Detection and Mapping of Flood Prone Areas of Jimeta, Adamawa State, Nigeria

By

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ABSTRACT

The detection and mapping of flood prone areas in Jimeta Metropolis using remotely sensed data and Geographic Information System (GIS) is aimed at identifying areas that are potentially susceptible to urban flooding. The objectives of the study include; analyzing the physical terrain attributes such as elevation, slopes, and drainages among others in relation to urban settlement under flood risk, to prepare Digital Terrain Model (DTM) and flood simulation model to serve as a tool for managing flood plains. The elevation data was obtained from Earth explorer (SRTM Dem) and Google earth (Landsat image). The satellite image from google earth software online has the advantage of taking points data with ease and was obtained at regular intervals. The study area was gridded into 400 grid squares that gave rise to 441 intersections of the grid lines which serve as the points whose X,-Y and Z coordinates were taken. Surfer 8 and ArcGIS 10.2 version were used to create Surface Elevation Model (SEM) and Digital Elevation Model (DEM) respectively. Other flood assessment maps such as detail contours and flood simulation models were created and analysed. The result reveals two extensive Benue floodplains at the northern and southern fringes of Jimeta metropolis. The factor that was responsible for serious flood hazards in Jimeta metropolis is the backflow of the runoffs due to insufficient carrying capacity of the River Benue and Lake Gerio which was filled with sediment deposits leaving very narrow channel and shallow reservoir respectively. The susceptible flood risk areas were identified and mapped using Buffer analysis for zone round the natural streams within Jimeta metropolis. Hence, it was recommended that, the people located at the river bank, be relocated and the area turn to green area. Secondly, there should be well-articulated sewer drains, in areas liable to flood, particularly in Doubeli and Damilu. Finally, there is need for dredging and expansion of both river Benue and Lake Gerio so as to accommodate as much as possible the runoffs that usually backflows. These will go a long way in mitigating the effects of flood in the mapped areas.

Key Words: Terrain, Uban Field, DEM, Floodplain, Flashflood, Mapping

INTRODUCTION

The pattern of human settlements across the earth surface is known by its proximity to natural water sources. Water on the other hand have some negative effects to man, being the major driving forces that give rise to negative fluvial processes. This is more manifest along river channels, areas liable to flood, floodplains and some highland plains that are commonly occupied with human social and economic activities. These areas are generally expressed in terms of low elevation above sea level, low angle of slope, and orientation of terrain. The terrain characteristics affects surface water flow and drainage pattern within any given environment [including urban fields]. Terrain can affect weather and climate patterns more especially over a large area. In most humid regions of the world, river floods threaten or cause damage to life and property. It has been shown that when river banks are over topped, water spreads over flood plain and comes into severe conflict with man (Dalrymple, 1960). Flood plain in itself is a belt of low flat ground bordering a river channel on one or both sides usually sub-merged by flooded stream water about once a year (Strahler & Strahler, 1977). However, the topography, geology, shape and size of a catchment basin area determine the amount of run-off that causes floods. For instance in 1989, Loko settlement located on upland plain in Song Local Government Area, Adamawa state, Nigeria was perhaps the worst hit by flood disasters in the state, about 1253 families were affected, (Tukur & Ray, 1995). The drainages in a basin receive runoffs differently; in a circular shaped basin a high peak discharge can occur if most of the tributaries converge on the basin outlet. The main channel receives runoff water from the surrounding at the same time thereby giving a sudden rise in discharge that the channel cannot contain. In elongated basin each tributary contributes flood water in turn, and the result is low or fairly high discharge being maintained for a considerable time; causing flood risk (Briggs, 1985). The geology of a catchment area influences the nature of runoff depending on the type of rock underlying the basin area. Soft rock will allow more infiltration than hard rock which gives higher runoff.

Urban impervious areas such as city buildings, pavements and roads, however, propels urban flood (Adeaga, 2009). The fact is that these infrastructures seal-off the land surface that could have allowed infiltration take place. The effect is high run-off within an urban environment, particularly, where there is no proper planning and design of drainage channel that could contain large amount of runoff.

The Geographic Information System (GIS) and Remote Sensing (RS) applications for flood risk assessment and mapping were used in this study. The applications has been used elsewhere by many scholars and the approach is yielding good results (Bera, Pal, & Bandyopadhyay, 2012), (Thilagavathi, Tamilenthi, Ramu, & Baskaran, 2011), (Uddin, Dio, Amarnath, & Basanta, 2013), (Masona, Giustarinib, Garcia-Pintadoa, & Cloke, 2014) (Mathew, 2013). The main aim of this study is to identify and measure the floodable risk areas as well as identifying areas that are potentially susceptible to urban flooding. The objectives of the study include; analyzing the physical terrain attributes such as elevation, slopes, and drainages among others in relation to urban areas under flood risk, and to prepare Digital Elevation Model (DTM) from elevation matrix and flood simulation model to serve as a tool for managing flood plains.

It is highly imperative that studies of this nature are undertaken to first identify vulnerability areas and to provide some insights and measures for mitigation within the identifiable areas.

The Study Area

Jimeta metropolis is one of the twin towns that constitutes Adamawa State Capital, the other twin sister is 'Yola town' located 7km away due south. The second administrative role of Jimeta is being the headquarters of Yola-North Local Government Area (LGA) of the state. Jimeta lies within Benue trough in the central zone of Adamawa state, Nigeria, it covers an area of 109 km²; it is the smallest local government area in terms of land size (Fig. 1).

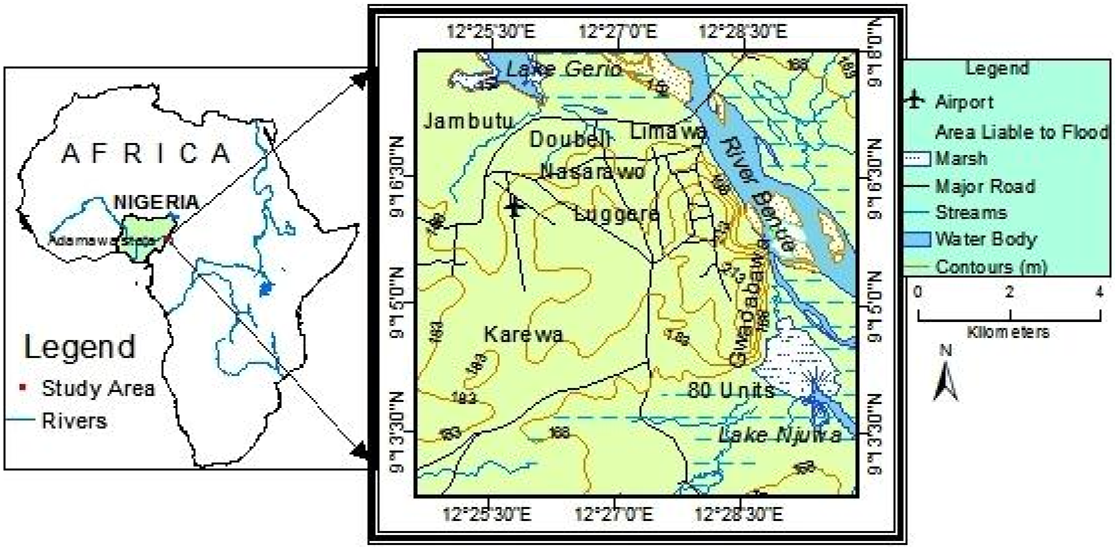

Fig. 1 Jimeta Metropolitan area (The Study Area)

The study is geographically located between latitude 9°13´30´´N and 9°18´30´´N and longitude 12°24´E and 12°29´E on the southern bank of the River Benue. Jimeta is the one of the first order core settlement in Adamawa state (Illesanmi, 1999). Consequently, the assigned functions create purposeful developments of social and economic infrastructures in the study area. As a result, all the required urban infrastructures are found in the densely populated -area, with urban population of male being 107,646 persons and female 90,601 persons giving a total population figure of 198,247 persons as of 2006 Census Results, (National Population Commission (NPC), 2006). The population density is very high. With a complex land use structure within Jimeta metropolis which comprise of residential, commercial, administrative, industrial, and agricultural land uses.

The Geology of the area can be described as oldest cretaceous sedimentary formations consisting of some alluvial deposits which unconformably overlie the cretaceous deposits. The sedimentary deposits within the rift that runs through the central axis of Yola arm, separate the political land of Adamawa state into two halves (Opeloye & Dio, 1999). Jimeta is underlain by the Albian-Aptian Bima Sandstone in the Northeast, Southeast and Southwestern parts. This is the oldest formation in the upper Benue Trough found at the base of the sedimentary succession and overlies the Basement Complex unconformably. While the recent river alluvium covers the northwestern and southern parts of Jimeta (Ishaku J. M., 2011). The recent alluvium sites in the area of study are likely to be prone to flood risks.

Relief in the study area is generally low ranging from 152.4m (500ft) to 213.4m (700ft) above the mean sea level (see Fig 1). Jimeta is located on an undulating rough and rugged terrain with some areas situated on the peak of the steep slope of sedimentary rock escarpment (213m high above sea level). Such places include parts of Limawa, and Gwadabawa (Dougirei) at the eastern part of Jimeta town restricted from expansion by the river Benue. The areas with 152.4m height are the Benue floodplain.

The climate of the study area is typically that of tropical wet and dry climate. The dry season commences averagely from 26th September and ends around 10th May i.e. a period of about 215 days, while the rainy season fully starts from 10th of May to 26th September i.e. a period of 150 days with a higher rainfall recorded during the month of August and September when the intensity assumes over 20% of the annual value. The average annual rainfall in the area is about 960mm. The driest months include January and February with an average relative humidity of about 28% (Adebayo, 1997; Adebayo, 1999).

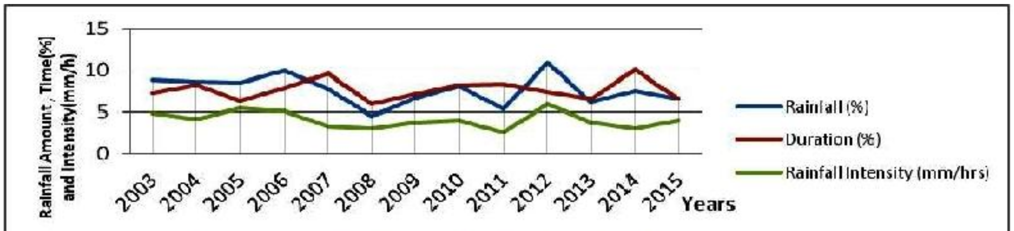

Figure 2: The relationship between the Amount and Intensity of Rainfall in Jimeta
(Source: Nigeria Meteorological Agency, Yola)

The rainfall distribution over a period of thirteen years as presented in Fig. 2 have shown that 2012 had the highest values for amount and intensity of rainfall in the study area the year that experienced one of the most destructive flood event. Low amount of rainfall was recorded in 2008 while low intensity was recorded in 2011 (Nigeria Meteorological Agency Yola, 2016).

Temperature is generally high throughout the year, with the average monthly temperature ranging between 18°C in December (coldest month) to 45°C in March/April (Hottest month), which is the peak of the seasonal maximum temperature. Relative Humidity varies from 80% during the wet season (August and September) to 20 percent during the dry season from (December to March) (Zemba, 2002).

The Vegetation of Jimeta can be described Guinea Savannah. In effect, most areas especially in and around the metropolis are covered with exotic species such as *Acacia hokie* (Kaya), *Azadirachta indica* (Neem), and *Adansonia digitata* (Kuka). Hence, Jimeta metropolis exhibits characteristics of a typical urban centre with a clear vegetation and reclaimed marsh and swampy areas (Zemba, 2002). The replacement of vegetated area with TIA is a factor that increases runoff that lead to floods in urban areas.

Two categories of Nigeria soils were recognized, in the Oguntoyimbo's classification of the Nigeria soils in the study area (Oguntoyinbo, 1978).

a. Mainly ferruginous tropical soils that were formed as crystalline acid rocks.
b. Hydromorphic and organic soils that developed on alluvial, marine and fluvio-marine deposits of variable texture, notably along the coast and river floodplains.

Therefore, the study area is characterized with category 'b'. However, the soil has deep profile and a great water retention capacity during dry season. But in extremely poorly drained conditions, they tend to develop surface accumulations of clay materials.

METHODOLOGY

The major data source for this study was the remotely sensed type. The study area was extracted from Landsat imagery that covers Jimeta metropolis (71.085 km²). Google Earth was used to create Digital Elevation Model (DEM) that allows viewing at required view point and scale as well picking spot heights for interpolation. Table 1 summarized the variety of data types and sources for this study.

Table 1: The type and sources of data

DATA	SCALE/RESOLUTION	YEAR	SOURCE	PURPOSE
SPOT and Landsat imageries from Google-earth and 30-m USGS SRTM DEM	Dynamic Scale/ Medium Resolution	2018	www.googleearth.com www.earthexplorer.com	Urban land use, X, Y and Z value of point data for DEM creation, , and Wetlands verification /analysis
Elevation and Co-ordinates (in UTM Zone 33)	--	2018	Google earth and Fieldwork; Navigation(GPS Readings) With GERMIN e-TREX	To obtain x, y, and z positional data at randomly selected point for comparative analysis
Topographical Map	1:50,000	1963	Federal Geological Survey Department, Nigeria	To serve as a study area base map / location and extraction of spot height from contours and creation of Isoline Map
Rainfall data	-	2003-2016	Nigerian Meteorological Agency Yola	To analyze and determination the rainfall and rainfall intensity.

Data Analysis

The detection and mapping of urban flood risk was made using Remotely Sensed data and Geographic Information System (GIS). Software Components include; Environmental System and Research Institute (ESRI) ArcGIS version 10.x, embedded with *ArcHydro* extension used for other hydrologic analyses, Golden software, *Sufer* 8.0 was used for generating contour lines as well as Surface Elevation Models (SEM). A schematic diagram of integrated data processing and analysis was also adopted Fig. 4, (Jeb & Aggarwal, 2008). The data sets on rainfall were subjected to descriptive statistical analysis. Rainfall Intensity was determined using the following formula; R***ainfall intensity (***Ir) = Amount / Time (mm/h)...............1

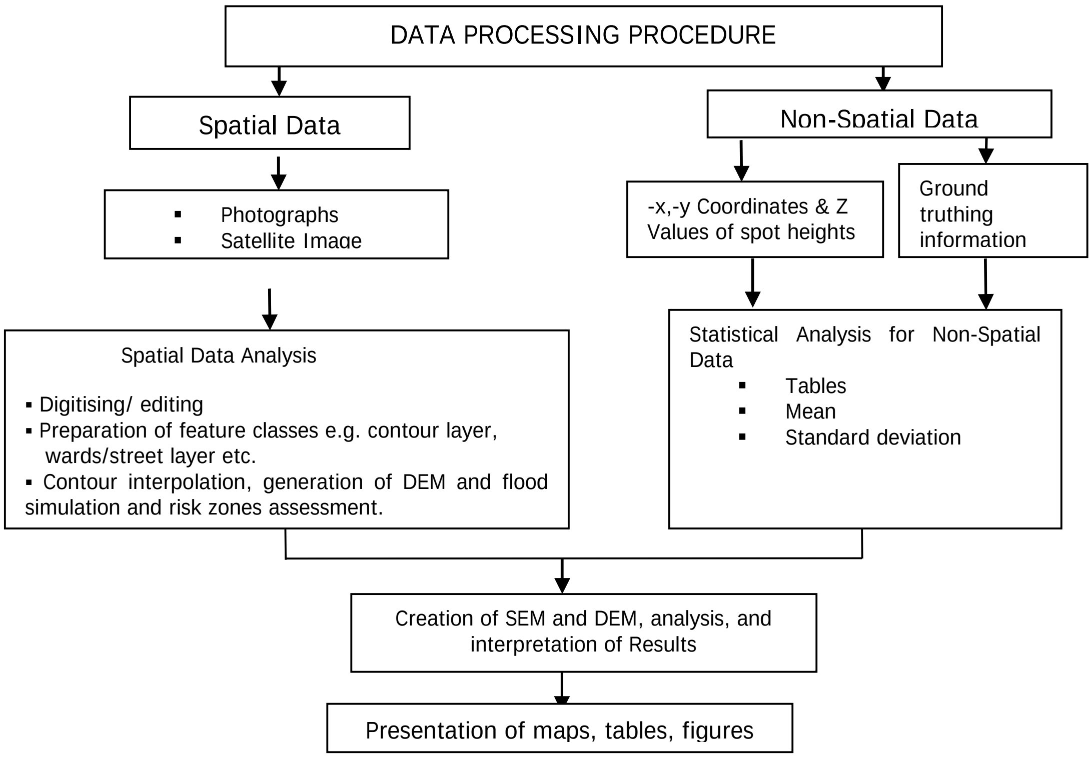

Figure 4: Integrated Data Processing and Analysis Flow Chart
Source: Modified from; Jeb and Aggarwal, (2006)

A criterion for choosing point data for interpolation was initiated to compare between various sources to ascertain the most reliable one for this study. The comparative analysis was carried out for the most accurate, accessible and reliable source of spot height. Table 2 shows the 10 points randomly selected and analysed.

The -X,-Y coordinates and Z value data about the ten randomly selected points were obtained from three different sources; GPS, overlapping orbital imagery and topographic map. The most reliable source of point elevation data was from the SPOT/Landsat imageries having the smallest difference of 1.69m when compared with topographic map the second reliable data source. The two have little difference than when GPS recorded heights were compared with any of the two. There was a large difference when GPS values were compared with any of the two sources. The mean differences between Z Values obtained from image and GPS was 4.87m while 9.55m was the mean difference between the topographic map and GPS.

Table 2: Comparative Analysis of Z Values of Points from three different sources

S/N	LATITUD	LONGITUD	H(ft)	LAT.(dd	LONG.(dd	X (m)	Y(m)	Z(m)
1	9°18' 30"	12°24'00"	576	9.308333	12.400000	**214376**	**102999**	**175.57**
2	9°18' 30"	12°24'15"	544	9.308333	12.404166	**214834**	**102999**	**165.81**
3	9°18' 30"	12 °24'30"	529	9.308333	12.408333	**215292**	**102999**	**161.24**
4	9°18' 30"	12 °24'45"	525	9.308333	12.412500	**215750**	**102999**	**160.0**
5	9°18' 30"	12°25'00"	521	9.308333	12.416666	**216208**	**102999**	**158.8**
6	9°18' 30"	12°25'15"	499	9.308333	12.420833	**216666**	**102999**	**152.10**
7	9°18' 30"	12 °25'30"	500	9.308333	12.425000	**217124**	**102999**	**152.40**
8	9°18' 30"	12 °25'45"	506	9.308333	12.429166	**217582**	**102999**	**154.23**
9	9°18' 30"	12 °26'00"	507	9.308333	12.433333	**218040**	**102999**	**154.53**
10	9°18' 30"	12 °26'15"	506	9.308333	12.437500	**218498**	**102999**	**154.23**

Creation and Manipulation of Elevation Matrix (3D point Data)

Table 3: The first 10 points data of 441 Points used for creating DEM

Description of point location	**Long (x)**	**Lat. (y)**	**Z value Sources**	**Height (m)**	**Z Value Differences Image /**	**GPS /**	**GPS**
Laila Cenema Round about	12°27' 57"	9°16 55"	GPS Satellite Topograph	179 166.1 165	1.1	12.9	14
Beacon Y278 at Yola Club Junction	12 ° 7'49"'	9°16' 13"	GPS Satellite Topograph	218 215.8 212	3.8	2.2	6
Boromji Junc. By Ibrahim Kashim. Way	12°28' 07"'	9 °15'3	GPS Satellite Topograph	207 209.1 207.3	1.8	-2.1	-0.3
Mountain edge at Boromji	12 °28'3	9 °15'3	GPS Satellite Topograph	186 183.8 182.9	0.9	2.2	3.1
Doubeli Junction at Mubi bye-pass	12°27' 04"	9°17' 14"	GPS Satellite Topograph	167 158.5 160	-1.5	8.5	7
Floodplain Down Ad. Water Board	12°28' 07"	9 °16'5	GPS Satellite Topograph	167 155.1 155.5	-0.4	11.9	11.5
Mubi Roundabout	12°27' 05"	9 °16'4	GPS Satellite Topograph	170 166.1 170.7	-4.6	3.9	-0.7
Afribank gate, Yola road	12 °27'2	9°14' 29"	GPS Satellite Topograph	175 175 175.3	-0.3	0	-0.3
80 Units Junc. by Yola road	12°27' 21"	9°14' 10"	GPS Satellite Topograph	171 168.3 167.6	0.7	2.7	3.4
Floodplain South of 80 Units	12°28' 00"	9°14' 10"	GPS Satellite Topograph	159 156.7 158.5	-1.8	2.3	0.5
			Absolute Value Total		16.9	48.7	95.5
				Mea	**1.69**	**4.87**	**9.55**

The study area was divided into 20 by 20 grid squares (Fig. 5), 15´´N (461m) by 15´´E (458m) regular grid lines spacing for both Northings and Eastings. This gave rise to 441 intersections (figs. 6) of the grid lines marked as points where -X,-Y, coordinates and Z values were recorded as shown in Table 3.

The Geographical coordinates were converted to decimal degrees before uploading into ArcMAP. Similarly, coordinate converter (file version 1.0.0.1) software was also used to convert from decimal degrees (dd) to Universal Traverse Mercator (UTM) coordinate system in meters. Thus, these processes of conversion were necessary in order to create a point data attributes that is compatible with GIS software's to enable further analysis. Conversion formula was adapted from (Dutch, (n.d.)).

(dd + mm/60 +ss/3600) to Decimal degrees (dd.ff)..................................(2)

Where; dd = whole degrees, mm = minutes, ss = seconds, ff= decimal fractions, dd.ff = dd + mm/60 + ss/3600

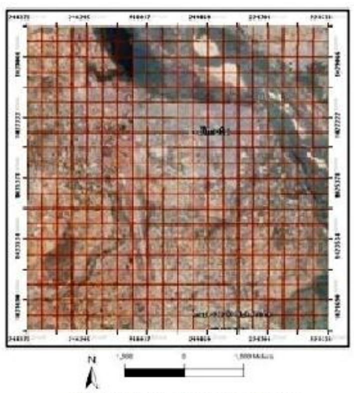

Figure 5 Gridded Image of Jimeta

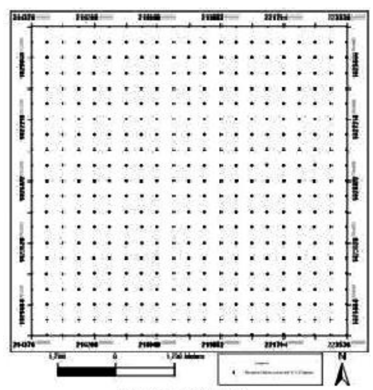

Figure 6 Elevation Matrix

Creation Digital Elevation Model from point matrix

A surface contains an infinite number of points, therefore, it is impossible to measure and record the z-value at every point. A surface model approximates a surface by taking a sample of the values at different points (Table 3) on the surface and interpolating the values between these points. There are several methods of interpolation in GIS softwares that converts the Topo to raster to create the Digital Elevation Model (DEM). ArcGIS and Sufer 8 softwares were used to create the 3D views of the study area, from different angle of view and methods which enabled critical analysis of the terrain surfaces.

The columns X, Y, Z of Table 3 were selected and saved in excel worksheet. This made it compatible for Surfer 8 software worksheet columns A, B, and C. Sufer8 automatically check for error and corrected them when the data was imported. The software converts the data to sufer8 format that carry its logo. The data was then used to create detail contour map, and the Surface Elevation Models (SEM) using the tools embedded in suffer8.

The SRTM DEM was used in ArcMAP to create Contour map and digital elevation models were symbolized in a beautiful color ramp. The maps layers created from both Surfer 8 and ArcGIS were used in analyzing the flood prone areas. The overlays analysis in ArcMap shows the relationship between terrain attributes and urban infrastructures that are usually in floodplains.

RESULTS AND DISCUSSION

The analysis consists of visual field interpretation from single and multiple layers and viewpoints. These include hierarchical visual field analysis, front-view analysis and visual corridor analysis from different angles and directions using remotely sensed data and GIS precisely the Sufer8, and ArcGIS. Two major type of floods were identified that is "Riverside Floods" detected and mapped using the DEM and "Flashfloods" detected in urban field using the SRTM DEM in ArcHydro.

Detection of Riverside Flood Prone Areas using Flood Simulation Model (FEM)

The ArcScene component of ArcGIS was used to create FSM. The model was created from digital elevation model (DEM) in ArcScene environment using animation that depicts levels of flood inundations into the urban area. As the water continued to increase over time three levels were captured and graded as low moderate and high flood inundation in the area. The low water level flowing just within the river channel considered as normal river flow Fig. 7(a). The moderate level is where the water flows over the bank but affecting the agricultural land use area and some properties at the riverside Fig. 7(b). Fig. 7(c) shows the maximum or high level of inundation that affects northern and southern parts of the urban land use areas of Jimeta metropolis.

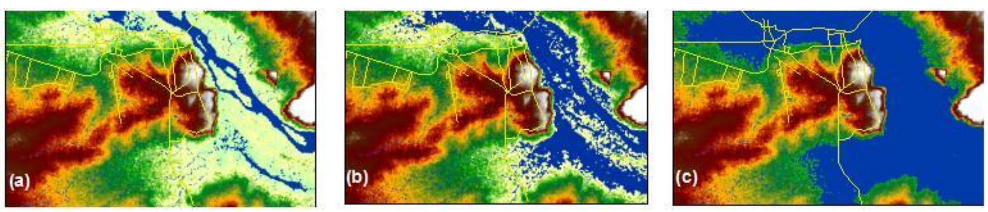

Fig. 7: Three Selected inundation levels of Flood Simulation Model (FSM)

Surface Morphology

The analytical observation of the Surface Elevation Model (SEM) that was oriented at 45^o field of view, 44^o angle of rotation and 33^o angle of tilt (Fig. 8a). Enabled us view the study area as a three dimensional block that show clearly all the physical morphological arrangement of the natural terrain. Two major lowland areas were identified at the north-western and south-eastern fringes from this view point. The North-western part is the extended Benue flood plain starting from the residential areas of Limawa, Rumnde, and Doubeli wards to the new urban extension sites, known as Jambutu ward. The South-eastern part is also an extension of Benue flood plain which is lying below 167m (ASL) known as 80 Units (Fig. 8b). These areas were identified and classified as high flood risk areas mostly affected by river Benue overbank flows.

The orthographic view of the surface elevation model revealed the present condition of Benue river channel, which is filled with sediment deposited over the years. As a result the Benue valley has no significant depth when compared with the floodplain (148-165m ASL). The channel became shallow and can no longer contain all the storm water that it could have contained from the catchment subsystems. Even the sand bars in some places raised above the banks levels. The siltation leaves some narrow and shallow paths that maintain the perennial water flows; hence increase in volume due to rainfall or releases from 'Lagdo dam' in Cameroun Republic (Tukur &

Ray, 1995) amount to backflow and over bank flow which inundates the urban environment. It is therefore clear that, overflows affects lives and properties located on the floodplains.

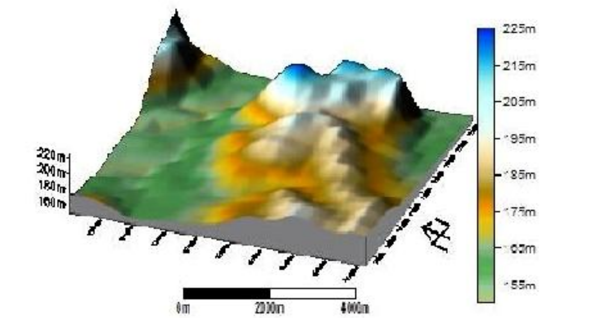

Figure 8a: Orthographic view of Surface Elevation Model of the study area

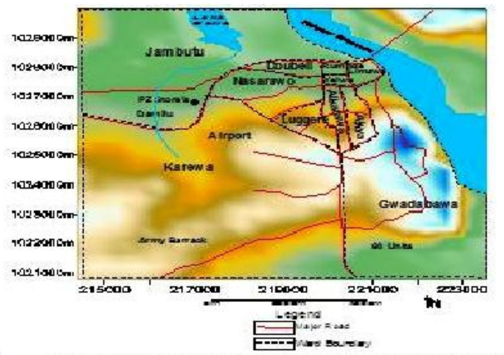

Fig. 8b: Overlays of Wards Boundary and Major Roads layers on SEM.

The surface elevation model oriented to yet another point of view described in angular measures as 45°, 0° and 90° for field of view, rotation and angle of tilt respectively (Fig. 8b). This shows the front-view of the SEM, overlaid with the eleven political wards and the streets layer. The streets and wards that fall within susceptible floods areas are further visualised at the northern and southern Floodplain in the study area.

The understanding of the spatial distribution of flood prone areas in relation to the DEM in Jimeta has been emphasized in Fig. 9. The one at the northern fringes of the study is an extensive flood plain (148-165m) partly covered with high density residential landuse of Doubeli, Rumnde, Yelwa, Limawa and Northern part of Nasarawo (Fig. 9, Plate 1and 3). The location of Doubeli and some parts of Jambutu on the northern Floodplains and their proximity to Lake Gerio make them vulnerable to floods risks.

The construction of Doubeli waste/storm water drainage and the current location of the outlet culvert at Goruba uku are adjudged to be a cause of flooding at northern part of Doubeli. When Lake Gerio is saturated the runoffs from Doubeli passing through Doubeli culvert will backflow and inundate the nearby buildings.

Even though, Yola-Mubi Bye-pass road pavement has prevented Doubeli residents from the effect of flood due to Benue overbank flows. The Doubeli drainage at the outlet culvert is almost at the same altitude (159m) with the Gerio Base Level, where it is expected to empty its contents (Fig 11a). The Channel gradient reduces over time due to mass deposition of sediments at the lower riches. Therefore, when water from Lake Gerio spilt over, the water enters the residential areas of Doubeli as backflow through the culvert and also forces back the forthcoming runoffs from the urban area. Hence, the culvert serves as a rout through which the water backflow from Lake Gerio and cause flood. Instead of performing the primary function it was designed for; to drain out all the runoff water from urban field into Lake Gerio.

The second floodplain identified at the southern fringes. Precisely, 80 units area in Gwadabawa ward, it is an area that the then Gongola State Government constructed 80 units of staff quarters more than four decades ago. Presently is found to be one of the worst hit areas by urban floods evident in the September/October 2012 flood events (Fig. 9, Plate 2). This could be attributed to locational factors identified earlier in addition to backflows from Chouchi river which could not discharged conveniently into the river Benue, hence the chouchi water inundates 80 units area, identified to be a concave landform between the Dougirei highland and some minor uplands in the floodplain.

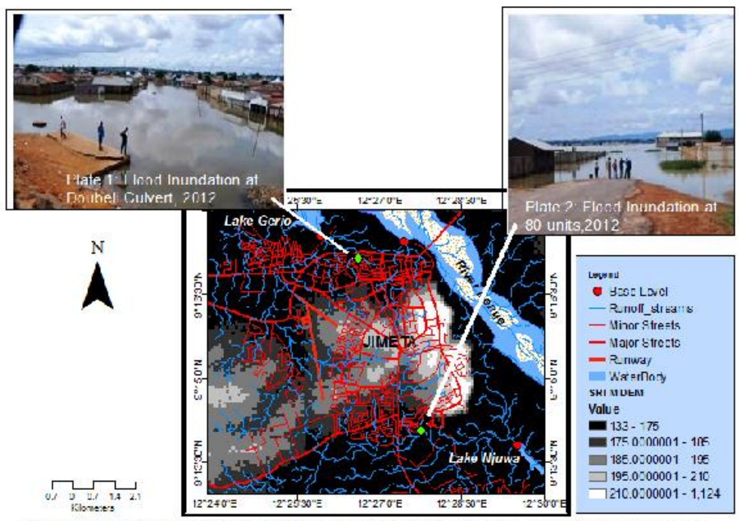

Fig. 9. Overlay Analysis of DEM and Streets Layers Showing Northern and Southern Flood Prone Areas of Jimeta .

During field investigation after the flood it was found that, water rises high above ground level (AGL) measured at some selected area with visible water marks on affected buildings (Table 4). The water mark signifies areas that the water stayed for more than a day. On the other hand the highest level when the flood was at its peak stayed for some hours and does not leave any clear mark. This was confirmed through the interaction with some of the residents in the worst hit areas. Most of them estimated that the peak level was about 0.3m above the existing water marks.

Table 4: Height of Flood Water above Ground Level (AGL)

S/No	Description of Location	GPS READINGS			Water Level (AGL) in Meters	
		Latitude	Longitude	Elevation (Meters)	Marked Water level	Estimated Peak level
1	Near River Bank in Limawa ward	9° 17'00"	12°27'58"	167	1.2	1.5
2	Inside Limawa	9° 17'02"	12°27'46"	162	0.8	1.0
3	Opposite 'Goruba Uku' Doubeli Ward	9° 17'09"	12°26'05"	160	0.5	0.8
4	Way to Lake Gerio, off Mubi bye-pass Jambutu Ward	9° 17'11"	12°25'50"	154	1.8	2.1

5	80 Units Housing, Southern Gwadabawa ward	9° 13'59"	12°27'33"	165	1.2	1.5

The areas investigated above were the densely populated slum with the exception of southern Gwadabawa 80 Units in particular. The larger parts of the densely populated areas were identified to be in northern flood prone areas (Plates 3), but the effects of flood is mild on the majority of People in the northern floodplain largely due to the road scarp or pavement extending from Jimeta Bridge through Yola-Mubi Bye-pass to the airport Roundabout. Certainly this has shielded the northern densely populated flood prone areas from the effects of backflows from Gerio Lake and river Benue. The road scarps here served dual functions of embankment to the road and as protection against flood to the immediate urban settlement (Plates 3).

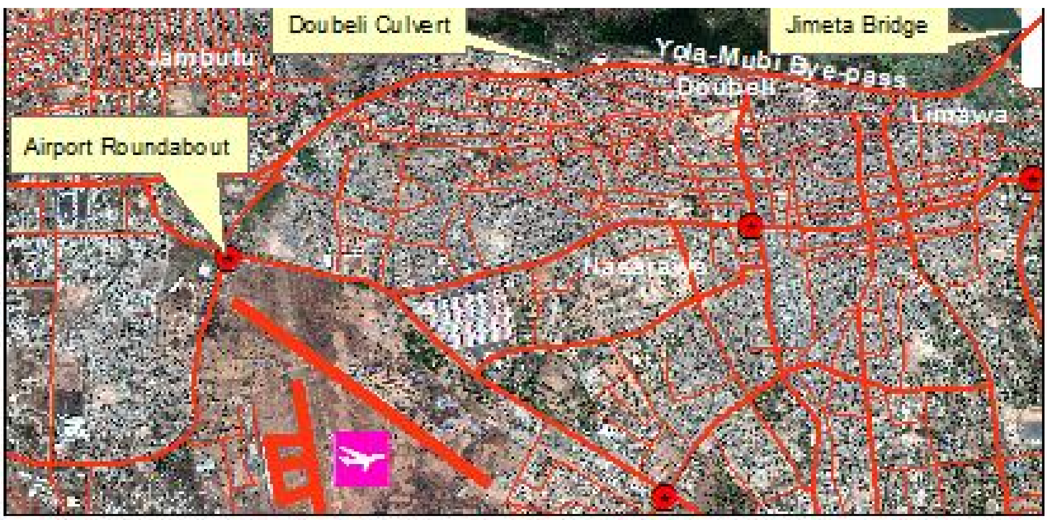

Plate 3: Google Earth Image showing the Road Scarp shielding the densely populated areas from flooding.

Analysing Flood in Urban field (Flashflood)

Flow Accumulation and stream definition tool in ArcHydro was used to bring out all the possible rainfall runoff drainages in the urban area. Similarly, Watershed Delineation tool was used to capture the catchment areas for the three outlets channels (Fig. 11a). Watershed is in this context synonymous to Sewershed. Within urban fields, it is referred to as ***Sewershed***; that is an area that cover a network of natural and man-made drains for storm and domestic waste water. Delineation of Sewershed is based on the premise that water flows in the downslope direction by the force of gravity and all the sewers in the study area are gravity driven. Three major catchment areas were delineated based on flow direction of the runoffs and accumulation toward a well-defined runoff channel. The Stream definition tool in ArcHydro was used to define a storm water runoffs streams in the urban fields using a cell threshold of 150 (Fig. 11). Using this cell threshold, all possible contributory streams within the catchment areas were revealed from first order streams (minor) to the third order stream (main) channel that drains out the accumulated runoffs to the Base Levels (BL). Base Level is the points where the runoffs are emptied into large river or lakes. Three BL are identified in the study area; along River Benue, Lake Gerio and Njuwa (see Fig.11). Streets on the other hand were constructed to follow as much as possible a flat or gentle slope terrains without pavement to raise the road above the floodplain, although roads were constructed with Sewer drains on both sides. Same flat or gentle slopes also favours water flows and accumulation that destroy road surfaces (Dereck Arens, 2018). Therefore, overlay of slope map and streets layers reveals that, the streets in flat or gentle slope areas with slope angles ranging between 0.7° (1.22%) to 1.7° (Fig. 10) are usually submerged by water during heavy downpour.

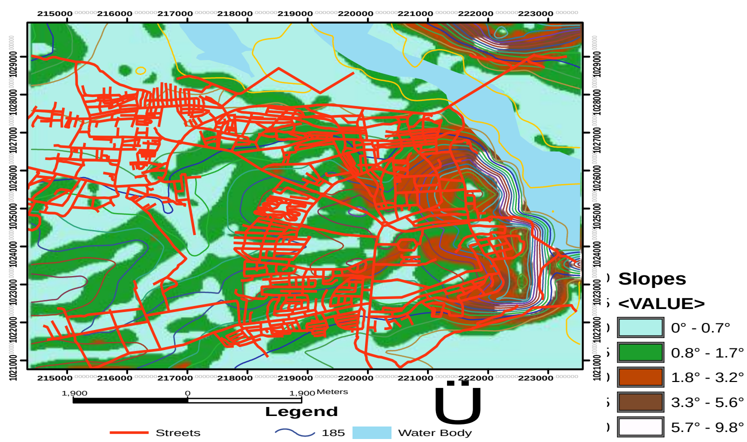

Fig. 10 Slope Map of the study area overlayed with streets and contour layers

In an urban field like Jimeta with much impervious surfaces (Adeaga, 2009), there is excess water as a result of fast accumulation of runoffs, the water that accumulate in the upstream more especially during heavy downpour can have devastating effects in areas that have no adequate and well planned sewer drains. Water that flows over the roads surfaces over time would starts developing potholes rills and gulley erosions. Some urban infrastructures such as buildings were also affected by this type of flood. This was physically observed, particularly where the streams crosses the road without culverts or where the culvert and drains were blocked by sediment or refuse causing the water to flow over the road surfaces (Fig. 11b).The major effect as noticed in some of the flat areas include; reduced strength of materials used in constructing the roads, and sand depositions that cover the streets and make it uncomfortable for the users and susceptible to further degradation due to loss of potency.

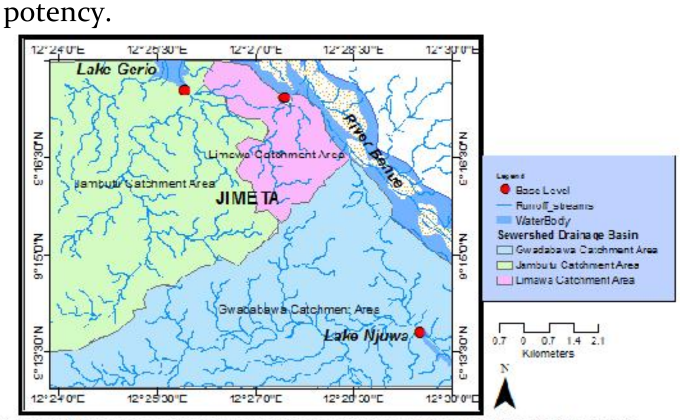

Fig. 11a Catchment Areas for Runoff accumulation Streams with a cell threshold of 150.

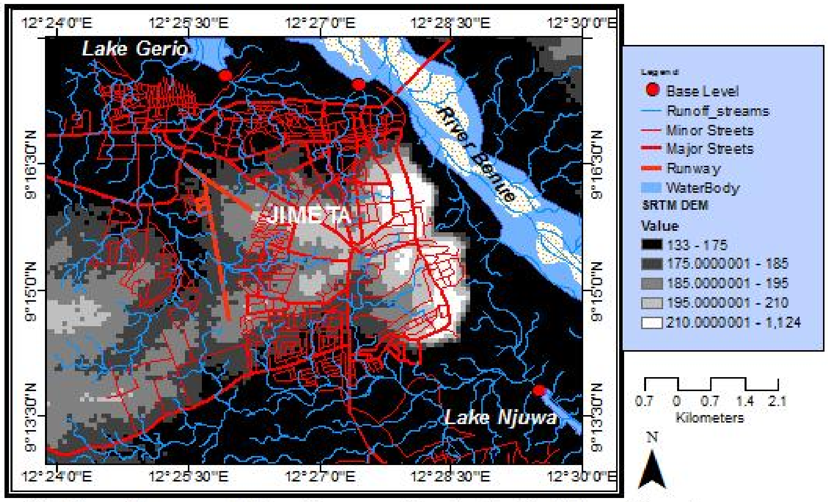

Fig. 11b Runoff accumulation Streams Overlaid with Urban Streets.

The spatial interaction between streets and the natural/man-made sewer drains was found to be running parallel or crossing each other at most places. More especially on gentle or flat slopes 0.7° (1.22%) and 1.7° (2.97%). Similarly, on steeper slopes 3.2° (7.11%) to 9.9° (17.45%) (Fig. 10). Furthermore, flood problems in the study area could be attributed to uncertainty in the volume of water that could be generated in other to construct the appropriate capacity of sewer channels for the expected increase in volume over time. Apparently this might be the cause of more damaging floods recently in Damilu (behind PZ in Jimeta), which happens after the construction of an open drainage systems in the area. This is an area for further scholarly research work in order to fill the gap.

Multiple Ring Buffer analysis

Creates multiple buffers at specified distances (100m) around the streams features. The relationship between the streams and the existing roads and buildings that fall within 100 meters buffer zones round the streams in the urban center were classified as flood prone areas (Fig. 12) that are largely affected by flashfloods within the urban fields.

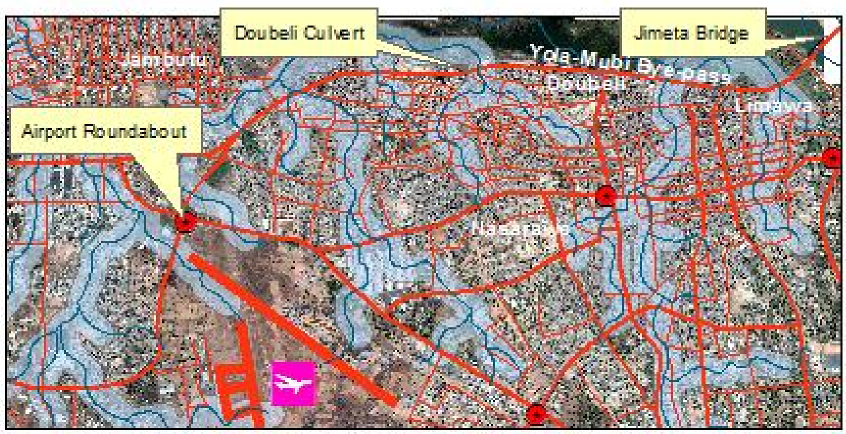

Fig 12: Google Earth Image showing the densely populated areas overlayed with 100m buffer zones round the runoff channels

RECOMMENDATIONS

The following suggestions and recommendations are made based on peculiarities of each identified flood prone areas;

a. First, Diverting high flows around developed areas; there is a need to block the present outlet culvert at Doubeli and redirect the channel to flow down slope due east, following the southern side of the road scarp to join the drainage along Shinco road. This will curtail the backflow effect and undue fear of flood hazards.

b. Second, elevating or flood proofing new buildings and retrofitting existing ones; there is need for an engineering work such as infillings and embankments before erecting any structure, so that building and streets are raised up at least 1.0m above the current low levels of 160m on the urban floodplain.

c. Thirdly, construction of well-articulated sewer systems in areas identified to be flood prone in the urban areas, as well expand the existing sewerdrains to the size that could accommodate all the expected accumulated runoffs to avoid overland flows which destroy the potency of roads and valuable properties within buffer zones identified in the study area.

d. Forth, Resettlement and restoring the landuse of floodplains for preserving the natural resources etc. Those located at the frontline of the identified high risk areas particularly, 80 Units, Limawa and Eastern part of Jambutu need to be relocated permanently, and put the areas to other uses. Precisely; the southern part of 80 Units should be part of the proposed Njuwa dam. The buildings at the eastern part of Jambutu wards and those at the river bank, eastern part of Limawa ward should be relocated and the areas be converted to green areas for aesthetics, because their altitude is too low (155m) and the flood water level was high (1.5 to 2m) with unexpected annual reoccurrence.

e. Fifth, if the Bed of river Benue will be dredged to its maximum width and depth, it is possible to have hazard free urbanized floodplains in Jimeta.

CONCLUSION

It is clear that terrain is a perceived figure of physical space and the process of urban terrain analysis is fundamental but very complicated. It combines domain knowledge of planning process with Map–based visibility analysis as demonstrated in the discussions above. The combination of the GIS and Remote Sensing technology is able to display the "field / actual site" on a Personal Computer. This aids morphological analysis of the inland areas that unraveled the undulating nature of the urban terrain. It exposed the hidden nature of the landscape in the mist of urban infrastructures. However, human activities are located within these same areas. As a natural phenomenon, it is assumed that flood will only occur in reserved or forest areas. Perhaps the occupation of these areas was either for the land being available or the needs for expansion sites due to urban sprawl and no deliberate action for mitigation before occupying the areas liable to floods. Therefore, flood becomes an unwanted phenomenon in such areas. The mapping of flood prone areas in Jimeta identified two major residential areas, occupying the floodplains at the northern and southern extremes of the study area. These places include Limawa, Doubeli and Jambutu in the northern fringes and 80 units housing at the southern fringes. Other flood prone areas were curved out and mapped with ArcHydro tools. Urban infrastructures such as roads and buildings located within the proximity of natural streams. Precisely, 100m buffer zones round the streams seem to be more vulnerable to urban flash floods. Finally, lack of proper analysis and planning by the relevant agencies exposes the people to the dangers of flood. Therefore, the observations and recommendations from this study would probably mitigate or avert the dangers of flood in the study area.

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