Geo-Mapping of Areas Vulnerable to Ala-River Basin Flood Disaster Risk in Akure, Ondo State, Nigeria

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ABSTRACT

Flood is identified as one of the major disasters in the world; it destroys both human and properties across the world, where lives are lost, properties, public infrastructure, farmlands and agricultural produce with farm crops carted away as a result of flood disaster. Studies revealed that the flood in itself is not the danger, but the level of human vulnerability to flooding disaster risk, which enhances its destructive capabilities. However, based on the challenges poses by flood disaster risk, this research identifies Ala river in Akure as a potential cause of flood, considering its location and other human activities around the river. Therefore, the research used Ala-river a case study to identify and mapped out areas susceptible to flood disaster risk. The research made use of both literature review and conducted goe-data gathering with the application GIS-computer database to retrieve georeferencing relevant data from the fieldwork in the study area of Ala-river basin to mapped out locations vulnerable to achieve the research aim. The research adopted a Geo-mapping of the vulnerable area to Ala-River basin using arc-GIS tool in combination with other software such as IKONAS and OLI (Operation Land Imager) for the production of the study area imagery, ER-ITERIM was used for the collection of rainfall data and FAO was applied for digital soil mapping. These applications produced; the land use/land cover map, digital elevation map, buffer map using 30 meters setback, annual rainfall map, soil types map, vulnerability map and soil textural table for the study area. Analysis of the produced and generated maps shows 316 buildings vulnerability to flood disaster risk; the soil texture and types, and alternative use to which the soil types can be useful. The research recommends that demolition of the identified 316 buildings prone to flood disaster and compliance of building construction to 30 meters setback by developers. Others are the conversion of the future land setback for urban agricultural purposes and preservation of water retention areas for agricultural activities during the dry season among others. The study concludes that relevant government agencies in the State and in particular in Akure South Local Government should ensure prompt compliance and implementation of the recommendations to avoid potential flood disaster risks.

Keywords: *Flood Disaster Risk; Vulnerability to Flood Disaster Risk; Arc-Geographical Information System (ArcGIS); Geo-Mapping.*

Introduction and Background

A flood could either be caused by man-made activities or natural processes. In many instances, it inflicts major hardships on the human environment, with its attendant consequences of loss of human lives, personal properties/public infrastructure and farm produce, or outright destruction of human society. Also, as cities and towns grow and swell in outward form to accommodate the growing population, this expansion and population growth alters the natural landscape, land uses and land cover process, hence made human being and their activities susceptible to potential disasters. Although, many reasons are said to be responsible for flooding, some of which are; climate related-change, length and regularity of rainfall, topography, the extent of land cover areas, and the permeability nature of the soil are the identified physical factors that make a city or town to be susceptible to flood disaster risk (Thakur et al., 2011). Many reasons are responsible for flooding; climate change, rainfall intensity, duration and frequency, topography, the degree of land cover, and nature of soils are some of the physical factors that predisposed a city or town to flood disaster risk (Thakur et al., 2011). There exist different types of flooding, some of which are; flash flooding, coastal flooding, urban flooding, dam burst levee flooding, river flooding and dam-spill flooding.

However, concerning flood disaster risk, the changing natural watercourse or flow as a result of urbanization tends to increase land area not inability to absorb rainwater and "impermeability" thereby vulnerable to flood hazard (Satterthwaite, 2011). The implication of this assertion is that city growth and urbanisation processes with increased built infrastructure without apparent vulnerability to flooding disaster mapping is a recipe for disaster. These increased growth and infrastructural construction especially in developing countries alter the natural flow of floodwater, hence complicates the processes of floodwater evacuation from the cities. In an urban centre, as the population of the city intensifies, modest flood storms could increase in river flows since there are more concrete surfaces in the city (Action Aid, 2006). Similarly, studies revealed that urban areas are vulnerable to increased risk of flash flooding because of numerous of large impermeable surfaces couple with an ineffective weak drainage system (Ajin et al., 2013; Chen et al., 2009; Huong and Pathirana, 2013; Sowmya et al., 2015).

Studies showed that urban floods in cities of developing nations result from drains blockage, inefficient storm sewerage system and its occurrences are most characteristic of all-natural disasters in the cities, with its consequential effects on huge losses both in terms of human social disruptions and infrastructural damages. (Vanneuville et al., 2011; Abhas et al., 2012). Additionally, research showed that flood impacts more lives negatively than any other type of natural disasters, with increase records of flood disaster being recorded across the world (Tsakiris, 2014; McCallum et al., 2016). Some studies focused on the implications of increasing urban population growth, resulting in urban expansion and increased densities exacerbate flood risk and reduce the resilience of cities' inhabitants to flood disaster risks (World Bank, 2008). Based on these perspectives of academic discussion, flood on its own does not constitute dangers, but the exposure to ***risk*** associated with flood makes people, properties, farm produce vulnerable to this disaster.

The flood in itself becomes a ***disaster*** if lives or people are exposed to associated risks, which potentially put humans in harms' way and vulnerable positions. Disaster is seen as an intense variation in the usual functioning of a human environment as a result of unsafe physical events intermingling with unsafe conditions causing unimaginable adverse effects on the environment, which often necessitate urgent interventions and responses to reduce losses (Lavell et al., 2012*).* Understanding exposure and vulnerability to flood disaster can, therefore, be measured by a range of elements at flood risk (Thieken et al., 2012). Disaster often than not are sometimes considered as external shocks *however, disaster risk is the impacts generated during the interface of process that produced the circumstances of exposure, vulnerability, and hazard acting together to generate the intensity and severity and occurrence of hazard, while the numbers of lives and properties exposed to these vulnerabilities increases the extent of the disaster* (Cardona et al., 2012; UNISDR, 2015). Therefore, ***flood disaster risk*** as explained in terms of risk to human society and environment is considered a product of the severity and probability of occurrence of flood disaster and the vulnerability of (human population) system to such adverse effects of flood-related hazards, and vulnerability to potential consequences on the people and the environment (Brooks, 2003; Milet, 1990; Merz et al., 2007; FWMA, 2010). The probability that floods of absolute magnitude and losses will arise in a given time is directly dependent on exposure, and vulnerability to such flood disaster risk (Thieken et al., 2006; Cardona et al., 2012).

 doi:10.20944/preprints201911.0184.v1

The concept of **vulnerability** as referred to in disaster risk include, characteristics of individual, group, community and other conditions that enhance their ability to expect, become resilience and resistance, and able to recover from likely adverse impacts of the disastrous physical situation(s), coupled with the tendency or disposition to be negatively impacted by the disaster (Wisner et al., 2004; Lavell, et al., 2012). People, element, or group of persons and environment can be vulnerable to disaster risk as a result of their socioeconomic background, location (topography, terrain) of the accommodation, political lineage or ideology, or cultural (ethnicity, race) background, institutional, natural resources, and environmental conditions and processes.

In most cases, this group of people who suffers these deprivations would tend to be vulnerable to disaster risk. Although, the analysis of vulnerability in its social context, identifies the significance of how the social-political process too can generate vulnerability and caused disaster (Cutter, 1996; Hilhorst and Bakof, 2004; Pelling, 1999). This socio-political process can be linked with locations, types of building or the economic status of the vulnerable groups living in the floodplain areas, slums, informal or squatter settlements. People in this group(s) and locations are prone to flood disaster risk, hence increases their vulnerability. This **vulnerability to flooding risk disaster**, therefore, indicates the inability of communities, persons or a group of people or elements to cope with certain conditions, such as (socioeconomic conditions, physical conditions, and environmental conditions), which ultimately makes such system to be susceptible to the damaging and destructive impacts of flood disaster risk.

Therefore, after an extensive review of literature in vulnerability to flooding risk discourse, this research concentrates its focus on river flooding with a particular focus on Ala-River as the case study for assessment. The research is carried out to identify and map the areas around and along the river basin that are prone to flood disaster risk. To help achieve the set objectives, the deployment of GIS and relevant software in identifying these vulnerable areas to produce vulnerability map and other related maps that can help stakeholders in reducing the levels of the community, people and individuals to potential flood disaster risk in the study area.

Study Area

The study area is Ala river basin, located in Akure , the city is located between latitude 7^0 57’ 34” N and longitude 8^0 45’ 39” E, while Ala river basin location is between 5^0 9’ E, 7^0 17’ N and 5^0 17’ E, 7^0 16’ N. The Ala river basin is located in Akure city under the administration of Akure South Local Government Area of Ondo State Nigeria. Acres has a tropical climate with significant rainfall, most months, although, with the short dry season, the climate is considered to be Am according to the Koppen-Geiger climate classification, with an average annual temperature of 26.70C, while the average rainfall is 2378mm (Climate-Data, 2018). Ala river is recognized as one of the tributaries of river Ogbese, while Ala river traversed an average total length of about 57km, but with a total length of about 14.8km within Akure township, the river took its source from the northwestern part of Akure city and flows towards the southeastern part of the city through Oba-Ile to Edo State (Ayeni et al., 2011).

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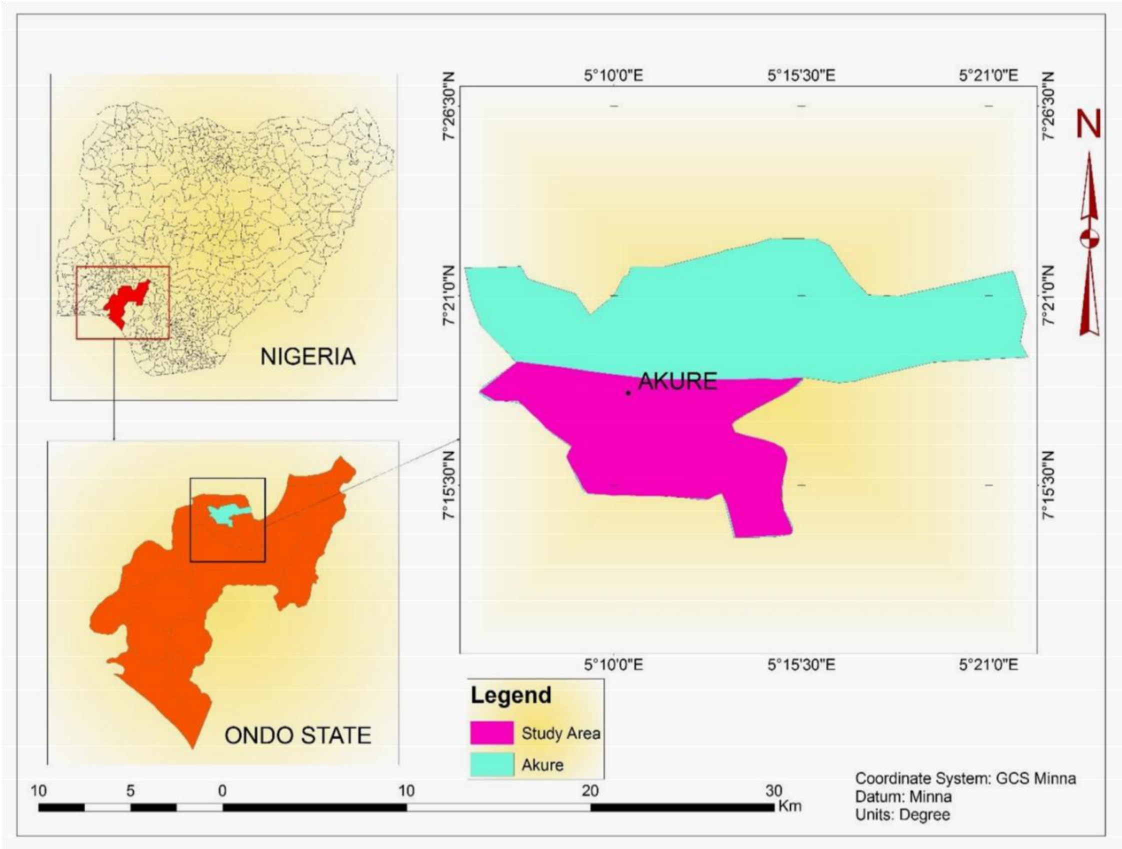
Fig 1: SHOWING MAP OF NIGERIA IN ONDO STATE SETTING AND ONDO STATE SHOWING AKURE RIVER ALA CATCHMENT AREA



Source: Bakare et al., 2017

Methodology and Material Used in the Study

Materials Used

Geo-mapping is known as a method of land, and sub-surface surveying that uses GPS to presents a detailed view of a site and the surrounding area including roads, buildings, mountains, rivers, estuaries, and pipelines. Geo-mapping present/provide a useful representation of the site conditions below and above ground, which made it a suitable method of investigating this study. In order to achieve the set objectives for the research, a GIS tool was used in combination with other software, where data in some ways referenced to locations on the earth to achieve the spatial mapping analysis.

The data used for this study include a high resolution (0.5m) IKONOS Image of the study area (Ala River basin). A medium-resolution Landsat 8 Operation Land Imager (OLI) of 2015 was also used to obtain map images, while ER-ITERIM rainfall data from the European Centre for Medium-Range Weather Forecasts (ECMWF). The study also made use of the F.A.O Digital Soil Map of the World, version 3.6 of 2003, as well as a 1:50,000 topographical maps of the study area. Also, Google Earth map and Garmin etrex Global Positioning System (GPS) were all used for the validation of data and ground-truthing. A reconnaissance survey was also paid to the study area for ascertaining the numbers of vulnerable buildings identified in the map, while soil samples were taken at eight (8) different (sections) locations within the study area.

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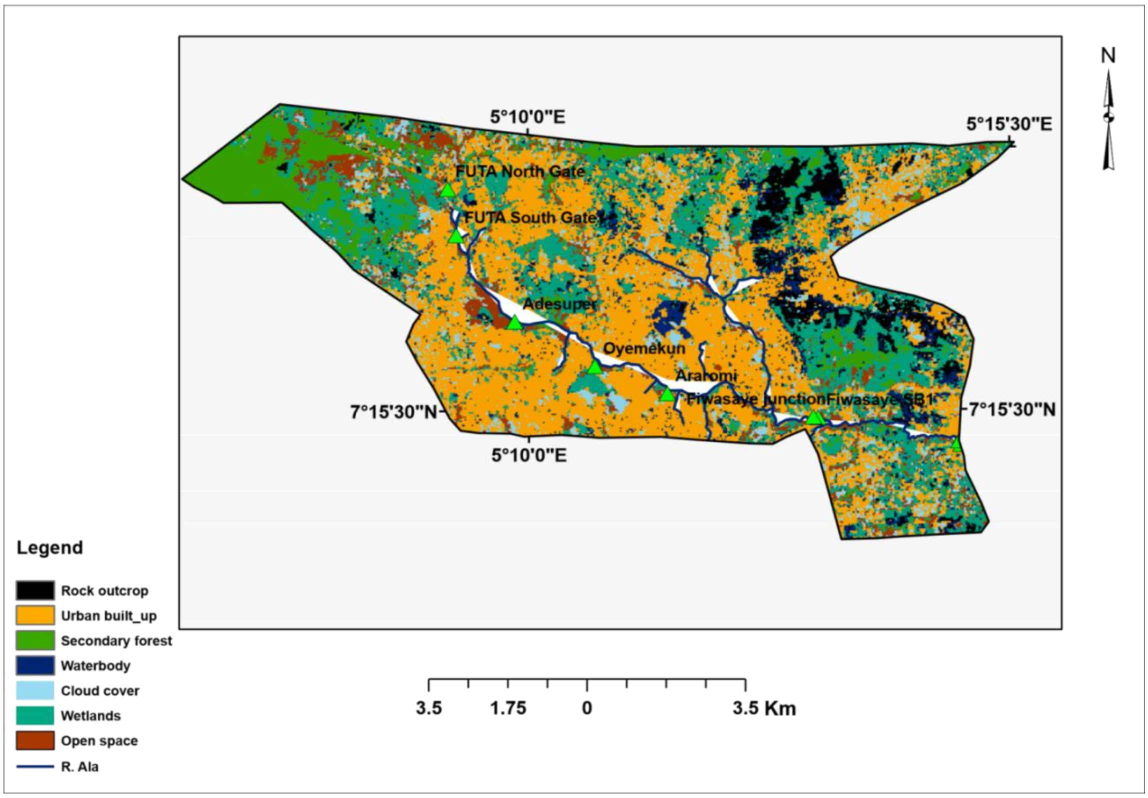
Fig 1: SHOWING LAND USE AND LAND COVER MAP OF AKURE (THE STUDY AREA)

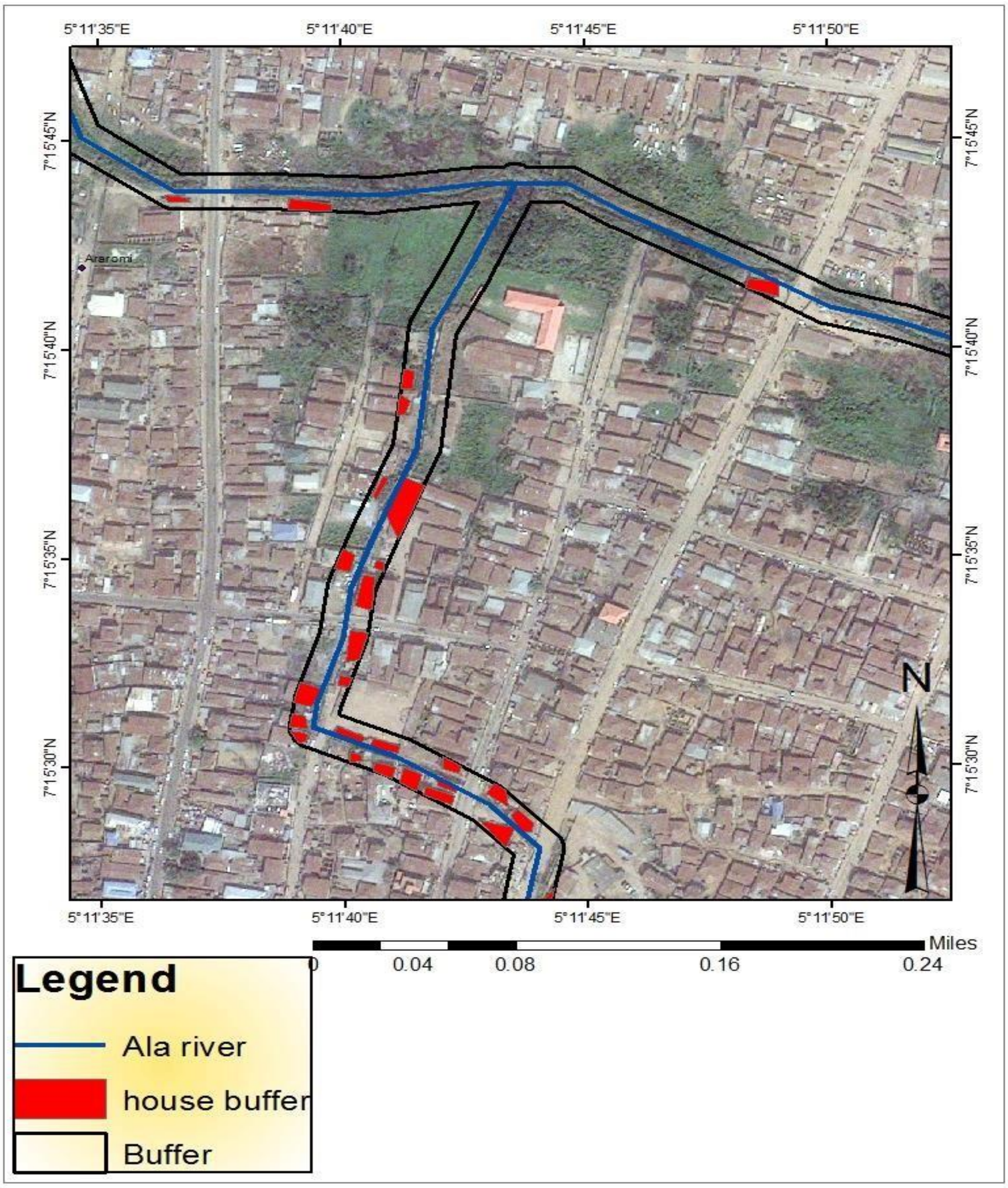


Source: Bakare et al., 2017

Land use/Landcover

This land use, the land cover map was generated through the use of image processing tools of ArcGIS 10.3.1 to classify the L8 OLI image using the maximum likelihood classification algorithm. The generated map identified different land use classes which incude; include light forest, rock outcrop, open space, built-up area, water body, and wetland. The urban built up is identified as the dominant land use in the study area, and rock outcrops are predominately identified in the Northeast of the catchment thereby constituting substantial impervious surfaces that reduce percolation and enhances rainfall-runoff and the presence of wetlands to the south of the catchment area.

Fig.4: SHOWING THE 30METER SETBACK (BUFFER) WITHIN THE FLOOD PLAIN AREA OF RIVER ALA



Source: Bakare et al., 2017

The entire drainage channels of Ala river and its tributaries were extracted from the 0.5m resolution IKONOS image using ArcGIS 10.3.1 application. The buffering of the river channels was carried out using the Geoprocessing toolset of 10.3.1 at 30m buffer distance (setback) to conform with the Planning Rules and Regulation of Development Control guidelines in Nigeria. The regulations stipulate that any building found within this 30m setback must be demolished. However, beddings found within the 30m buffer distance were digitized and identified for enumeration on the ground, and modelling of the flood risk to generate the required setback. Fig 4 showed the expected 30-meter setback as a buffer zone, but observation from the existing map showed several buildings constructed and built within the minimum setback in the study area. These identified buildings were hatched in colour red

 doi:10.20944/preprints201911.0184.v1

which indicates buildings that fell within the buffer that are potentially vulnerable to flood disaster risk.

TABLE 1: NUMBER OF BUILDINGS AT THE RISK OF FlOODING ALONG THE FLOODPLAIN OF RIVER. ALA

S/N	Location	No of Affected Household
1	Oba Ile	34
2	Fiwasaye	21
3	North Fiwasaye	75
4	Araromi	73
5	North East of South Gate	62
6	North of North Gate	51
	Total	316

Source: Bakare, et al., 2017 Fieldwork based on the 30m Buffer Analysis of River Ala

Table 1 indicates a total number of 316 buildings identified to have contravene building and planning regulations of obstructing a distance of 30 meters setback from the watercourse. These setback are to serve as a buffer zone to the River. However most of the building obstructing the buffer are located in the Northern parts of Fiwasaye and Araromi areas with 75 and 73 buildings respectively, while Oba-Ile has the least buildings with 34 due to obvious reasons. However, a total of 316 buildings fell within the buffer zone of River Ala.

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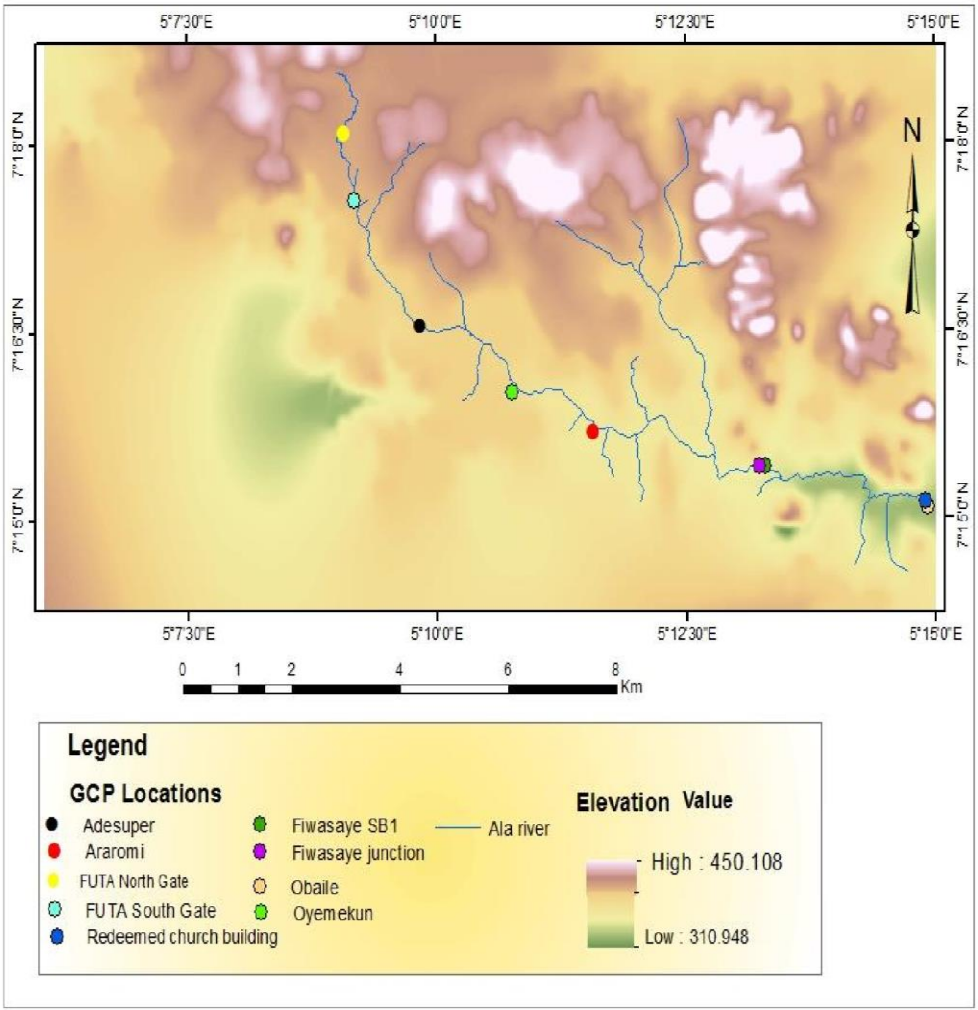
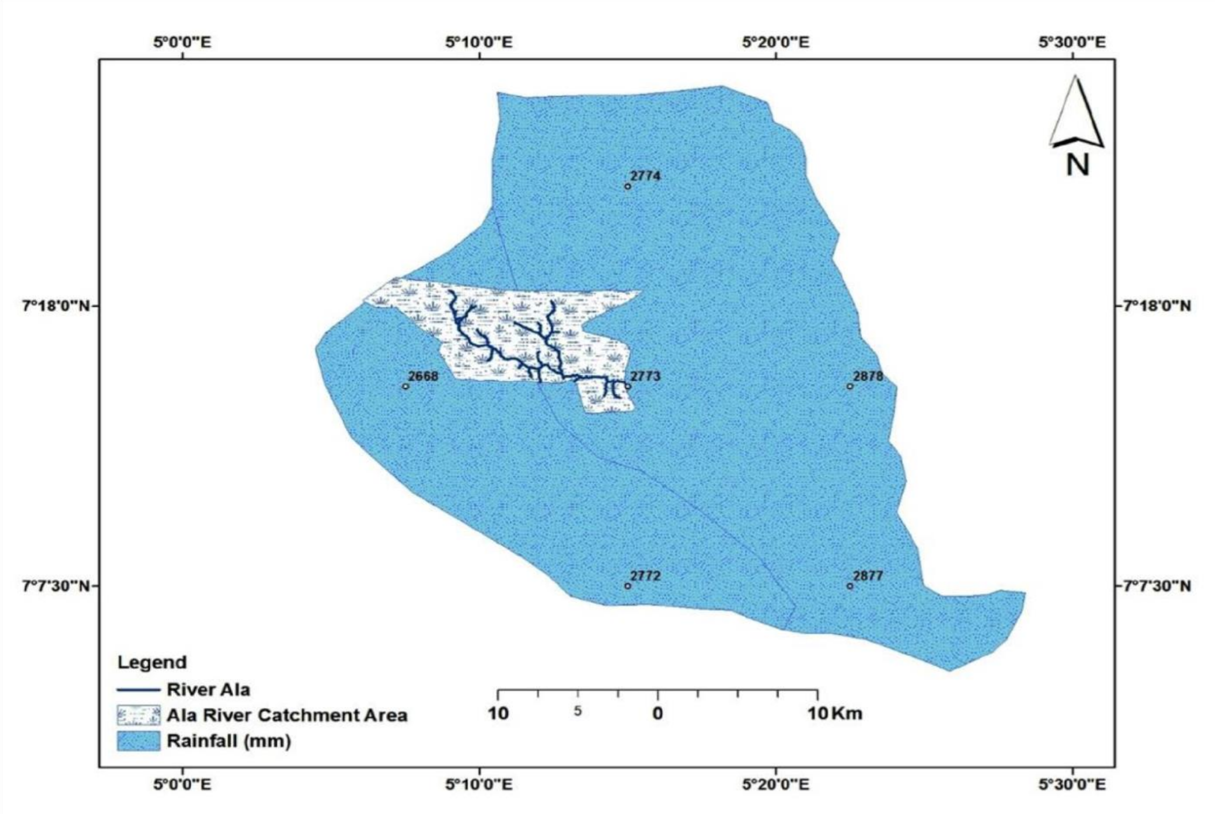
Fig 5: SHOWING THE DIGITAL ELEVATION MODEL OF THE STUDY AREA



Source: Bakare et al., 2017

The contour of the study area was extracted from the topographical map of the study area for the generation of Digital Elevation Model (DEM) using the Raster Interpolation toolset (Topo to Raster) of ArcGIS 10.3.1. Hence Digital Elevation Model (DEM) was produced and exported to ArcScene for the generation of the TIN model of the Ala drainage channel. The observed elevation of the catchment area of the river ranged from 311m to 450m, while the land slopes are mostly found in the North East-South West direction of the study area.

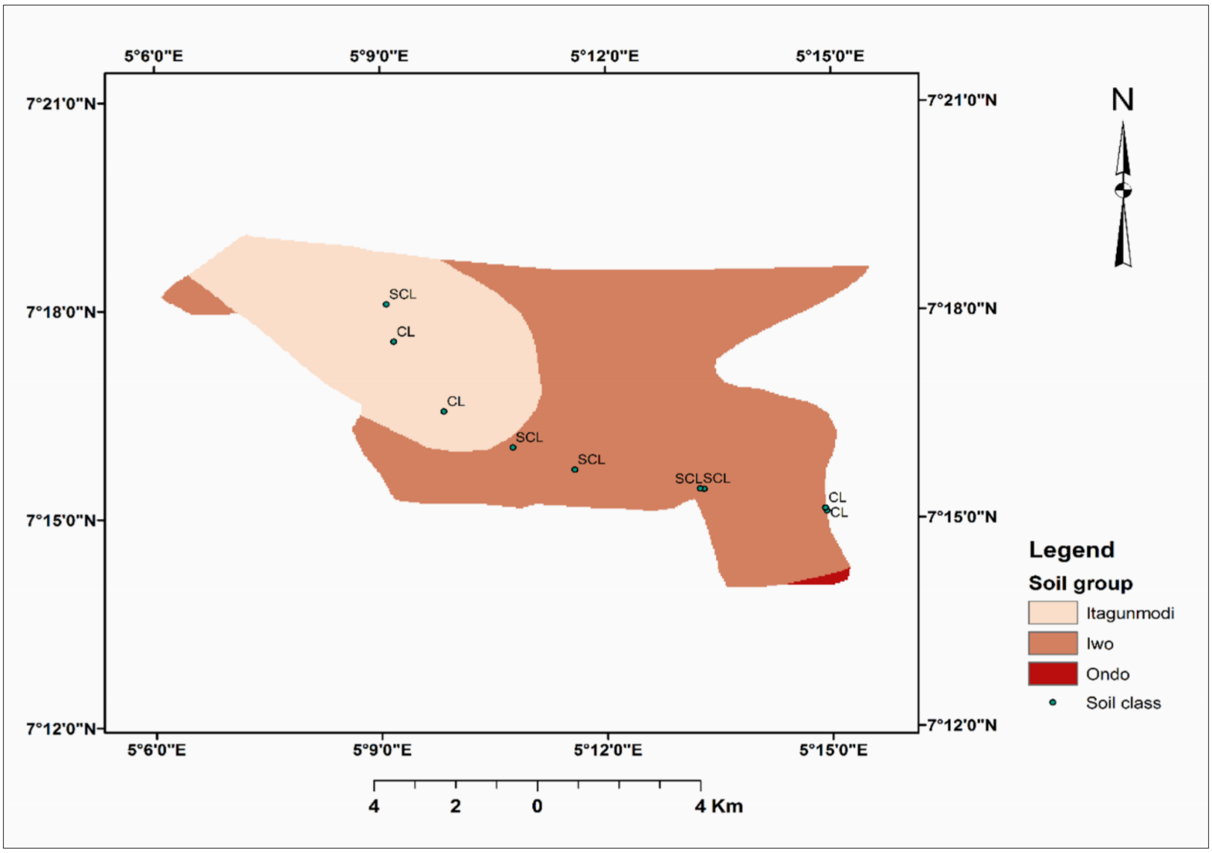
Fig. 7: SHOWING THE ANNUAL RAINFALL MAP OF THE STUDY AREA



Source: Bakare et al., 2017

Information about the rainfall pattern of the Ala river basin was derived from the rainfall map of Akure as obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF). A point map showing the distribution of rainfall in Akure city and Ala river drainage was created using thi map. However, Fig. 7 showed the annual rainfall data of the study area, while rainfall within the catchment of River Ala ranges between 2668 mm to 2773 mm annually. However, rainfall is much higher in the lower reach of the river than the upper reach as can be seen from the map.

Fig. 8: SHOWING THE ANALYSIS RESULT OF SOIL TEST IN THE STUDY AREA



Source: Bakare et al., 2017

The soil map of the study area was created by clipping the F.A.O. Digital Soil Map of the World, textual analysis of the collected soil sample was carried out, and used for the validation of the clipped soil in the study area. Fig. 8 showed the results of soil test carried out in the study area, eight (8) soil samples from FUTA North Gate Area, FUTA South Gate Area, Redeemed Church Area, Ade Super Hotel Area, Araromi Area, Fiwasaye North Area, Fiwasaye Main Area, and Oba-Ile Area locations were taken for laboratory test. Thereafter, the analysis of these soil samples showed that there are 3 soil formations in the study area, which includes Itagunmodi, Ondo and Iwo soil formation. The soil formation in the study area is therefore classified as CL- Clay Loam, SCL- Sandy Clay Loam, the soil classes enable the knowledge of the soil permeability in the study area.

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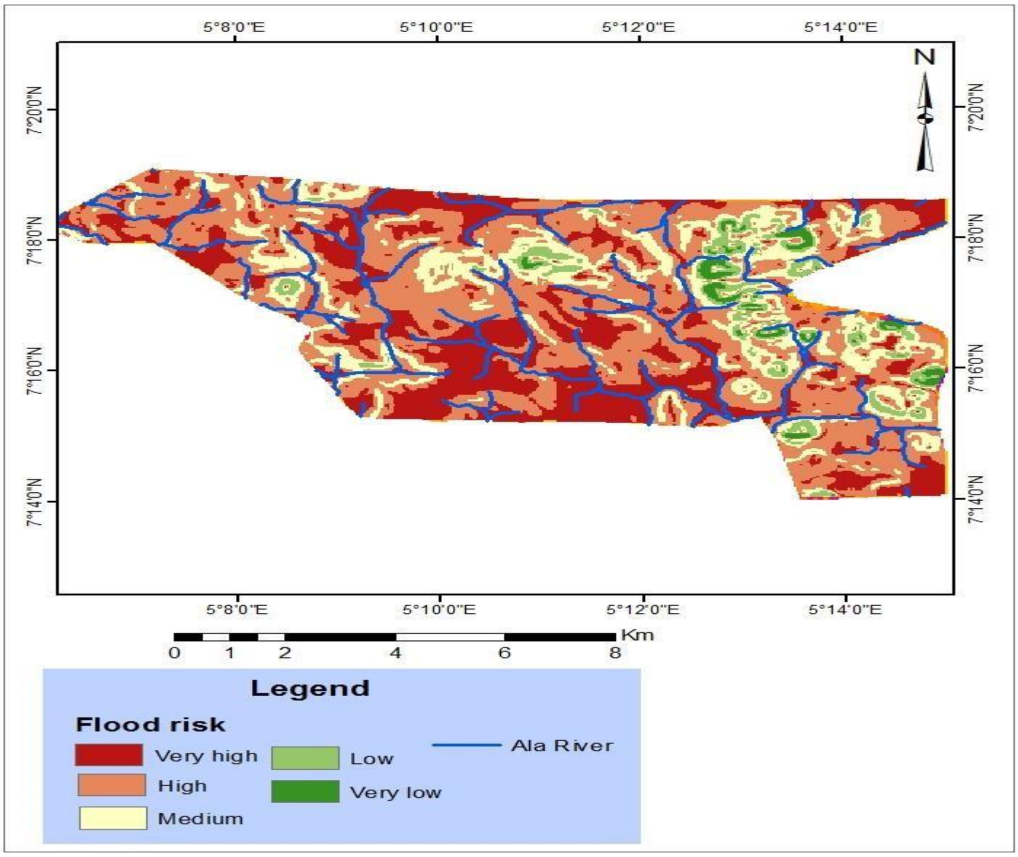
Table 2: Textural Class of Soil in the Catchment Area of R. Ala

Sample Locations	Sand	Silt g kg-1	Clay	Textural Class
Obaile	320	300	380	CL
Redeemed church building	440	250	310	CL
Fiwasaye SB1	500	200	300	SCL
Fiwasaye Junction	470	260	290	SCL
Araromi	480	200	300	SCL
Ade super	310	250	320	CL
FUTA South Gate	380	360	370	CL
FUTA North Gate	420	240	340	SCL

KEY: CL= Clay loam, SCL= Sandy Clay loam
Source: Bakare et al., 2017

Fig. 10: FLOOD RISK MAP OF ALA RIVER (VULNERABILITY MAP)



Source: Bakare, et al., 2017

The vulnerability map of the study area was created using the weighted overlay function of ArcGIS 10.3.1 tool, the land use/land cover map, a rainfall map, the soil association map and Digital Elevation Map (DEM) to produced the flood hazard map for this study. Hence, Fig. 10 showed the vulnerability flood risk map of Ala river, the vulnerability risk is classified into low; very low; medium; high and very high. The map therefore indicates that most buildings located around the River Ala catchment area are at great risk of river flooding should there be an outbreak of flood in the study area.

Recommendations and Conclusion

The following recommendations are put forward to the concerned stakeholder, such as the neighbourhood living and own landed properties around the Ala river basin and both the State and Local government agencies.

a. Demolition of the Identified Buildings Prone to Flood Disaster Risk: The 316 buildings identified in the vulnerability map should be demolished to give way for the extension of the river course. Similarly, this will pave the way for the Town Planning recommended 30-meter setback, reduce human and properties vulnerability to flooding disaster risk in the study area. Although, the research recommends compensation for any of the 316 building owners whose properties possessed the required legal documents.

b. Compliance of Building Construction to Recommended Setback: Any future development(s) should be made to comply with the town planning recommended 30-meter setback for a river of this nature. Effective compliance should be ensured and maintained by the Development Control Unit of Akure South Town Planning Authority. This compliance enforcement would go a long way to reduce the vulnerability of human lives and properties to flood disaster risk in the study area. Similarly, any future property developers found to have contravened this regulation should be properly sanctioned according to laid down Town planning regulations regardless of the personalities involved.

c. Conversion of the Recommended setback for urban agricultural purposes: The recommended setback should be converted to the use of agricultural crop products. Similarly, the setback can also be used for the planting of greenery such as shrubs to enhance the aesthetic of the river basin areas and add values to the properties located along the identified neighbourhoods where the river basin transverse. The setback can also be converted for recreational purposes, where city residents can go for a walk along/near the Ala-river for sightseeing, relaxation and appreciation of nature's endowment.

d. Use of Produced Maps as Guides: The research recommends that all the maps produced should serve as a guide to relevant government agencies in Ministry of Physical Planning and Urban Development, Ministry of Agriculture and Forest Resources among others. Using these maps as guide will help to reduce flood disaster risk in the study area. Similarly, these maps will also help to guide development of various human activities along the Ala-river course.

e. Preservation of water retention areas for agricultural Uses: The parts of the river basin in Ade Super area, sawmill areas in Isolo/stadium area, Adgbemile area, behind Fiwasaye area and deeper life area adjacent to Mobile Filling station area identified as water retention areas can be converted to agricultural uses during the dry season. These areas can be used to grow vegetables and other crops that would otherwise not grow during the dry season. This shall serve as source of providing fresh produce for urban consumption and also a source of capital for the would-be urban farmers. Additionally, the water retention areas can be converted to fish pond(s) as noticed behind the Adegbemile/Fiwasaye axis of the study area, as these fish

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farming can serve as sources of livelihood to the would-be fish farmers and provide fresh-water products to Akure city's residents.

f. Draining and Expansion of the River course: The research recommends that river course should be drained and expanded from FUTA area to Oba-Ile area, to allow for the free flow of rainwater during rainfall, avoid urban flooding and reduce the likelihood of flood disaster risk in the study area. However, expansion of bridges connecting Isolo to Stadium road, Redeemed Christian Church bridge in Oba-Ile Housing Estate area should be ensured. Also elevation of dual carriageway between Iye-oma plaza and Fiwasaye area should be ensured to avoid constant rainwater erosion on this axis of the road whenever it rains as this would reduce disruption to human activities whenever it rains.

Conclusion

Based on these recommendations, the study concludes that relevant government agencies in the State and in particular in Akure South Local Government should ensure prompt compliance and implementation of the recommendations to avoid potential flood disaster risks. Similarly, residents along the river course, church owners and saw-millers located on the river course and other stakeholders that may likely be affected by the recommendations put forward should be sensitized about the dangers associated with living near the river basin/course. However, where huge cost is likely to be incurred in the implementation of these recommendation(s), assistance from the State or International development partners such as UNDP or World Bank should be requested.

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