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Title; Modelling Flooding sites around River Niger area of Onitsha town Nigeria using Remote Sensing and GIS Application

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Abstract;

Increasing frequency and severity of flooding have caused tremendous damage in Onitsha area of Nigeria, requiring more efficient and effective way to reduce the risk and damage people face. In this study, the Digital Elevation Model (DEM) of the study area was used in consideration of terrain's influence on flooding of the town. The Compound Topographic Index (CTI) of the area was calculated to extract areas that represent wetness, which shows areas liable to flooding. The DEM was further queried to identify the part of the town that will be flooded whenever River Niger rises to 5 metres above the current level. The result shows that of the 1226610m^2 of the study area, flooding will inundate area approximately to 2400m^{2,} representing 0.47% of the DEM cells of the total study area. The slope map indegrees identified areas with more than 89^0 to be safe from flood inundation when the river rises and areas less than 89^0 to be areas liable to flooding. The analysis of this model shows that the proposed model can be a valuable tool that will guide city planners to avoid areas that are liable to flooding being used as residential or commercial purposes and for minimising damages from flooding.

Keywords: Flooding, River Niger, Remote Sensing, Geographic Information System and Digital Elevation Model.

Compliance with ethical standards statement

The study was done by me (Dr Sylvanus Iro) with no grant from any agent or foundation. This work was carried out as my way of contribution to incessant flood inundations in Onitsha and its environs under research standard of Imo State University, Owerri southern Nigeria

Introduction;

The growing urbanization and industrialization have given rise to increase in land devastation and degradation (Song et al. 2012), thereby demonstrating the city’s higher exposure to major risks, e.g. flood risk (Ashley et al. 2007). Equally, climate change will lead to a huge increase in frequency of several natural hazards (Dean et al. 2007). Cities should use new technology like GIS to model areas that are particularly vulnerable, future disasters and improve their resilience when facing such hazards. Virtually every Nigerian is vulnerable to disasters, natural or man-made. Every rainy season, wind gusts arising from tropical storms claim lives and property worth millions of naira across the country (Nwigwe and Emberga, 2014). Flash floods from torrential rains wash away thousands of hectares of farm land. Dam bursts are common following such flood. In August 1988 for instance, 142 people

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died, 18,000 houses were destroyed, and 14,000 farms were swept away. When the Baguada Dam collapsed following a large flood. Urban flooding such as the Ogunpa disaster which claimed over 200 lives and damaged property worth millions of naira in Ibadan, are common occurrence.

In 2012, more than two million Nigerians were forced from their homes by that year's floods, and 363 people were reported killed from the flooding (National Emergency Management Agency, 2012). It has been observed that this was the worst floods in five decades that have affected many areas of the country - especially near the River Niger Figure 1. The damage done by flood in the affected areas has been enormous. For instance, the entire Nzam, Aguleri Otu, Odekpe, Osomala, Osuche, Atani, Amii, Umuzu, Onitsha among other areas in Anambra state were submerged and properties worth millions of dollars in the four local government areas destroyed. Also, the Ogbaru Anglican Cathedral and the Catholic Church in Atani, the Divisional Police Station and the High Court and Magistrate Courts in the area, as well as secondary and primary schools were totally submerged by flooding (Nduka 2013).

Figure 1: Parts of Onitsha inundated by flooding in July 2012 (AllAfrica, 2012)

Flooding is a prominent feature around Onitsha, occasioned by frequent high intensity tropical rain storms which inevitably generate extremely high run-off that quickly exceeds the capacity of the urban storm water drainage system and coupled with rise of river Niger causing frequent flooding across Onitsha city, but especially in the low-lying valleys and wetland areas that are typical of the environment. Flooding impacts all socio-economic groups but those urban poor who are occupying the low-lying lands and wetlands are most vulnerable (Davidson et al. 1991). As Anambra state government and other city's environmental authorities experience great difficulty to manage the Onitsha physical development, there is need to identify areas that are vulnerable to flooding with GIS and Remote Sensing approach. This can guide the city planners on how to avoid allocating building construction and other construction activities on the mapped risk areas and help to relocate residents during bad weather.

Study Area

Onitsha is located between Lat. 06^0 38' 34''N and Log. 06^0 59' 30''E and Lat. 06^0 02' 56''N and Log. 06^0 37' 30''E. Onitsha is a city located on the eastern bank of the Niger River, in Nigeria's Anambra State Figure 2. A metropolitan city, Onitsha is known for its river port and as an economic hub for commerce, industry, and education. It hosts the Onitsha Main Market, the largest market in Africa in terms of geographical size and volume of goods. Onitsha lies at a major east-west crossing point of the Niger River and occupies the northernmost point of the river, regularly navigable by large vessels (Nwaogu 2017). These factors have historically made Onitsha a major centre for trade between the coastal regions and the north, as well as between eastern and western Nigeria. Onitsha possesses one of the very few road bridge crossings of the wide Niger River (Daily Sun, 2007) and plans are in place to add a second bridge near it. Today, Onitsha is a textbook example of the perils of urbanization without planning or public services. Rapid urbanization in recent years negatively affects natural vegetation and local landscape of Onitsha including flooding and soil erosion.

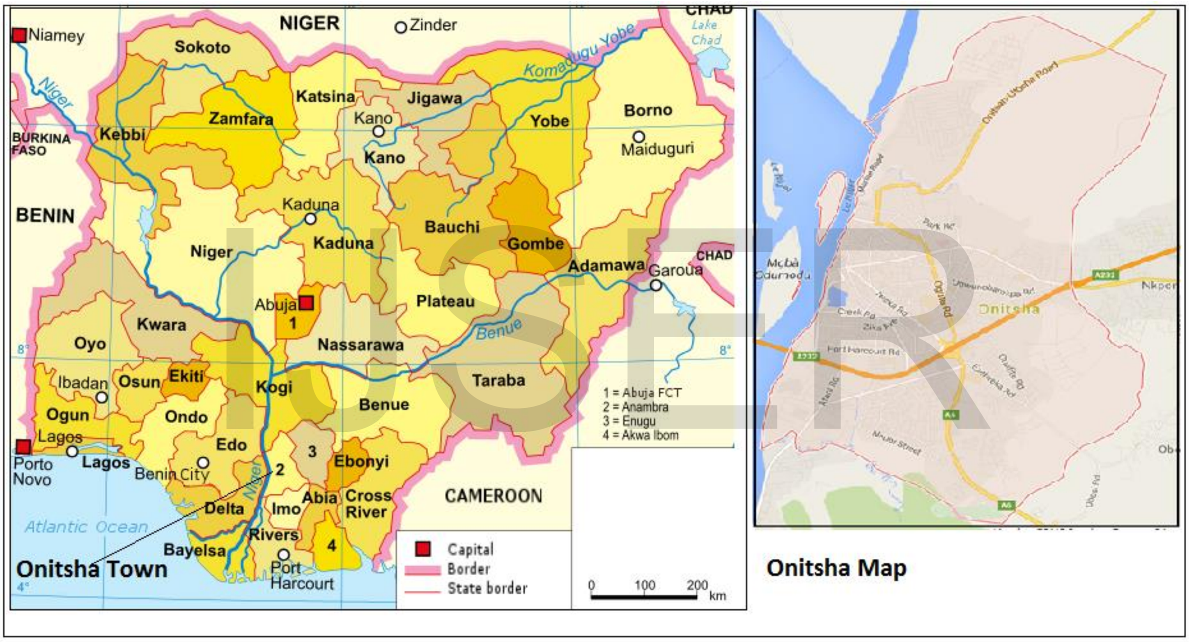

Figure 2: Nigeria map with the study area in context (Iloeje, 1998).

Onitsha and its environs lie in the north-western part of Anambra State, in SouthEastern Nigeria. The settlements covered by the study include: Onitsha, Obosi, Nkpor, Okpoko and Iyiowa Odekpe (Ezeomedo and Igbokwe 2013). The area is about 3,063 square kilometre and It serves as the gate way between the South-Eastern and South-Western part of Nigeria. The population figure of Onitsha Metropolis according to 2006 population census of Federal Republic of Nigeria is presented in about 7,425,000 people National Population Commission (2006). The metropolis since it is found about 1680, has been a centre of commercial activities, an ecclesiastical centre and an administrative centre Mozie, et al (2008).

Topography

The topography within 2 miles of Onitsha contains only modest variations in elevation, with a maximum elevation change of 466 feet and an average elevation above sea level of 184 feet (Ifeka and Akinbobola 2015). Within 10 miles contains only modest variations in elevation (794 feet). Within 50 miles contains significant variations in elevation (1,818 feet). The area within 2 miles of Onitsha is covered by artificial surfaces (31%), bare soil (20%), trees (16%), and water (16%), within 10 miles by cropland (26%) and shrubs (25%), and within 50 miles by cropland (36%) and shrubs (22%) (Ifeka and Akinbobola 2015).

Geology

Geologically, Onitsha and its neighbouring towns are situated within the vast sedimentary basin of the Niger-Benin trough of the upper middle Eocene strata known as the Bende Ameke group. Within this area, there are large areas of alluvium from the Quaternary Period (Ifeka and Akinbobola 2015). Topographically the planning area is traversed and drained mainly by the Niger River and its many tributaries, notably Anambra (which lends the state its name), Nkissi, and Idemili Rivers, all draining into the Niger. The Anambra River is the largest of all the tributaries of the Niger south of Lokoja, the confluence of Benue River with the Niger. The geology of the area is characterized by the Orlu cuesta, which terminates at the Niger River bank. This upland area, which varies between 150 and 240 metres in height, is dissected by several small streams draining into the Niger (UN-Habitat, 2012).

Climate

Onitsha and its neighbouring towns are located in the transition area between the sub-equatorial and the tropical hinterland climatic belts of Nigeria Figure 3. The climate here is influenced by two major trade winds: the warm moist south-west trade winds during the rainy season (April–October) and the north-east trade winds during the dry and dusty harmattan (November–March) (UN-Habitat, 2012).

Temperature

In Onitsha, temperatures are generally high, between 25 and 27 degrees Celsius, with maximum temperatures experienced in the December–March period and minimum temperatures in the June -September period.

Rainfall

Annual rainfall averages about 1,850 millimetres (74 inches) per annum, which is reasonably high. Most of the rain falls between mid-March and mid–November; rain in the dry season is infrequent.

Relative humidity

Relative humidity is generally high throughout the year, between 70 percent and 80 percent. The highest figures are experienced during the wet season and the lowest during the dry.

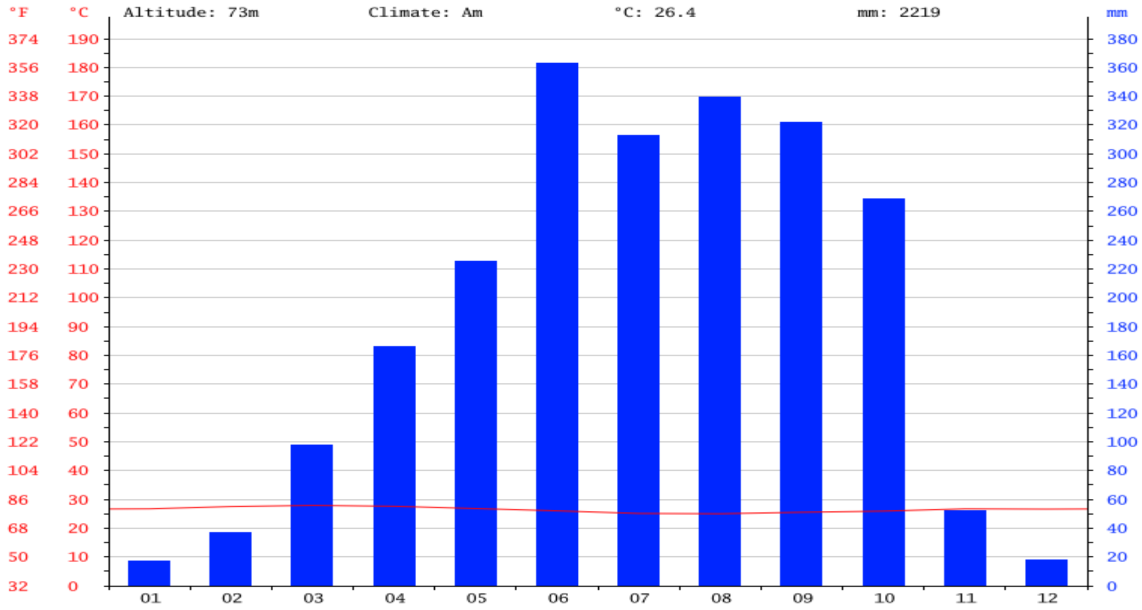

Figure 3: Climate Graph / Weather by Month of Onitsha Southeast Nigeria (Climate-Data.Org)

VEGETATION

The vegetation of the study area has changed to sub-climax from the original rainforest, having been virtually cleared due to development (Ezeomedo and Igbokwe 2013). The vegetation of this region is light forest interspersed with tall grasses. The trees are not too tall and include both hardwood and softwood varieties; domesticated trees such as the mango, palm tree, guava, orange, and almond are found. Much of the natural vegetation has been felled and the land utilized for development., August is the coldest month of the year and Mean annual Rainfall is between 1,500mm to 2,500mm.

SOILS

Around Onitsha and on the banks of the Niger River is a wide plain of alluvium. There are also sandy and loamy soils around Nkpor and Ogidi.

The Effects of Natural Climatic Factors on Urban Design and Living

The factors of climate, geology, and vegetation influence the lifestyle of the community and how they build their cities and houses. For example, the two prominent trade winds the northeast and southwest tread winds influence the orientation and the design of buildings. A long span of buildings is oriented in a south-westerly and north-easterly direction. This is to reduce the effect of intense warmth from the south-west and cold from the north-east (UN-Habitat, 2012). The cropping season starts in March immediately the rains sets in, and the traditional new year begins at the end of the harvesting period (October/November). The porous nature of the soil dictates special consideration for foundation and landscape design and nature conservation. Onitsha's high temperatures are a great asset for promoting outdoor recreational pursuits and tourism. Nigeria Hydrological Services Agency (NIHSA) has issued an alert warning Nigerians of imminent increased flooding, in September 2019 (Premium Times, 2019). This was disclosed by the director-general NIHSA, Clement Nze, during a press briefing in Abuja. The agency also accused state governments of failing to heed its previous warnings on floods released earlier this year. It, however, urged state governments to pull down structures built on flood plains. NIHSA is the agency responsible for issuing flood alerts in Nigeria. The Abubakar Tafawa Balewa University (ATBU) issued a notice for students to vacate the campus after a flood disaster killed four students on campus. A pedestrian bridge which collapsed and killed four of the students of the institution and left many others injured. It was reported that no fewer than 74 Local Government Areas (LGA) in 30 states including local governments in Onitsha and its environs in Nigeria would experience severe flooding in June, July, August, and September 2019, according to the hydrological agency (Premium Times 2019). Another 279 local government areas in Nigeria would experience minimum flooding across the country in the period, it added. Recently, a director at the FCT high court in Abuja got missing after a flood submerged his vehicle (Premium Times 2019). The incident occurred last week at a bridge along Galadimawa roundabout in Abuja. This is the second flood within the area in a month. On October 4, 2018, the National Emergency Management Agency (NEMA) declared 12 states along the River Niger and Benue as worst affected by flood disaster, while other states were being monitored. Nigeria's climate has witnessed significant spatial and temporal changes with extreme weather and climate conditions with ocean surges and floods becoming more regular, according to the Nigeria Meteorological Agency (NiMet). These shifts come with several socio-economic impacts on agriculture, hydrology, construction, education and health. Nigeria has faced flooding in recent years, with hundreds killed and thousands displaced especially around Onitsha and its environs.

Literature Review

Flood is a body of water which rises to overflow land not normally covered with water. This environmental problem is as a result of numerous causes of which the most important results from climatic effect of rainfall (Okorie, 2010). Flooding is one of the most environmental hazards ravaging different parts of south-eastern states, Nigeria (Duru and Chibo, 2014). The high volume of storm water during rainy season, as well as release of water from various dams can result in severe damage to properties and force several people to evacuate the flooded areas, in the process rendering some people homeless. Most floods caused by precipitation are made serious by various conditions. Among these conditions includes but not limited to; the characteristic features of the basin i.e. basin geology, soil nature and characteristics, topography, plant cover and land use; the drainage network characteristics, i.e. whether it is graded, plain, or gorges or valley. Globally, flooding is one of the recent environmental problems experienced in most part of the globe. In Europe, after 3 years of flooding in Eastern Europe, year 2000 saw a switch to major flooding in western and northern Europe and United Kingdom (Arokoyu et al 2004). According to them, April 2000 started a wet year in England with a total of 143 mm falling over combined England-Wales region. As a result of the intensity, (WMO, 2003), observed that about 80,000 lives were lost and properties worth over 10 million US dollars were damaged annually. In Africa, the second half of 1996 was relatively a time for flooding. In August 1996, heavy in Awash River Basin of Ethiopia caused widespread flooding, affecting about 30,000 people (Duru and Chibo, 2014). Flooding as an environmental problem has taken place in different parts of the globe. In Nigeria, West Africa, the September 2012 flood episode is regarded as the largest and most ravaging flood, which caused a lot of destruction in the affected areas. Peru in South America experienced devastating flood in 1998, a situation consistent with the effect of warm El Nino southern oscillation (ENSO) phase. Hazards linked with flooding can be divided into three – primary, secondary and tertiary hazards. Primary hazards result due to direct contact with floodwater, whereas secondary hazards result because of the flooding. Secondary hazards associated with flood include disruption of services, health and nutritional problems such as hunger and disease. Tertiary hazards result from changes in the position of river channels. Throughout the last century globally, flooding has been rated as one of the costliest disasters in terms of both damages to properties and human casualties. For instance, in China, major floods killed about 2 million people in 1887, about 4 million people were killed in 1931, and over 1 million lives were lost in 1938. The 1993 flood event on the upper Mississippi River and Midwest lead to the death of 47 people, though the U.S. Army Corps of Engineers put the estimated total economic loss at between 15 and 20 billion dollars (Nelson, 2015). Floods can be such devastating disasters that it can impact negatively almost to anyone, any time. As demonstrated in the water cycle, when water falls on the surface of the earth, a lot of things happen to it and the water must find its route through somewhere. Two main approaches can be taken to predict flood, thereby reducing the risk associated with flood. They are, statistical studies which can be undertaken to determine the probability and frequency of high discharges of water that cause flooding. Second approach involves flood modelling and mapping to determine the extent of possible flooding when it occurs in the future. Since it has been determined that the main causes of flooding are abnormal amounts of rainfall and sudden thawing of snow or ice, storms and snow levels can be monitored to provide short-term flood prediction.

The uncontrolled growth of urban areas in terms of population and area coverage have become a very crucial issue stressing town planners all over the world because of the escalating problems of urban congestion, poor housing, crowded transportation, lack of basic services, ill health, flood inundation, low educational status and high unemployment. The complication is increased due to poor urban planning and uncontrolled land use, lack of financial resources and inadequate investment in environmental management is leading to the increase urban area coverage causing more impact on the environment (Ishaya et al, 2008). This is becoming a glaring issue in Western Africa and Nigeria in particular (UNCHS, 1996; Fekede, 2002). Thematic Committee (2001) opines that in Nigeria the growth and complexity of human settlements and the process of urbanization has been phenomenal. 1950, the percentage of the total Nigerian population living in urban centres was less than 15 per cent; by 1975, this proportion had risen to some 23.4 per cent. By year 2000, the proportion had gone up to more than 43.5 per cent and it is been projected to be more than 50 per cent by the year 2025 (Ishaya et al. 2008). The growth in urban and populations leads to various population pressures, climatic variability, and fragmentation of tenure and traditional systems, contribute to degradation of soil and vegetation, diminishing yields, people inhabiting areas liable to flooding and worsening food insecurity in rural areas mostly at the fringe of the rapidly growing urban settlements due to the conversion of arable land built environment to incorporate growing residential and industrial estates (Vernon, 2002; UN-Habitat, 2003; Ifatimehin and Ufuah, 2007). According to Iro et. al, 2011, this as a result has helped in flood inundation and destructions in various cities in Nigeria.

Methodology;

DEM represents land elevation data Figure 4, which are crucial for mapping vulnerable areas liable to flooding and other land surface information. The maps were derived by the processing of a 30-meter resolution digital elevation model (DEM) from USGS of the study area. This was done to extract areas liable to flooding whenever river Niger rises above its bank again.

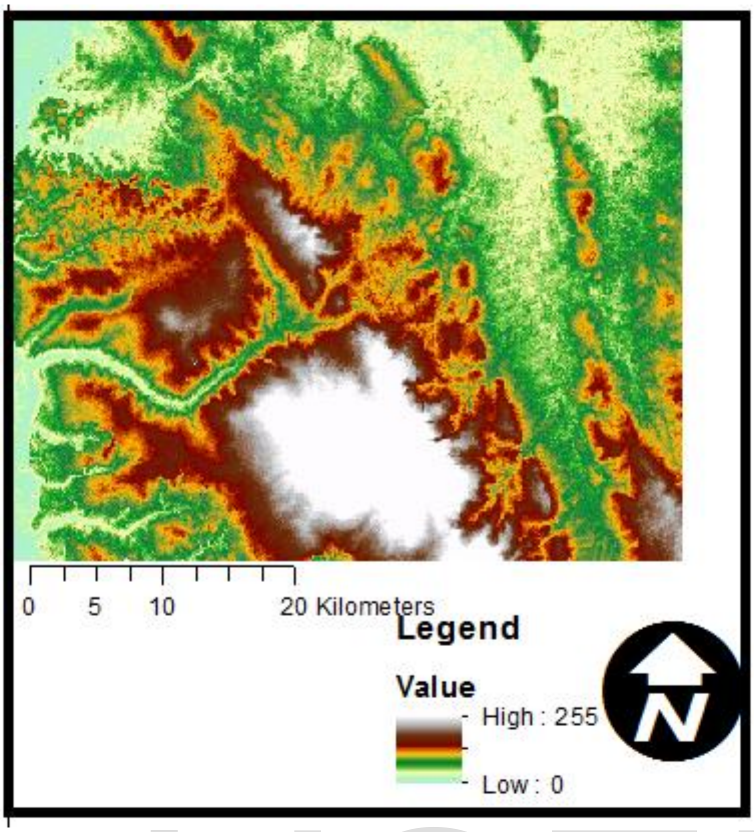

Figure 4: Onitsha DEM

The CTI also called Topographic Wetness Index (TWI) is a steady-state wetness index. In some areas, CTI has been used to predict flood as can be found in Minnesota River Basin Flood Mapping and Impact Assessment (Mekeel 2011) and Mapping of flash flood potential areas in the Western Cape South Africa (Bangira 2013). The value for each cell in the output raster (the CTI raster) is the value in a flow accumulation raster for corresponding DEM. Higher CTI values represent drainage depressions and lower values represent higher area like crests and ridges.

The slope map of the study area was derived from DEM and was used with the Digital Elevation Map of the area to derive the Compound Topographic Index map. This was done by calculating the Log of flow Accumulation added by a factor of 0.001 to avoid zeros (in Flow Accumulation DEM) divided by the slope divided by 100 because the slope is in percent rise added by a factor of 0.001 to avoid zeros (in slope DEM). Ln(flowacc_DEM+0.001)/((slope_DEM/100) +0.001).

The DEM of the study area was further queried to identify what part of the town that will be flooded when the level of the river Niger rises to 5 meters above the current river level. Therefore, identifying cells that will be under water, that is ≤ =5metres and anything below zero will be flooded.

A reclassified flood area map of Onitsha showing areas that fall into the criteria 1 are areas liable to flooding under the condition prescribed. A slope map of Onitsha was processed again in degrees and superimposed on the geographical map of Onitsha to find out if indeed it will identify those part of the town that will be flooded when the level of the river Niger rises to 5 meters above the current river level.

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Results;

Number of cells that contain the value 1 is 568427 (count).

Size of the cell = 0.0003×0.0003= 0.0009

Therefore, 568472×0.0009= 511 cells will be flooded

The total area of the study = 1226610m^2

Total area covered by flood will be total area/flooded area of the study =1226610/511= 2400m^2.

2400m^2 will be the total area that will be flooded if the river rises again to 5meters in Onitsha town.

Therefore, the percentage coverage will be 0.47% cells of the study area will be flooded.

The processed slope map of the study area in degrees also identified those part of the town that will be flooded when the level of the river Niger rises to 5 meters above the current river level, thereby corroborating the result obtained from the CTI calculation.

Discussion

The results obtained from the model reveal that most of the area is generally a flat area from the CTI calculation Figure 5. This means that the whole area is vulnerable to flooding.

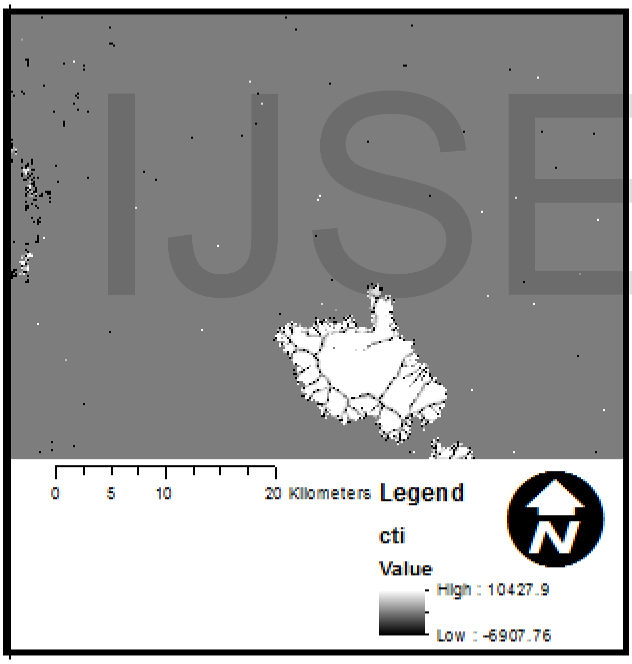

Figure 5: Compound Topographic Index of the study area

The high values indicate wetness, showing that there is fairly flat land.

From the reclassified flood map Figure 6, 2400m^2 will be the total area that will be flooded if the river rises again to 5meters in Onitsha town, which represents 0.47% of the total area. The area that will be submerged under this scenario include Anambra east, Atani road, Creek Road, port Harcourt Road and Nnobi Street, parts of Ogbaru, Iyiowa and Odikpa axis of the town. This research work has corroborated the works of Abdou et al. 2017; that used this approach to delineate land subject to flash flooding before they can approve residential development in the town of Inverloch, Victoria, Australia, also, Pourali et al. 2019 maintained that through the application of spatially distributed models, this approach can be used as an alternative to the traditional approach of delineating flood-prone areas using contours alone.

The topography of Onitsha is a moderately flat area, most of it under 350 meters. At the same time, the river network is becoming weak having travelled all the way from Futa Djallon in Guinea. The entire study area with a topography that is flat, when Cameroun Republic at the eastern boarder of Nigeria tried to discharge its Dam through the river Benue, the area gets flooded easily. River Benue is a tributary to River Niger and the two rivers met in Lokoja in central Nigeria

The results indicate that identifying areas likely to flood will reduce the negative impact of flooding in Onitsha town. It is of note here that some of the areas listed above where inundated by flooding during the year 2012 flood in the town.

Figure 6: A Reclassified flood area map of Onitsha

The slope gradient is one of the most important factors affecting flooding (Qing-quan et al. 2001). Also emphasises the importance of slope by showing that the identified flood sites are mostly located at areas that are flat. Figure 7 below reveals that the identified areas like Atani road, Creek Road, port Harcourt Road and Nnobi Street, parts of Ogbaru, Iyiowa and Odikpa axis of the town are located on areas with slope between 0^0 to 89^0. The slope map identified areas with more than 89^0 to be safe from flood inundation when the river rises and areas less than 89^0 to be areas liable to flooding. All the areas liable to flooding identified by Figure 7 The Slope map of Onitsha in degrees superimposed on geographical map of Onitsha collaborates with Figure 6 the reclassified flood area map of Onitsha.

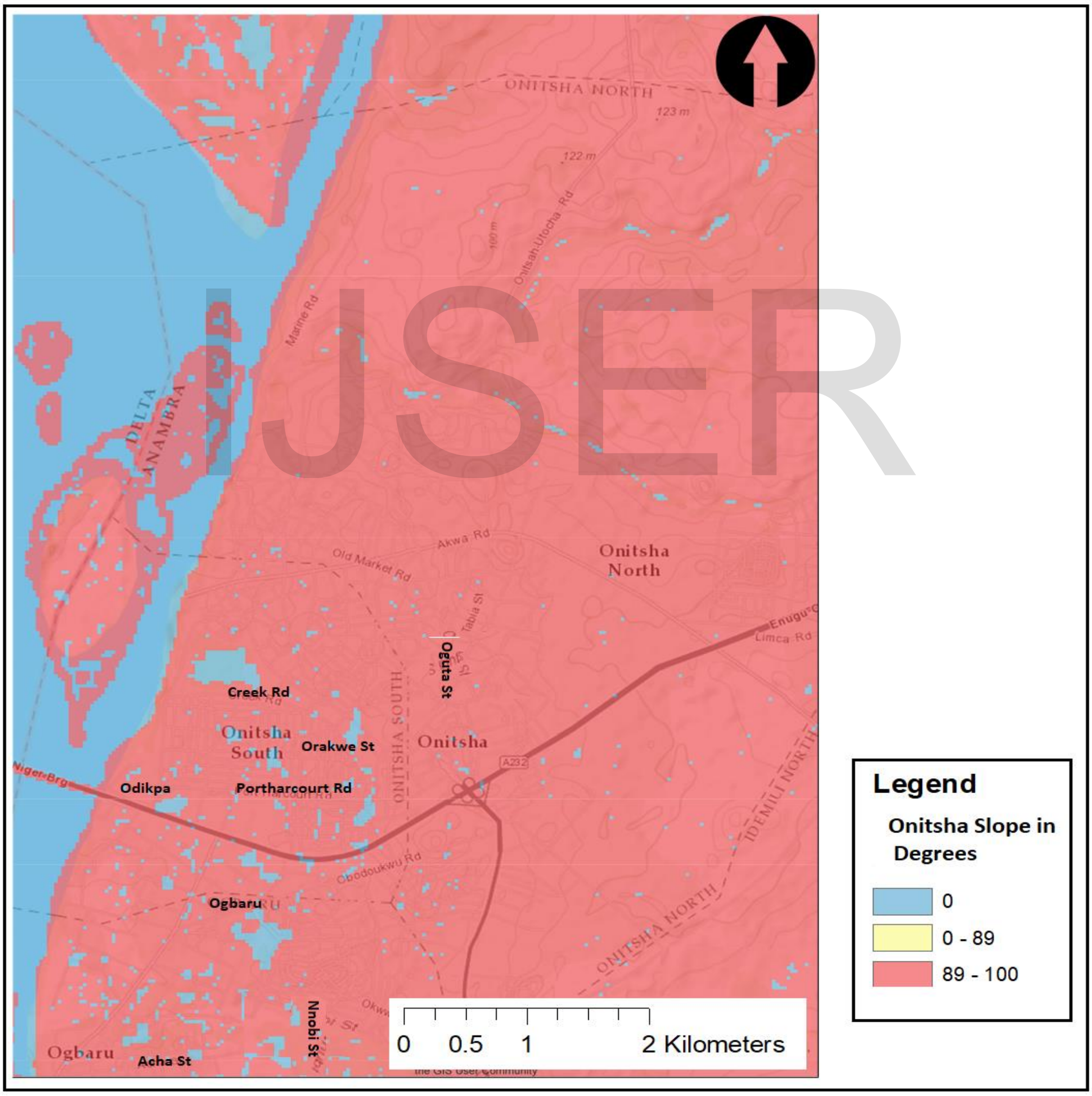

Figure: 7 The Slope map of Onitsha in degrees superimposed on geographical map of Onitsha

Conclusion;

The model presented is a simple and useful tool in finding solutions to prevent flooding, minimise flood disasters and to equip city planners on a better way of planning. Equally, Environmental planners can provide a means of redirecting the excess water flow from the river and design a better way of even dredging the river to reduce its negative impact on the residents. The model equally has identified some towns that can be threatened by flooding on the study area, these are Anambra east, Atani road, Creek Road, port Harcourt Road and Nnobi Street, parts of Ogbaru, Iyiowa and Odikpa axis of the town. This will go a long way in informing the residents and city planners on how to avoid these areas especially when climatologists/meteorologists predict high rainfall for the year. There should be measures that can control and redirect the water flow from the actual location of the risk areas. Also, this investigation can be used to support a case for tackling the actual problems at its source to prevent vulnerable areas downstream from flooding.

Availability of data and materials: The data was derived by the processing of a 30-meter resolution digital elevation model (DEM) from USGS of the study area (Onitsha southeast Nigeria)

Competing interests: I, S. I Iro states that there are no competing interests in this manuscript

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Authors' contributions: S. I Iro, acquired, pre-processed and processed the data used in developing and writing this research work

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References:

Abdou B, G Mohammed, A. El Battay, M. Rouai. 2017. Detection of Areas Associated with Flash Floods and Erosion Caused by Rainfall Storm Using Topographic Attributes, Hydrologic Indices, and GIS, In book: Global Changes and Natural Disaster Management: Geo-information Technologies, Chapter: 13 Publisher: Springer International Publishing AG 2017 Editors: S. Pirasteh and J. Li

Arokyu, S.B.and Weli, V.E. “Global Environmental Problems in Arokoyu, S.B. et al. 2004. Perspectives on World Issues and Problems” Porthacourt, Nigeria. Amethyst and Colleagues Publishers.

Ashley R, J Blansky, J Chapman, J Zhoun. 2007. Towards Integrated Approaches to Reduce Flooding Risk in Urban Areas. Pennine Water Group, Environmental Agency, Bristol UK.

Bangira T. 2013. Mapping of flash flood potential areas in the Western Cape South Africa. Faculty of Geo-Information science and Earth Observation, University of Twente. (Analysis of Terrain model) https://www.youtube.com/watch?v=IXmgLGCsC0A

Bangira, T. 2013. Mapping of Flash Flood Potential Areas in The Western Cape (South Africa) Using Remote Sensing and in Situ Data. Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in Geo-information Science and Earth Observation. Specialization: Water Resources and Environment Management

Davidson N.C., Laffoley D, Doody J.P., Way L.S., Gordon J., Key R., Drake C.M., Pienkowski M.W., Mitchell R.M., Duff K.L. 1991. Nature conservation and

Dean K, Gehbauer S, M. Mueller. 2007. Balanced Scorecard for Natural Disaster Management Projects. Disaster Prevention and Management 16(5):785-806. Jan.

Duru, P.N and Chibo, C.N. 2014. "Flooding in Imo State Nigeria: The Socioeconomic estuaries in Great Britain. Nature Conservancy Council, Peterborough, UK. 422pp

Ezeomedo I. and J. Igbokwe. 2013. Mapping and Analysis of Land Use and Land Cover for a Sustainable Development Using High Resolution Satellite Images and GIS. Environment for Sustainability, Abuja, Nigeria, 6 – 10 May

Fekede, W., 2002. Deficits in Urban land management and informal responses under rapid urban growth, an international perspective. Habitat International, 24(2): 127-150

Implication for sustainable Development" in Humanities and Social Science letters, 2 (3):129 -140

Iro S. I; Duru P N and Mbano E (2011) "Application of Geographic Information System in Mapping Otamiri River Watershed in Owerri Imo State", Published at International Journal of Geographical Information Science, Volume 25, Number 7, (July 2011), pp.461-471.

Ishaya S., O.O. Ifatimehin, and C. Okafor. 2008. Remote Sensing and GIS Applications in Urban Expansion and Loss of Vegetation Cover in Kaduna Town, Northern Nigeria; American-Eurasian Journal of Sustainable Agriculture, 2(2): 117-124,

Mekeel W.J. 2011. Minnesota River Basin Flood Mapping and Impact Assessment. Dissertations, And Other Capstone Projects, Minnesota State University - Mankato

National Emergency Management Agency.2013. Nigeria Post-Disaster Needs Assessment 2012 Floods. A report by The Federal Government of Nigeria With Technical Support from the World Bank, EU, UN, and Other Partners.

Nduka, E.K (2013). Openness and Economic Growth in Nigeria. Journal of Education and Practice, Vol. 4, No.1. PP. 68-73.

Nwaogu, C, O. J Okeke, Onyedikachi, O. O Fadipe, K. A Bashiru and P. Vilém. 2017. "Is Nigeria losing its natural vegetation and landscape? Assessing the land use-landcover change trajectories and effects in Onitsha using remote sensing and GIS". Open Geosciences. 9 (1): 707–718. doi:10.1515/geo-2017-0053.

Nwigwe C and T. T Emberga. 2014. An Assesment of causes and effects of flood in Nigeria; Standard Scientific Research and Essays Vol 2 (7): 307-315, July

Okorie, F.C. 2010. "Great Ogberuru in its Contemporary Geography". Owerri, Nigeria. Cape Publishers,

Pourali S.H, C Arrowsmith, N. R. Chrisman, D. P Mitchell. 2016. Topography Wetness Index Application in Flood-Risk-Based Land Use Planning, Applied Spatial Analysis and Policy, 9(1)

Premium Times. 2019. Nigeria to experience more flood next month – NIHSA. August 8th. https://www.premiumtimesng.com/news/headlines/345634-nigeria-to-experience-more-flood-next-month-nihsa.html

Qing-quan L, L Chen and J. Li. 2001. Influences of Slope Gradient on Soil Erosion. Applied Mathematics and Mechanics., Vol. 22, Issue 5, pp 510–519, May

Song, H., J.F. Thisse and X. Zhu, 2012. Urbanization and/or rural industrialization in China. Regional Sci. Urban Econ., 42: 126-134.

The Daily Sun. 2007. "The second Niger Bridge". -02-20. Retrieved-04-06.

Thematic Committee. 2001. Sustainable Urban Development and Good Governance in Nigeria – Istanbul

UNCHS-United Nations Center for Human Settlements, 1996. An urbanizing World: World Global Report on Human Settlements. Oxford University Press, New York

UN-Habitat, 2003. The Challenge of Slums. Global Report on Human Settlements 2000. Earthscan, London:

United Nations Human Settlements Programme (UN-Habitat). 2012. http://www.unhabitat.org

Vernon, H., 2002. Urbanization in Developing Countries; The World Bank Research Observer, 17(1): 89-112

Willy J. Mekeel. 2011. Minnesota River Basin Flood Mapping and Impact Assessment (Minnesota State University, Mankato Cornerstone: A Collection of Scholarly and Creative Works for Minnesota State University, Mankato)

WMO. 2003. “The Global Climate System Review June 1996 – December 2001”. World Climate Data on Monitoring Data. WMO No. 950,