic Information System. While their methodology appears similar to that adopted in this study, this study recognized the importance of spatial quarries in ArcGIS. Ikusemoran et al (2014) studied flood disaster vulnerability assessment in Niger State, Nigeria. The terrain of Niger State was modeled and buffering operation was adopted to identify areas that are vulnerable to flood. However, their study is limited to Niger State and not nationwide. Similarly, Awodumi (2020) studied flood-vulnerable buildings along river Agboyi in Lagos State, Nigeria. Buffering and overlay operation was adopted to delineate buildings that contravened the standard setback along the river. However, the model adopted in his study will be hectic to model large study areas such as the entire landmass of Nigeria, it can only be used to model small study areas.

Several studies (Piloyan and Konecny, 2017; Klingseisen et al, 2007; Franklin, 1987; Niyongabire et al., 2016; Ikusemoran et al., 2014; Iwahashi and Pike, 2007) conducted to classify physical morphology characteristics have always adopted DEM extracted from Shuttle Radar Topographical Mission (SRTM) and none of these research based on the national level and utilized spatial query. This study contributes to existing knowledge on physical classification and delineation of morphological features in determining flood susceptible areas at a national level, by considering not only terrain modeling but also spatial queries in ArcGIS.

This study, therefore, aims at taking a terrain modeling and spatial query approach to identify administrative states in Nigeria that are naturally vulnerable to flood as a result of topographical factors. To accomplish this, geo - the morphometric parameter concept was adopted coupled

with GIS Approach. This addresses a problem of subjectivity in the delineation of landform units using traditional methods of photo-interpretation for applications such as geomorphologic parameters analysis (crest, slope, aspect, depression, and height).

Study Area

Nigeria is an Anglophone country located in sub – Sahara West Africa, bounded in the east by the Republic of Cameroon, west by Benin Republic, north by Niger Republic, and south by the Atlantic Ocean. Nigeria is one of the largest countries in Africa and has a landmass of 923,678 sqm lying within the tropics along the Gulf of Guinea on the coast of Africa, between the latitude of 4^{o} and 14^{o} north of the equator and 3^{o} and 15^{o} east of Prime Meridian. Nigeria is located within the tropics and has a tropical hot climate with the south experiencing warm and wet conditions. The northern part of the country most often experiences desertification due to hot, dry conditions in the Sahel (Iloeje, 1982).

The temperature in Nigeria varies according to its two seasons (dry and wet). The dry season which from October until April and the wet season begins in April most often in October. The average temperature in Nigeria falls between 23^{0}C and 31^{0}C. However, this temperature at the peak period can rise to 43^{0}C, especially in the northern part of the country, and drop to 5^{0}C in raining season. The average rainfall along the coast in the southern region varies from 18mm in the west to 43mm in certain parts of the East. And often drop to 5mm in the extreme northern part of the country which triggers flooding (Iloeje, 1982).

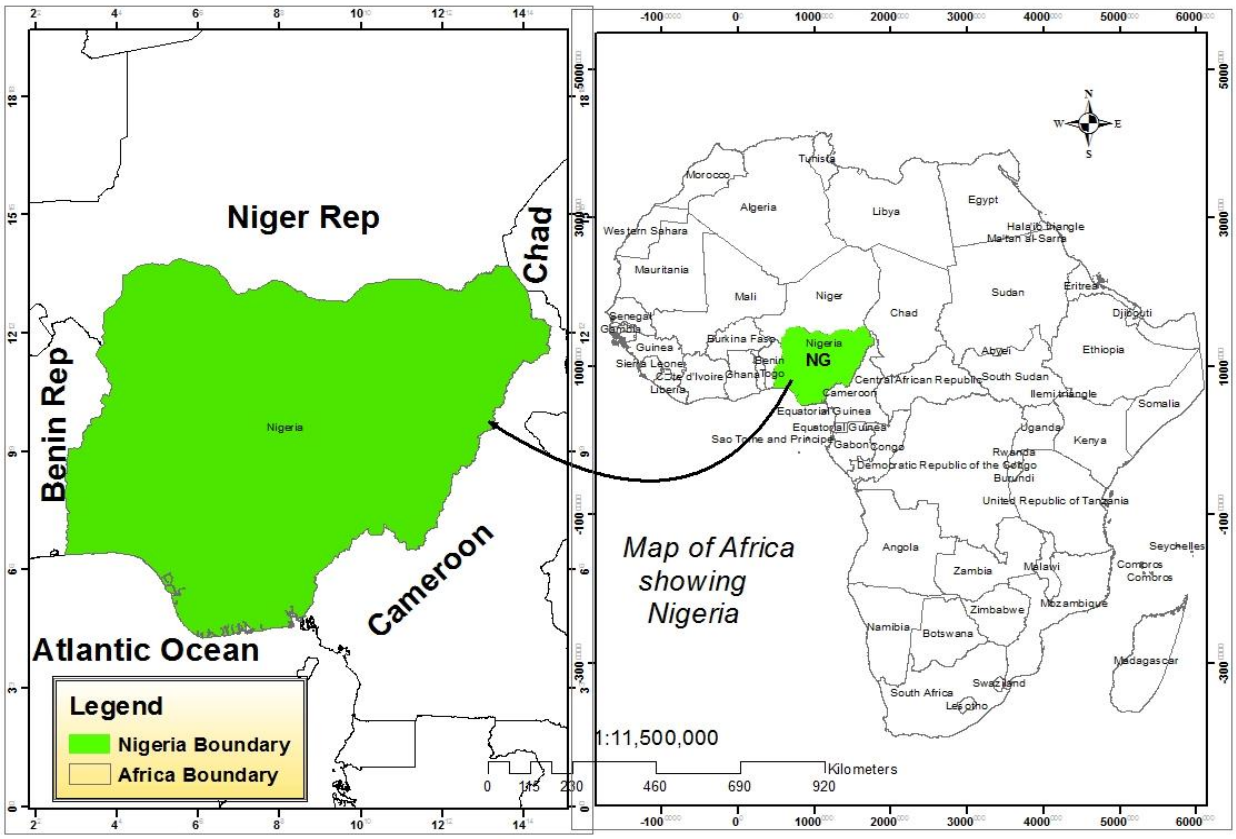

Figure 1: Map of the African continent indicating Nigeria

Recent Flood Incidences in Nigeria

The United Nations Office for the Coordination of Humanitarian Affairs estimates Nigeria as the most hit by a flood in Africa, with the number of people affected rising to over 3.2 million, including over 600 fatalities and over 1.4 million people displaced (UNOCHA, 2022). In 2020, floods affected 320 local government areas in 35 states including the Federal Capital Territory (FCT), displaced over 129,000 persons, 68 persons lost their lives, and farmlands and property were also destroyed. Moreover, over 100,000 people were directly affected by flash floods in Adamawa State of Nigeria, while around 600 people died, 1,546 were injured and over 100,000 persons were displaced by floods across Nigeria since the on–set of raining season in 2022. One of the major natural causes of flooding in Nigeria is river overflow and ocean surge. All the administrative states along Niger–Benue trough were affected by the recent opening of the Cameroonian Lagdo and excessive overflow of water from its channel. Similarly, administrative states along the Atlantic Ocean experienced a massive surge of water from the ocean. Shittu, (2022) argued that in 2012, Nigeria lost 2.6 trillion naira (USD 4,343,671.20) to flood disasters, 7 million people were displaced, 597,476 houses were damaged and 3636 were killed. He further expected the figure to increase by at least 45% in 2022. The government estimates that over 1.3 million people have been displaced and more than 200,000 homes were destroyed, expecting the flooding, which has affected 27 out of 36 states, to continue till–the rainy season. According to Lasisi (2022), the states' most hits are Anambra, Benue, Delta, Bayelsa, Kogi, Cross River, and River State.

Methods and Materials

Data Source and Conversion

This study utilizes mainly secondary data (remote sensing) from Shuttle Radar Topographical Mission (SRTM). Terrain modeling of Nigeria was developed through SRTM DEM which was overlaid on the administrative shapefile of Nigeria indicating the 36 states including the Federal Capital Territory. The study aims to determine morphological landform features that aid flash flood occurrences under certain causal factors such as highly extreme rainfall events and the opening of dams. To accomplish this, the idea of Skidmore (1990) on landform modeling was adopted.

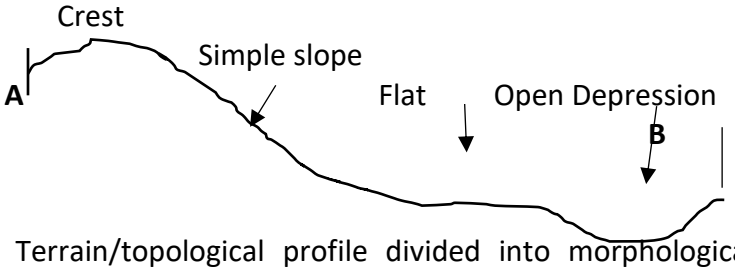

Figure 2: Terrain/topological profile divided into morphological landforms (adapted from Klingseisen et al., 2007).

As revealed in Figure 2, the crest (mountain range) comprises very elevated areas of a landscape, having positive plan and/or profile curvature (Speight, 1990). Open depression (lowland) is an area low in the landscape, having a negative plan and/or profile curvature, and extends at the same or lower elevation, Flats (relatively lowland) are defined as areas having a slope gradient smaller than 3% while simple slope (relatively high) is an adjacent below a crest or flat and

adjacent above a flat or depression (Speight, 1990). In the study area, crest, simple slope, and flat and open depression were determined and mapped. This allows the identification of areas that relatively receive more quantities of water input than the surrounding environment during rainfall season in general and flood events in a particular. These areas, likely to be affected by flooding, are located on depression surfaces and altitudes less than 217m above the sea. Also, Nigerian rainfall data was sourced from World Development Indicator (WDI) to show the trend of rainfall received in Nigeria over the years.

Cartographic Modeling

This is a geo - methodology for processing geo - data which builds the spatial data as a variable in spatial algebra. It is the process of linking or organizing basic analysis operations in a logical sequence such that the output from one is the input to the next. In this research, the cartographic model reveals the step-by-step procedures of a combination of declared data to the generation of the geomorphological parameters used to determine areas that are naturally susceptible to flood in Nigeria in sequential order as shown in figure 3.

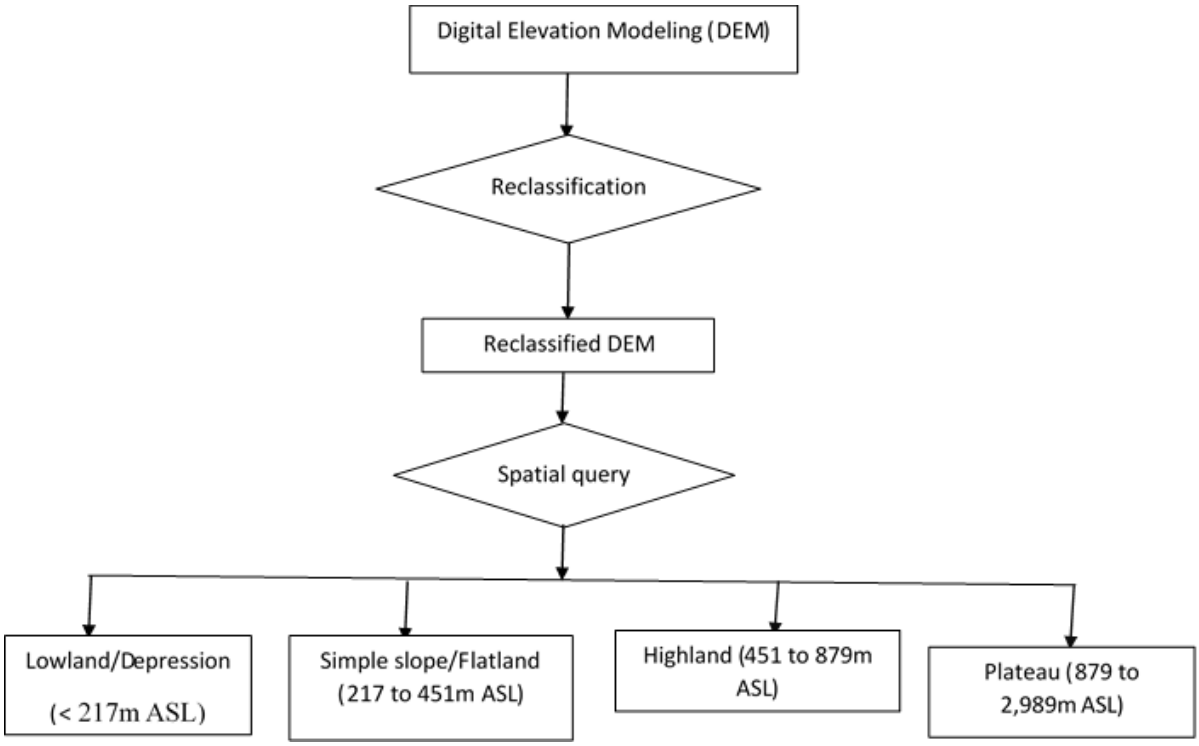

Figure 3: Cartographic Model

Spatial Analysis and Findings

The analytical power of GIS used in this study encircles the combination of spatial data, especially in a multi-criteria situation. Spatial queries adopted in this study include single criterion queries. The spatial queries include plateau/very high elevation/creep, highland, upland/relatively lowland, and depression/lowland. Crest/plateau/very high elevation is considered as an area free from flooding; simple slope/relatively highland as less susceptible; relatively lowland as susceptive and lowland as very susceptible to flood.

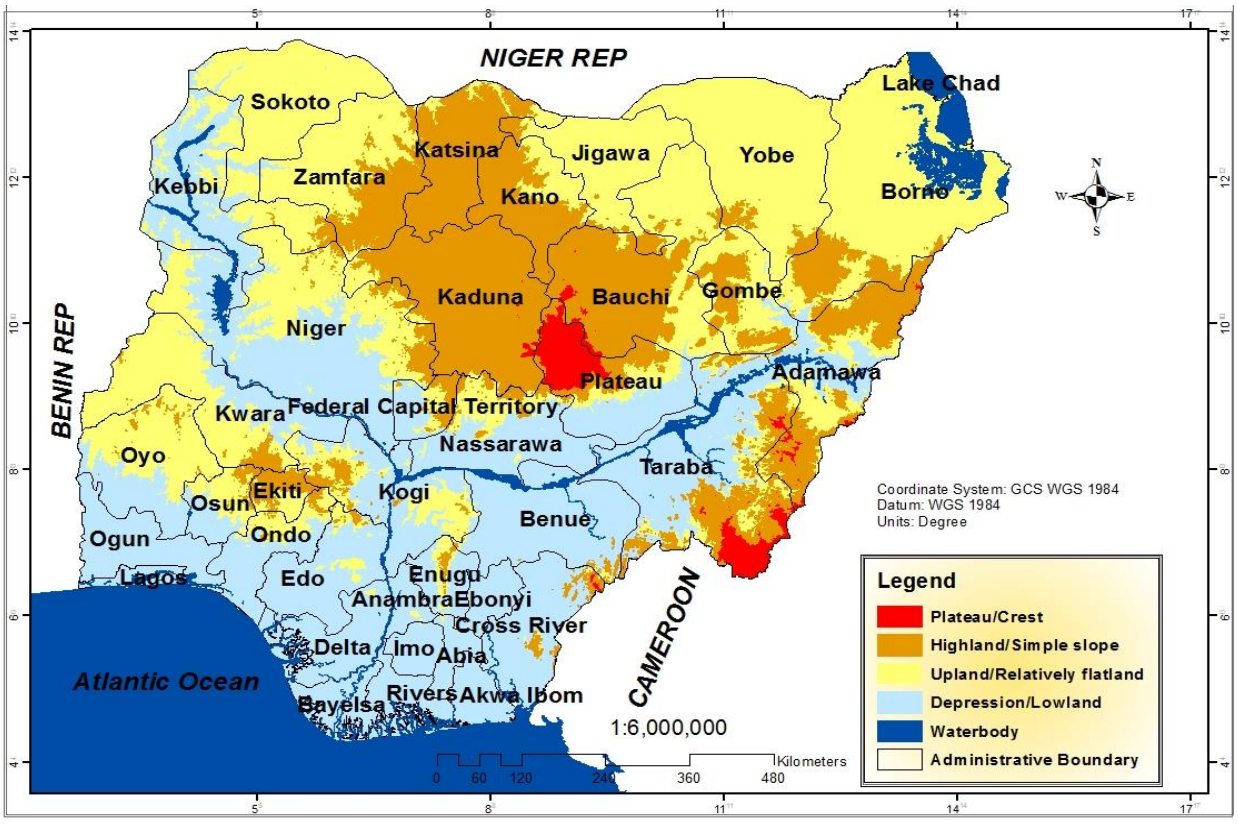

Figure 4: Map showing terrain modeling of Nigeria

Query expression 1

SELECT FROM Terrain modelling WHERE "Modeled Terrain" = 'Plateau/Very High Elevation'

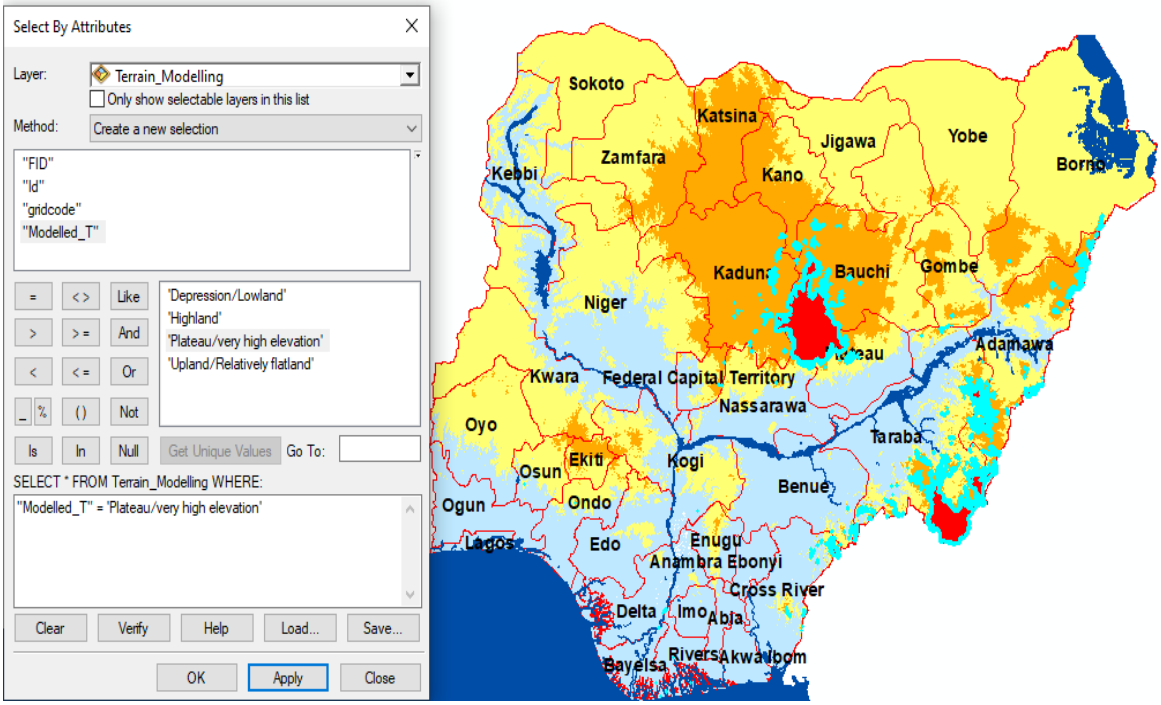

Figure 5: Query areas with plateau/extreme elevated/crest areas in Nigeria.

Figure 5 shows the query and result of states in Nigeria that possess highly elevated areas which are far less susceptible to flood. The query shows that Jos in the uppermost part of Plateau State is not in any way prone to flood, also some portions of Kaduna such as Kaura Local Government are less prone to flood. The southwestern part of Bauchi State, which has the extension of Jos Plateau, is also far less vulnerable to flood. Two local government areas (Akampa and Obanliku) in Cross River State in the South-South geo-political zone are far from flooding. The possession of Oban hill in the Akampa local government area and the Obudu cattle ranch plateau in the Obanliku local government area prevent the areas from flooding. At the extreme southeastern part of Taraba State, the Mambilla Plateau in the Gembu local government area prevents the surroundings from flooding. Also in the southern part of Adamawa State, Toungo and Ganye local government areas are far less prone to flooding due to extremely high elevation. Again, Madagali and Michika local government areas in the uppermost north of Adamawa State are very less vulnerable to flood as shown in Figure 5. These areas have elevation between 879m and 2,989m above sea level which prevent them from flooding.

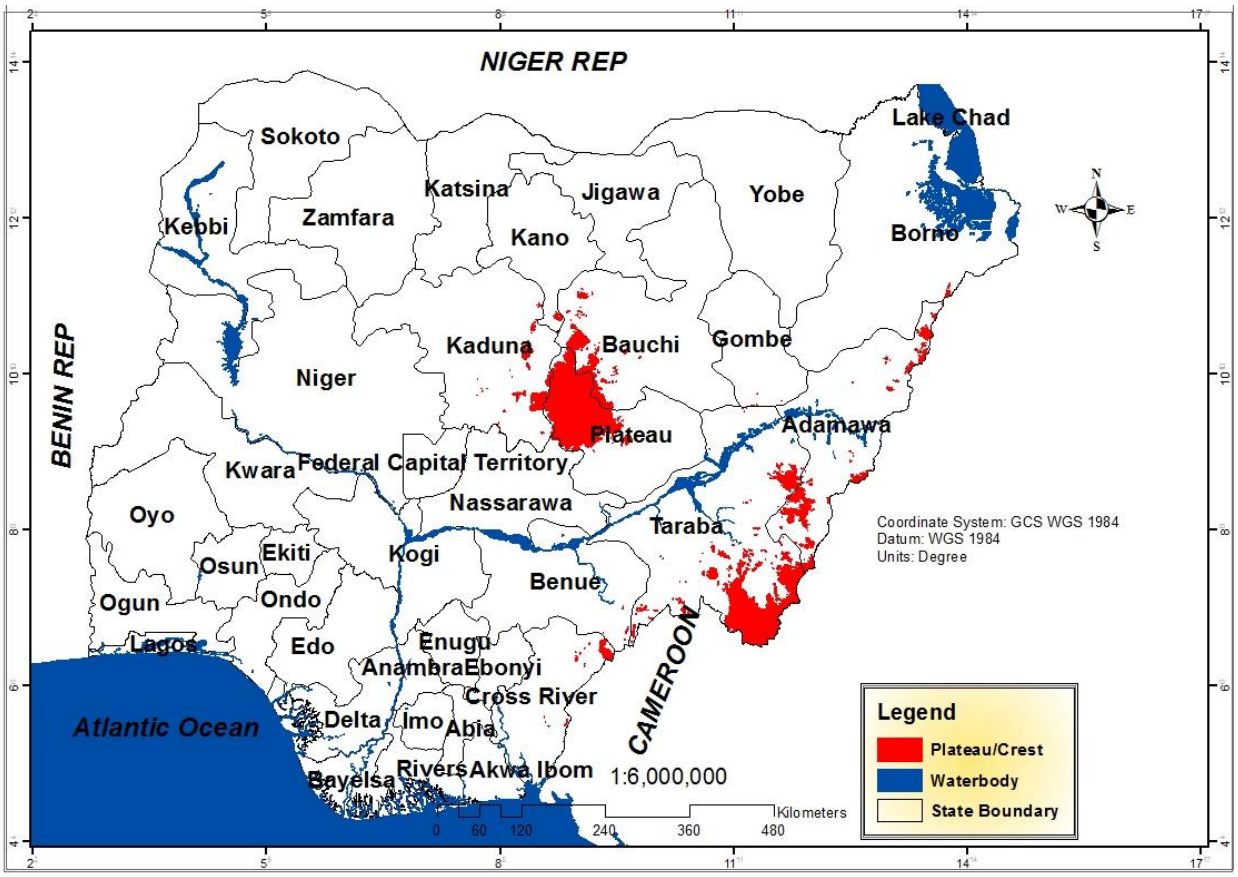

Figure 6: Result/Map showing states in Nigeria having elevation between 879m and 2,989m above the sea level (Plateau/Crest)

Figure 6 shows areas in Nigeria that are far less susceptible to flood. These areas include Jos in Plateau State, some portions of Adamawa, Taraba, and Cross River State which are collectively

called the great eastern highland, east of Kaduna, and southwest of Bauchi State. Due to elevation, these areas are very less vulnerable to flood.

Query Expression 2

SELECT FROM Terrain modeling WHERE "Modelled Terrain" = 'Highland'

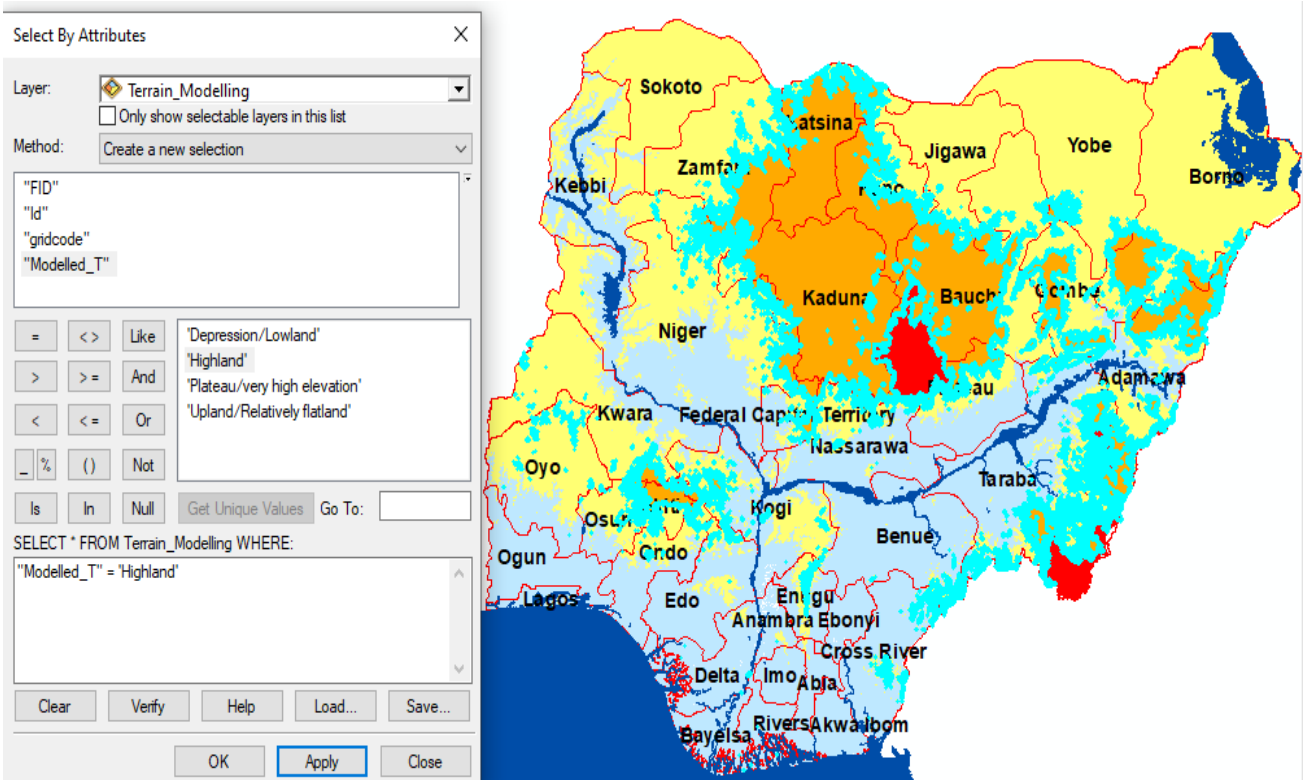

Figure 7: Query of areas with highlands in Nigeria

Figure 7 presents the administrative states in Nigeria that are situated in the highland. These areas are less prone to flood except in extreme precipitation cases. These areas have an elevation between 451m and 879m above sea level. These areas include the majority of Kano State, Katsina State, southeast of Zamfara State (Tsafe, Gusau, and Meru), Kaduna State, the majority of Bauchi State, the northern and southernmost part of Adamawa State, Borno south (Biu), Gombe center, and southeast of Taraba State. Others are north of Ekiti State (Moba, Ileje meje, Ido–Osi, Oye, Ikole, and Umuo), extreme north of Ondo State (Akoko North), Kwara State (Irepodun and Isin local government area), Cross River State (Obudu, Obanliku, and Akampa), Enugu (Udi local government), Kogi State (Kaba and Ijumu) and some tiny portion of Oyo north.

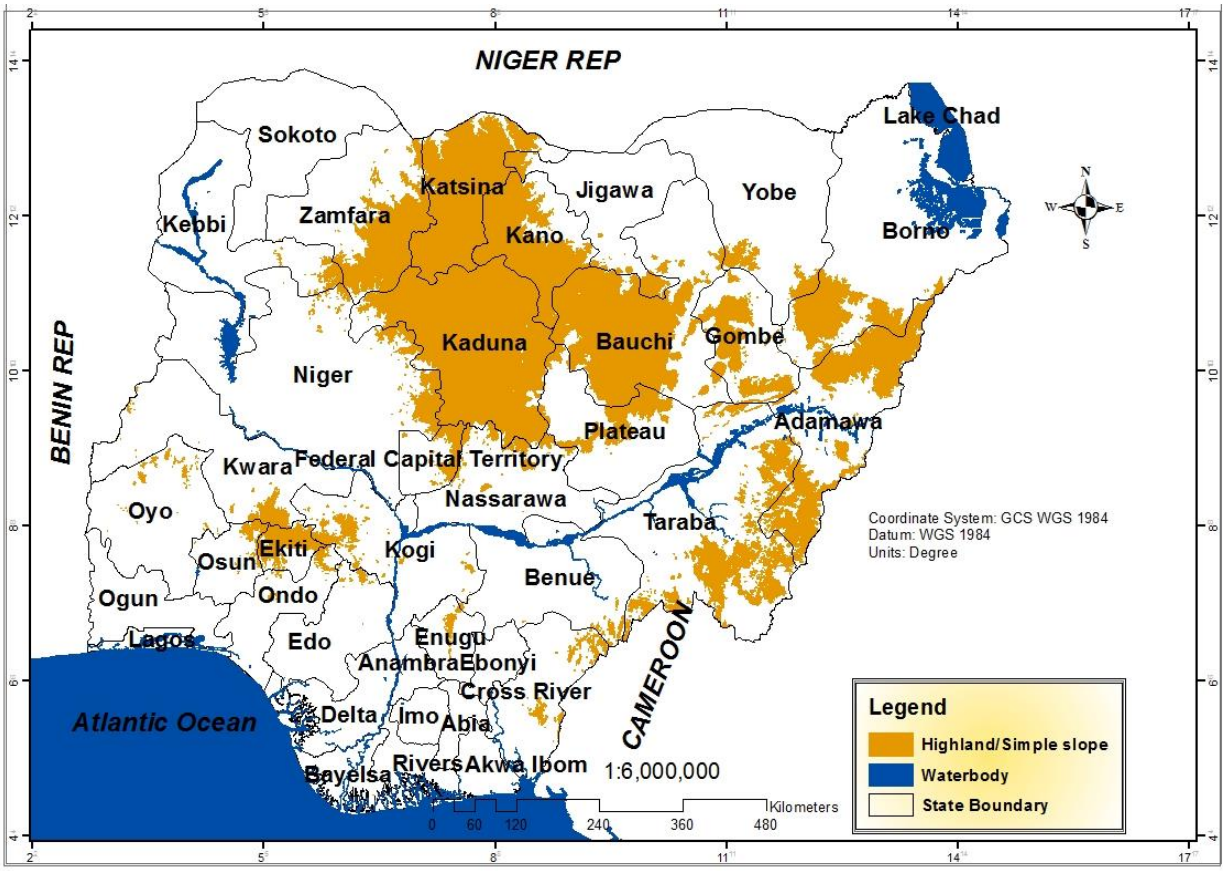

Figure 8: Result/ map of States having an elevation between 451m and 879m above sea level (highland/Simple slope)

Figure 8 shows administrative states that are only prone to flood as a result of heavy rainfall. These states include Kastina, the majority of Kano, Kaduna, Bauchi, Plateau center, majority of Gombe south of Borno, north and east of Federal Capital Territory, the eastern part of Taraba (Sadauna), Enugu center (Udi) and Eastern part of Zamfara, Adamawa north, and south, Cross river (Obanliku, Obudu, and Akampa), Ekiti, Ondo North and some portion of Oyo State.

Figure 9 presents the administrative states in Nigeria that are situated on relatively upland/flatland/simple slopes in Nigeria. These states have an elevation between 217m and 451m above sea level. In the southwest, these states include the majority of Oyo State, Osun State, Ekiti, and Ondo north. In the south-south, they include Edo State (Uhunna wonde, Akoko – Edo, and Owen East), Cross River State (Obudu, Obanliku, and Akampa), and the majority of Enugu State. For the north center, these include Kogi and Kwara States except the areas along the trough, Niger north, some portion of FCT and Nasarawa State (Karu, Akwanga, Kokoma, Wamba), some portion of Plateau, Taraba and Adamawa States except the areas along the Benue trough. In the northeastern geo-political zone, these states include Gombe, southeast of Bauchi, Borno, Yobe, and Jigawa. In North West, Sokoto, Zamfara, and Kebbi State are situated on relatively upland. These states, due to their elevation, are susceptible to flood in most extreme rainfall cases.

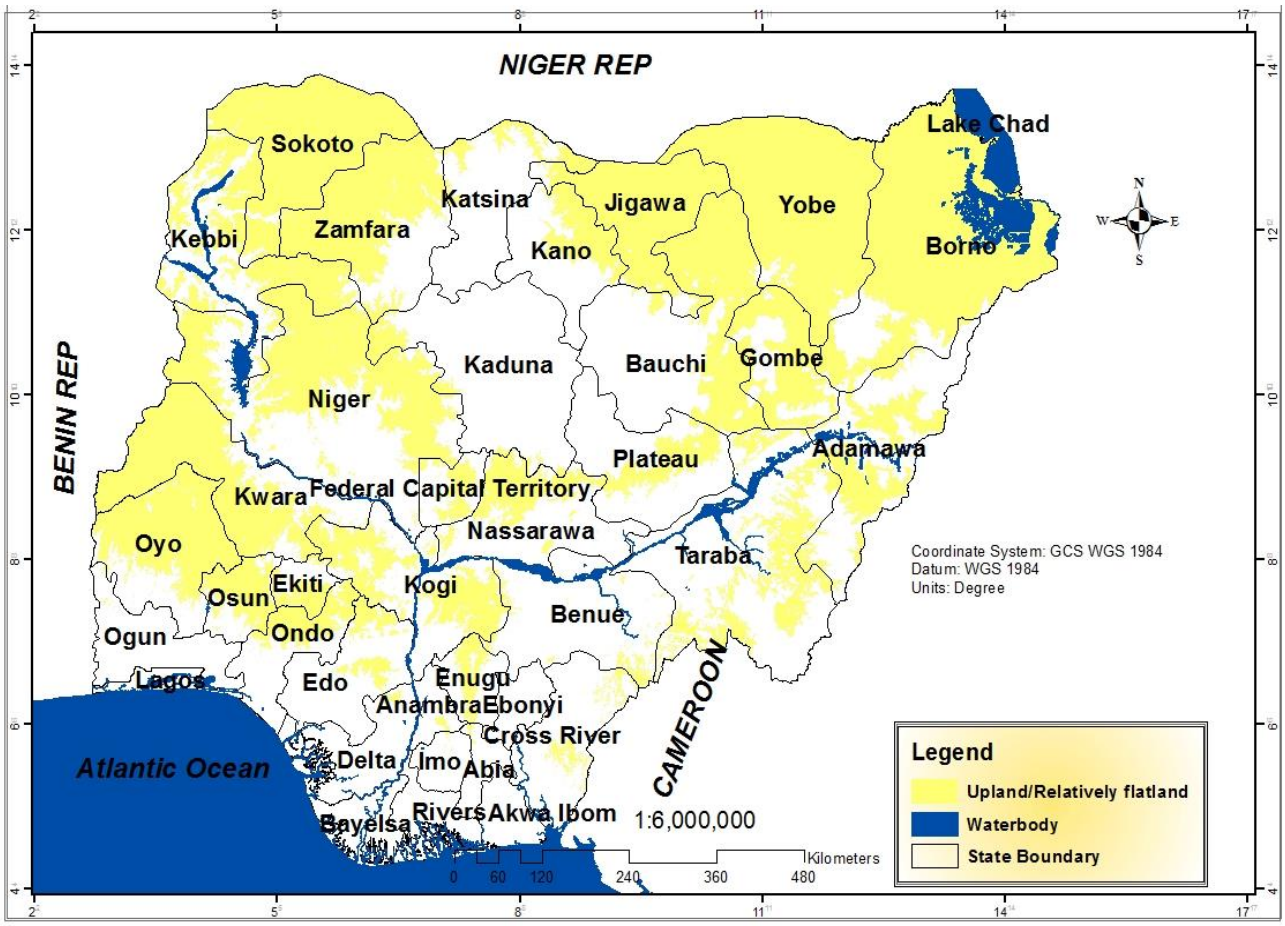

Figure 9: Result and map of administrative states in Nigeria situated on relatively flatland/upland/simple-slope

Figure 9 is the map presenting all the administrative states in Nigeria that are vulnerable to flood as a result of topographic factors. This shows that 4 administrative states in the southwest are vulnerable, 9 in the north center, 5 in the northeast, and 3 in the North West. These administrative states are vulnerable but not susceptible compare to the ones in figure 11

Query expression 3

SELECT FROM Terrain modeling WHERE "Modelled Terrain" = 'Depression/lowland'

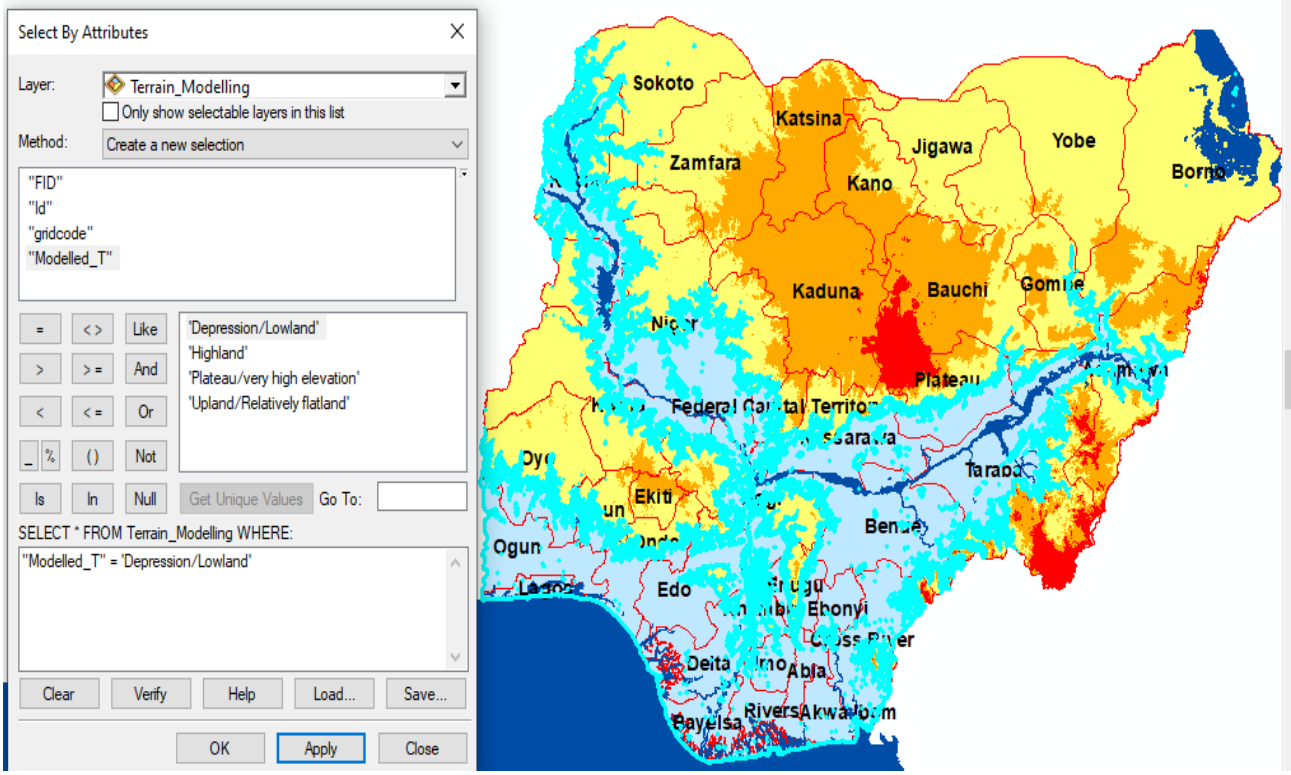

Figure 10: Query of depression/lowland areas in Nigeria

Figure 10 shows the query of administrative states in Nigeria that are situated on lowlands/depressions and are most often called a basin. These areas have an elevation of less than 217m above sea level and therefore most susceptible to flood. These states include all the states along the Niger–Benue syncline (Kebbi, Niger, Kwara, Kogi, Nasarawa, some portion of Federal Capital Territory, Benue, Taraba, Adamawa, Anambra, and Delta,). Also, states that are along and/or a few kilometers away from the Atlantic Ocean always experience ocean upsurges. They include Lagos, Bayelsa, Rivers, Ondo South, Akwa-Ibom, Delta, and Cross River States. Other States that are very vulnerable to flood in Niger–Benue basin includes Ogun, south of Oyo and Osun, Edo, Plateau south, Imo, Abia, and Ebonyi States. These administrative states, due to their elevation, are highly at risk of perennial flooding. These areas, therefore, being naturally prone to flood, require intensive mitigation, planning, and modern technology to alleviate flood incidences.

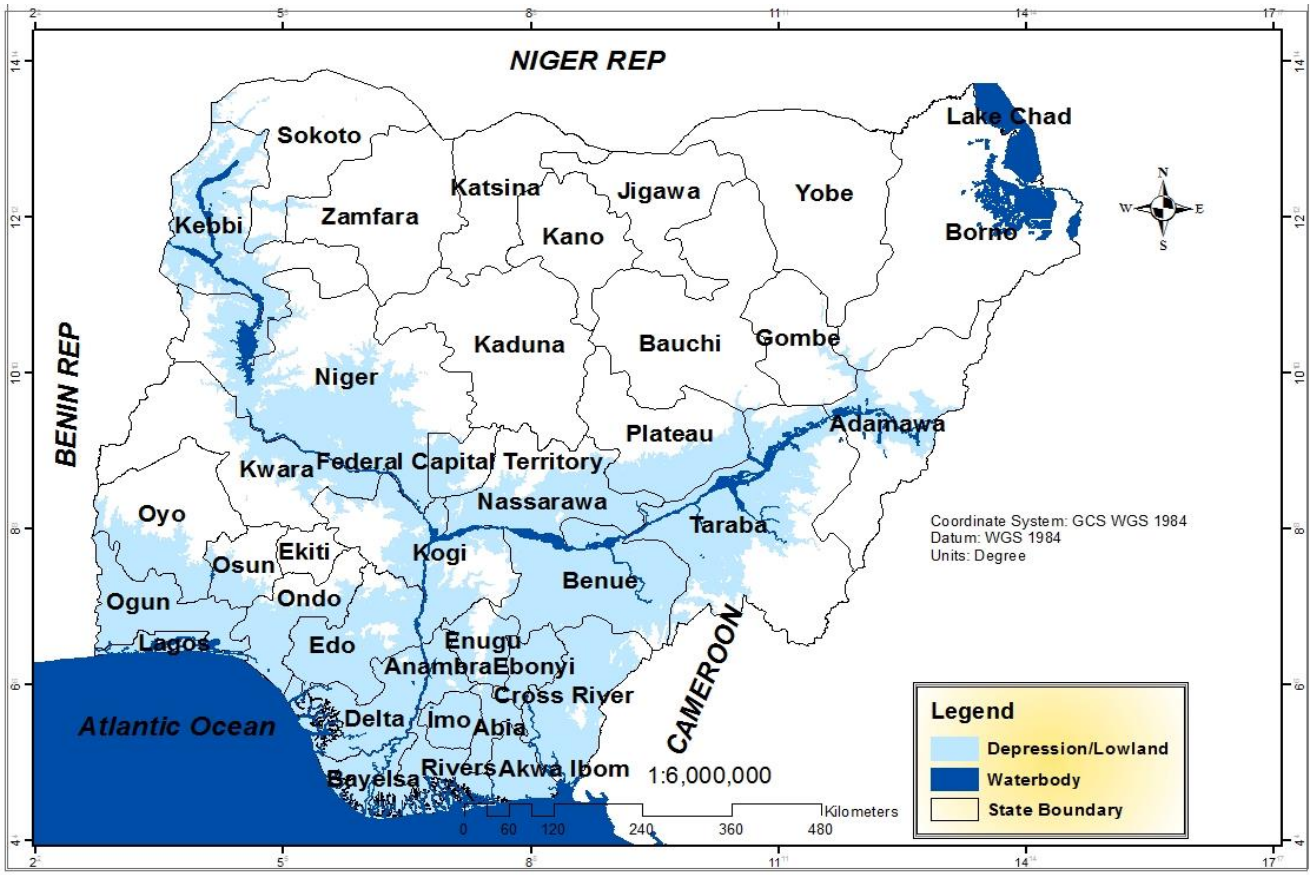

Figure 11: Map showing Administrative states situated on lowland/depression

Figure 11 is a map showing administrative states in Nigeria that are naturally most susceptible to flood considering topographic factors. This shows that 10 administrative states including the FCT in the north center, 5 states in the southwest, 6 states in the south-south, and 5 in the southeast of Nigeria are highly prone to flood.

Climatology of precipitation, Mean, Minimum, and Maximum Temperature of Nigeria (1991-2020)

Figure 9 present the variation of monthly precipitation and temperature received in Nigeria in the year between 1991 – 2020. This shows that for 29 years, monthly rainfall and temperature in Nigeria have not significantly changed in variation. Rainfall has always been at the peak in August and at minimum in January and December. The onset of raining season over the years is in March. Rainfall starts rising in March and drops to its lowest by December. Thus, the months of February-March being the on-set month should be months of flood preparation and mitigation planning. The temperature in Nigeria starts to rise in January and at its peak in April, and starts falling in May through September as a result of the intense of raining season. This rises in October due to falling in precipitation and drops again in November as a result of harmattan.

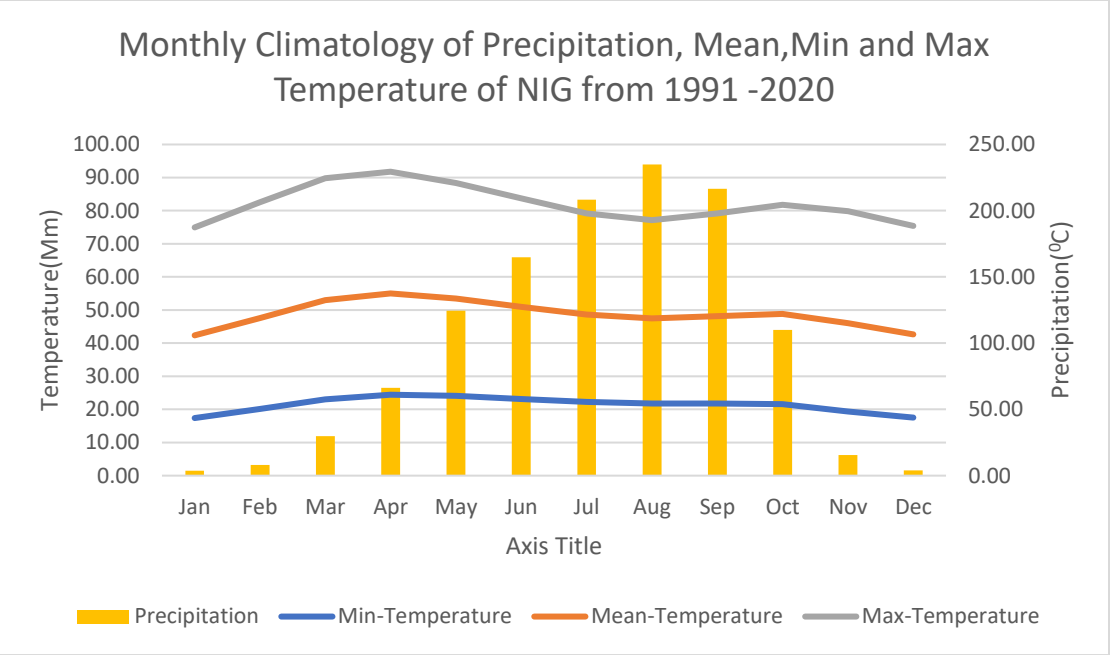

Figure 12: Climatology of precipitation, Mean, Minimum, and Maximum of Nigeria (1990 -2020)
Source: World Bank database (2022)

Conclusion and Recommendation

Flood in Nigeria has become a serious concern for not only the Nigerian Government but international bodies such as UN OCHA. Various parts of Nigeria have experienced flooding and the correlating loss of farmland, lives, and property. Despite the historical incidences, the recent case of flooding appears to be the worse Nigerians have experienced in decades. South-south geo-political zone most especially has been impacted by extreme rainfall, upsurges of water from the ocean coupled with the release of water from the Lagdo dam in Cameroon. However, the gravity of flooding differs across the administrative states in the country. While some are badly affected, others are either less or not affected. This study identifies areas that are most affected and vulnerable to flood and areas that are free from flooding. The study indicates Ekiti as the only state free from flooding in the southwest part of the country. Also, Udi local government area in Enugu State is the only portion of the southeast free from flooding.

This study recommends that the Nigerian government must be proactive by utilizing Geographical Information System (GIS) coupled with meteorological data to give early warning and proactive measures. Also, a buffer dam should be constructed along the Benue River to absorb excessive water coming from any source. This buffer dam is also a means of providing irrigation for farmers along the river. Dredging of River Niger and River Benue's tributaries should be considered to accommodate large volumes of water. Moreover, adequate planning and standard setback should be mandated to prevent people from erecting structures in the flood plains. Lastly, Green Infrastructure (GI) should be encouraged in the administrative states in Nigeria.

References

Awodumi, O. E. (2020): GIS Approach Delineation of Flood Vulnerable Buildings along River Agboyi, Nigeria. *British Journal of Environmental Sciences.* Vol.8, No 4, pp. 17 - 35

Bates, P. G., Anderson, M. G., Horrit, M. (1998): Terrain Information in Geomorphological models; stability, resolution, and sensitivity. In: Piloyan, Koneecny. M (Eds): semi-automated classification of landform elements in Armenia based on SRTM DEM using K – means Unsupervised classification. *Quaestiones Geographicae* 36(1). 2017.

Butler, D. (2001). Geomorphic process-disturbance corridors: a variation on a principle of landscape ecology. *Progress in Physical Geography* 25: 237–248. DOI: 10.1177/030913330102500204

Egbinola, C. N., Olaniran, H. D. and Amanambu, A. C. (2015): Flood Management in Cities of Developing Countries: the example of Ibadan, Nigeria. *Journal of flood risk management. DOI: 10111/jfr3.12157*

Ikesemoran, M., Kolawole, M., Adegoke, K. (2014): Terrain Analysis for Flood Disaster Vulnerability Assessment, A Case Study of Niger State, Nigeria. *American Journal of Geographic Information System. 2014, 3(3): 122 – 134.*

Iloeje, N. P. (1982): *A New Geography of Nigeria.* Fifth Edition. Longman Nigeria Plc.

Iwahashi, J., Pike, R. J. (2007): Automated Classification of Topography from DEMs by an Unsupervised nested – means algorithm and three-part geometric signature. Geomorphology 86, 409 – 440.

Khalid, I., and Maishman, E. (2022): *Nigeria floods*: Overwhelming disaster leaves more than 600 people dead. BBC News Abuja, 16th October 2022. https://www.bbc.co.uk/news/world-africa-63280518

Klingseisen, B., Metternicht, G., Paulus, G. (2007): Geomorphometric Landscape Analysis using semi – Automated GIS – Approach. Environmental Modelling and Software. 1 – 13

Lasisi, O. J. (2022): *Nigeria records the highest number of people affected by flood;* in United Nation Office for Coordination of Humanitarian Affairs, Business Day Newspaper, 24th October 2022

Niyongabire, E., Hassan, R., Elhassan, E., Mehdi, M. (2016): use of digital elevation model in a GIS for flood susceptibility mapping: a case of Bujumbura city.

Piloyan, A., and Konecny, M. (2017): Semi-Automated Classification of Landform Elements in Armenia based on SRTM DEM using K – means Unsupervised classification. *Quaestiones Geographicae 36(1).*

Shittu, J. (2022): *The real issues in Nigeria's recent floods*. Premium Times Newspaper, 0ctober, 2022

Skidmore, A. K. (1990): Terrain Position as Mapped from gridded digital elevation model. *International Journal of Geographic Information Systems*, 4, 33 – 49

Speight, J. G. (1990): Landform. In: Klingseisen. B. Metternicht. G. Paulus. G (Eds): Geomorphometric Landscape Analysis using semi – Automated GIS – Approach. *Environmental Modelling and Software*. 1 – 13.

Steven, E. F. (1987). Terrain Analysis from Digital Patterns in Geomorphometry and Landsat MSS Spectral Response. *Journal of Photogrammetric Engineering and Remote Sensing*. Vol; 53:1 pp: 59 - 65

This Days Newspaper. (2022). *Tackling the problem of flooding in Nigeria*. 4th November 2022

Townsend J. R. G. (1981). Terrain Analysis and Remote Sensing. George Allen and Unwin, London. In: Piloyan, Koneecny. M (Eds): semi-automated classification of landform elements in Armenia based on SRTM DEM using K – means Unsupervised classification. Quaestiones Geographicae 36(1). 2017.

United Nation – Water. (2011). *Cities coping with water uncertainties. Media brief*, UN-Water Decades Programme on Advocacy and communication

UNOCHA. (2022). NIGERIA Situation Report. United Nations Office for the Coordination of Humanitarian Affairs (Last updated: 1 Nov 2022), accessed on 18 Nov 2022 at https://reports.unocha.org/en/country/nigeria/

World Bank Data. (2020). https://climateknowledgeportal.worldbank.org/country/Nigeria/trends-variability-projections.