Generation of flood maps and drainage basin of Umueze Anam

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Key words: Shuttle Radar Topography Mission (SRTM), Drainage Basin, Urbanization, Floods, Terrain Preprocessing, Digital Elevation Model (DEM), and Digital Terrain Model (DTM)

SUMMARY

Urbanisation which has been described as the physical growth of urban areas as a result of rural migration and even suburban concentration into cities, particularly the very largest ones has its merits and demerits; one major merit is it brings about the raising of living standards when proper plans precede development. A demerit of note is sprouting of slums, urban sprawl and distortion of urban aesthetics due to invasion of the urban space.

Umueze Anam area which is liable to flood has witnessed an encroachment by urban settlements within its precinct. This has been accompanied by inundation which is retained on the land as a result of the impervious nature it has turned into. Lands which hitherto had been rice paddies and farms are being transformed into residential landuse.

Last year the overflow from the Anambra River coupled with that of River Niger left a lot of the communities and beyond below water. This led to hasty evacuation of people from the communities affected. Detailed, proper hazard and flood maps based on recorded rainfall data for the study area needs to be done so as to assist in the formation of adequate mitigative measures. A triangular irregular network (TIN) was created. The resulting triangulation satisfies the Delaunay triangle criterion, which ensures that no vertex lies within the interior of any of the circumcircles of the triangles in the network.

In the study, topographic data was used to model flood kinematics in Umueze Anam and environs. The result revealed the flow direction of flood water in the area. This have shown that the numerical terrain descriptor method is effective in modeling flood water motions.

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1. INTRODUCTION

1.1 Background Of The Study

Rivers can often behave in an unpredictable, non linear and possibly chaotic way (Coulthard et al, 2007). It is known that changes in rainfall can lead to different problems on the surface of the earth; in some cases it could cause erosion, in some accretion and flooding in others. To determine how rivers react to floods, an understanding of sediment movement is important, because whilst water determines where sediment is moved, the deposited sediment then prescribes where the river can flow. It is partly this complex interaction that leads to apparently chaotic behaviour, allowing rivers to change rapidly and unpredictably through time and space.

Figure 1.1 Umueze Anam flooded by the Rivers Ezichi and Anambra
(Source: www.anamites.com, 2012)

Only recently the Lagdo Dam in Cameroon which is located close to Riao and Bame communities released water into the River Benue which inundated towns and villages located along its banks right up to Lokoja in Nigeria (See figures 1.2 and 1.3).

Figure 1.2 A crocodile swimming along a flooded street in a Benue community that was inundated by the River Benue (source: www.omg.com, 2012)

The release of the water from the dam coincided with the release of water from the Kainji and Jebba dams' into the River Niger. The level of water in the Kainji dam was reputed to be the highest in 29 years and the subsequent inundation along the River Niger is beyond imagination.

Figure 1.3 Human and traffic gridlock along the Abuja-Lokoja road flooded as a result of waters from the Rivers Niger and Benue ((Leadership Newspaper, 2012)

Two thirds of the coastal disasters recorded each year are associated with extreme weather events such as storms and floods. There are likely to become more pervasive threats due to shifts in climate and sea level rise (Adger et al., 2005). A study by the Danish Meteorological Institute showed that CO^2- induced warming can lead to a shift towards heavier intensive summertime precipitation over large parts of Europe (Christensen et al, 2002). Extreme river floods have been a substantial natural hazard in Europe over the past centuries and radiative effects of recent anthropogenic changes in atmospheric composition are expected to cause climate changes, especially enhancement of the hydrological cycle, leading to an increased flood risk (Mudelsee et al, 2003).

The 2003 World Development Report notes the pronounced difficulties the poor face when disaster strikes. Developing countries are particularly vulnerable because they have limited capacity to prevent and absorb…effects [of natural disasters]. People in low-income countries are four times as likely as people in high-income countries to die in a natural disaster…. Poor people and poor communities are frequently the primary victims of natural disasters; in part because they are priced out of the more disaster-proof areas and live in crowded, makeshift houses… poor families are hit particularly hard because injury, disability and loss of life directly affect their main asset, their labour. Disasters also destroy poor households' natural, physical and social assets, and disrupt social assistance programmes (IEG, 2006).

Approaches to limit disruption and damage from flooding have changed significantly in recent years. Worldwide, there has been a significant move from a strategy of flood defense to one of flood risk management. This change in approach reflects the future uncertainties in flood prediction, arising from climate change, urban sprawl and recognition that continuing to strengthen defenses against flooding is no longer tenable. Flood risk management includes defense, where appropriate, but also that society learns to live with floods and develops resilience to their impact. The success of this approach requires integration of enhanced defense and warning systems with improved understanding of the causes of flooding linked to better governance, emergency planning and disaster management (Pender, 2006).

Urbanization restricts where floodwaters can go by covering large parts of the ground with roofs, roads and pavements, thus obstructing natural channels, and by building drains that ensure that water moves to rivers more rapidly than it did under natural conditions.

Figure 1.4 Flooded neighborhoods in Anam West along the River Niger
(Source: Sahara Reporters, 2012)

Large-scale urbanization and population increases have led to large numbers of people, especially the poor, settling and living in floodplains in and around urban areas (Douglas et al, 2008).Part of the problems attributed to Urbanization were highlighted by Erege (2011) who said 'Acute flooding and soil erosion are amongst the numerous problems plaguing our natural environment at the present time, as a result of high surface runoff'.

Figure 1.5 Another scene of an inundated neighbourhood in Anam West along the River Niger (source: Sahara Reporters, 2012)

The Nigeria Meteorological Agency (NIMET) in its 2012 Seasonal Rainfall Prediction (SRP), warned some states, especially in the North, should watch out for flash floods. Eventually in July (2012) in a rare twist of fate, the National Emergency Management Agency (NEMA) announced that flood had devastated three North-eastern states of Borno, Bauchi and Taraba, washed away over 4,000 farms and destroyed over 5,000 houses. Also in the same month of July (2012) there was a serious case of flooding in Jos after a down pour that led to wide spread destruction. At least 20 per cent of the population is at risk from one form of flooding or another (Etuonovbe, 2011). Flooding in various parts of Nigeria have forced millions of people from their homes, destroyed businesses, polluted water resources and increased the risk of diseases (Baiye, 1988; Akinyemi, 1990; Nwaubani, 1991; Edward-Adebiyi, 1997).
In addition to this is the loss of the home which is seen as a form of security from the outside world. The home is often conceived as an emotional sanctuary providing refuge from the outside

world (Sibley, 1995). Flooding is the most common of all environmental hazards and it regularly claims over 20,000 lives per year and adversely affects around 75 million people world-wide (Smith, 1996). Floods are natural phenomena, but damage and losses from floods are the consequences of human action (Douglas et al, 2008).
Climate change appears to be altering the pattern of flooding in Africa. Modelling shows that the pattern of rare large floods is going to change much more than long-term average river flows. An example is the work done by Ayila et al (2012) using CAESAR MODEL, the flood analysis and overlay operation, a large number of settlements in the Adamawa State floodplain were seen to be at risk. Prolonged heavy rains may increase in volume and occurrence (Mason et al, 1997).

1.2 Study Area

The study area is Umueze Anam, a major community of Anam clan in Anambra West Local Government area of Anambra state. The study area map is shown in figure 1.6. Towns that make up the Anambra West local government are Ezi Anam, Ifite Anam, Nzam, Olumbanasa, Oroma-etiti, Umueze-Anam, and Umuenwelum Anam. Anambra west is located in the western part of Anambra state. Its local government headquarters is Nzam.
Umueze Anam is located on the map along the longitude 6°48'60"E; 6°51'36"E and latitude 6°21'16"N; 6°18'48"N It is bounded on the east by Anambra (Omanbala) River that runs southwards to its tributary in the River Niger at Ukwubili (west) and Onitsha (east). On the north it is bounded by the Ezichi River Further east of Anambra River, are Aguleri, Umuoba Anam, Umueri (all collectively referred to as Otuocha), and Nsugbe; at the south easternmost end is Onitsha. On the northern border, is Iyiora Anam, while Mmiata Anam is on the northwest. Oroma Etiti Anam, Umuenwelum Anam, Umudora Anam, and Umuikwu Anam are on the western fringes of Umueze Anam border.

Broadly speaking Anam towns are classified into two according to geographical contiguity: Ezi and Ivite. While Umueze, Umudora, Umuikwu, Oroma, and Umuenwelum constitute the Ezi, Mmiata, Iyiora, and Umuoba-Aboegbu constitute the Ivite Anam. Mmiata-Ovia-Nwagboo and Umuoba-Oboro-Igbo are outside this classification, having permanently fused with Otuocha, the headquarters of a neighbouring Anambra East Local Government Area.

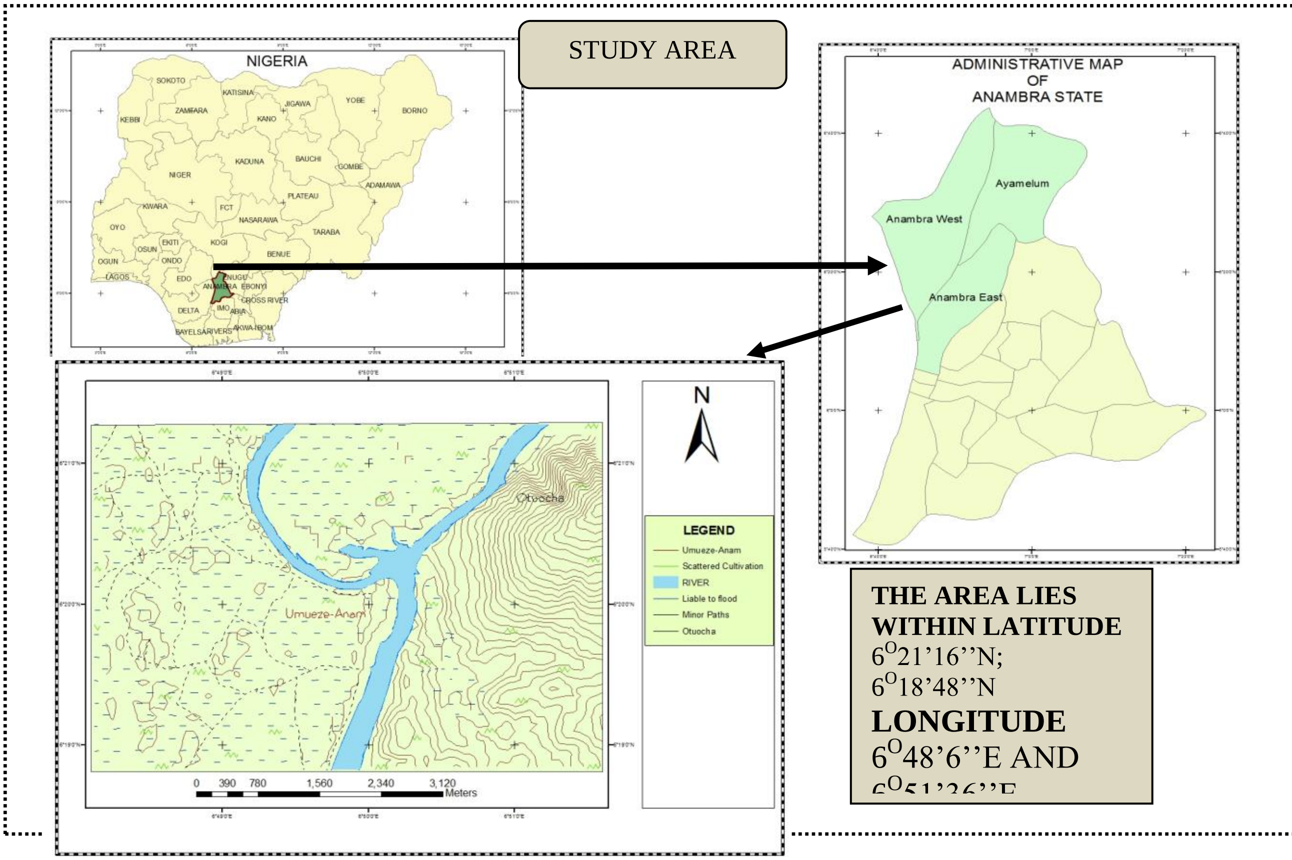

Figure 1.6: Map of Umueze Anam showing Otuocha separated from it by the Anambra River on the east and Ezichi River on the north (source: Author)

1.3 Statement of the Problem

Drainage basin could be described as an area where surface water from streams, rivers and rivulets converge to a single point which in this case is the exit of the basin, where the water joins a larger body of water. The Anambra & Ezichi Rivers are located within the Anambra River Basin and both meet at a confluence between Umueze Anam and Otuocha. While the Anambra River is wider and longer from its source (Gala Plateau) in Kogi State, the Ezichi River is not and could be traced to Orania Otu in Anambra West local government. Otuocha is position at a higher elevation with the lowest point being 100 metres above sea level while the highest point is 300 metres. On the other hand Umueze Anam is situated below sea level with its entire land labeled liable to flood. Necessary information for flood water motions in the Umueze Anam floodplain is not available for the floodplain management, planning and sustainabilty of the environment. There is therefore, no reliable terrain management information that could be used to check inundation by floods if there are heavy rains and accompany flash floods.

1.4 Research Aim

This study is aimed at modelling flood water kinematics (motions) in the Umueze Anam floodplain using terrain descriptors and topographic map information. The following objectives were used to achieve the exercise:

- Generate Digital Terrain Model of the study area from topographic map, as input for surface roughness and flood motion modelling.
- Generate the surface roughness vector models (slope, aspect, relief, etc).
- To model the floodplain flow pattern
- Regions of high flood hazard and risk would be identified.The vulnerability of Umueze Anam and surrounding communities to flood would be analyzed
- Suggestions would be made with a view to generate ideas on mitigation measures against flooding.

2. DATA AND METHODS

2.1. DATA ACQUISITION AND MODIFICATION

Data acquired during the research were obtained by spatial and aspatial methods.

2.1.1 Spatial Mode of Data Acquisition

The primary mode by which data for the research was acquired is:

2.1.2 SRTM DEM

The Shuttle Radar Topography Mission DEM was acquired from the official website. The SRTM imagery covering the entire region is srtm_38_11 and the study area was clipped out from the imagery.

2.1.3 Topographic Maps

The Office of the Surveyor General of the Federation served as the source of the topographic maps which were scanned, Geo-referenced and digitized thereby serving as a data base

2.1.4 LANDSAT

This imagery was downloaded online from United States Geological Service website. The path and row are P189R55and P189R56, though the area of study is small but, it lies between two scenes.

2.1.5 SEDIMENT TYPE

Sediment types within the study area were obtained as it would assist in understanding the fluvial morphology better.

2.1.6 A spatial Mode of Data Acquisition

Aspatial mode of data acquisition includes literature and making reference to geographic data. This complements the CAESAR flood model as well as non-stationary data, remotely sensed data and topographic maps.

2.2 Data Processing Procedure

2.2.1 Map Digitization

The topographic map was first scanned, georeferenced, before the digitization process could commence. The digitization process took place within ArcGIS 9.3 environment and it took into cognisance contours, rivers, areas liable to flood etc.

2.2.2 Image Classification

The Landsat imagery acquired for the research was classified using ENVI 4.3 software. First Unsupervised classification was applied so as to have a rough estimate of the number of features that may be contained within the image. The Supervised means of classification was later used first, by setting up training sites or regions of interest to estimate and identify features by their spectral reflectance (signature). The features represented by classes which we are interested in are;

- Areas liable to flood
- Waterbodies
- Wetlands
- Elevated areas

The features presented above were edited in ARCGIS; this was done because in some cases there was duplication of spectral reflectance. The final map turned out to be a fair representation of the imagery.

2.2.3 Pre-processing of SRTM Imagery using Arc-hydro

Terrain Preprocessing uses DEM to identify the surface drainage pattern. Once preprocessed, the DEM and its derivatives can be used for efficient watershed delineation and stream network generation.

2.2.4 Fill Sinks

This function fills the sinks in a grid. If cells with higher elevation surround a cell, the water is trapped in that cell and cannot flow. The Fill Sinks function modifies the elevation value to eliminate these problems.

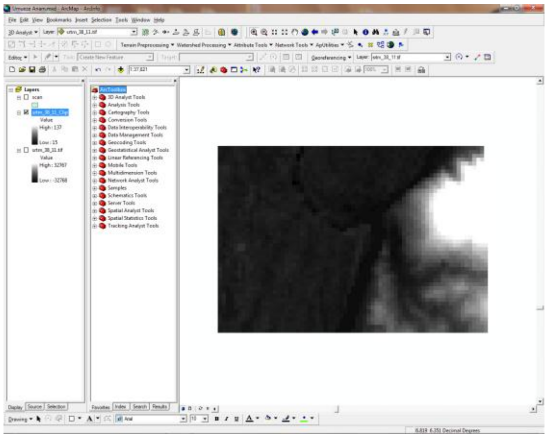

Fig 2.1 SRTM Imagery just before Fill tool is used

2.2.5 Flow Direction

This function computes the flow direction for a given grid. The values in the cells of the flow direction grid indicate the direction of the steepest descent from that cell.

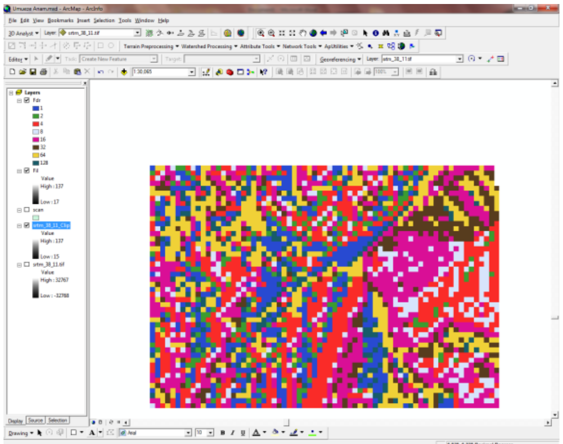

Fig 2.2 Flow Direction from SRTM

2.2.6 Catchment Grid Delineation

This function creates a grid in which each cell carries a value (Grid code) indicating to which catchment the cell belongs. The value corresponds to the value carried by the stream segment that drains that area, defined in the stream segment link grid.

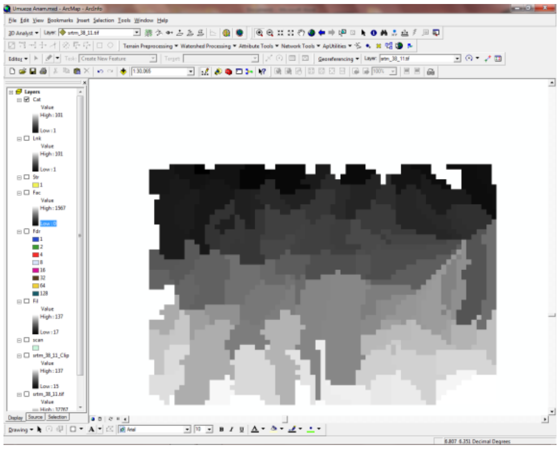

Fig 2.3 Catchment Grid Delineation

2.2.7 Drainage Line Processing

This function converts the input Stream Link grid into a Drainage Line feature class. Each line in the feature class carries the identifier of the catchment in which it resides.

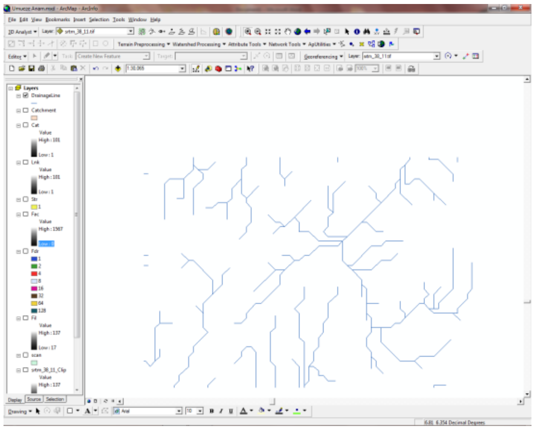

Fig 2.4 Drainage Line Processing

3. RESULTS AND ANALYSIS

3.1 Triangulated Irregular Network

Topographic surfaces are non-stationary (Pike et al, 1975), i.e., the roughness of the terrain is not periodic but changes from one land type to another. A regular grid therefore has to be adjusted to the roughest terrain in the model and be highly redundant in smooth terrain. It is apparent that, if one is to model these non-stationary surfaces accurately and efficiently, one must use a method which adapts to this variation. Peucker et al (1975) while modelling the surface of a terrain as a sheet of triangular facets described it as Triangulated Irregular Network. A triangulated irregular network (TIN) is a digital data structure used in a geographic information system (GIS) for the representation of a surface. A TIN is a vector-based representation of the physical land surface or sea bottom, made up of irregularly distributed nodes and lines with three-dimensional coordinates (*x*, *y*, and *z*) that are arranged in a network of nonoverlapping triangles. TINs are often derived from the elevation data of a rasterized digital elevation model (DEM). An advantage of using a TIN over a raster DEM in mapping and analysis is that the points of a TIN are distributed variably based on an algorithm that determines which points are most necessary to an accurate representation of the terrain.

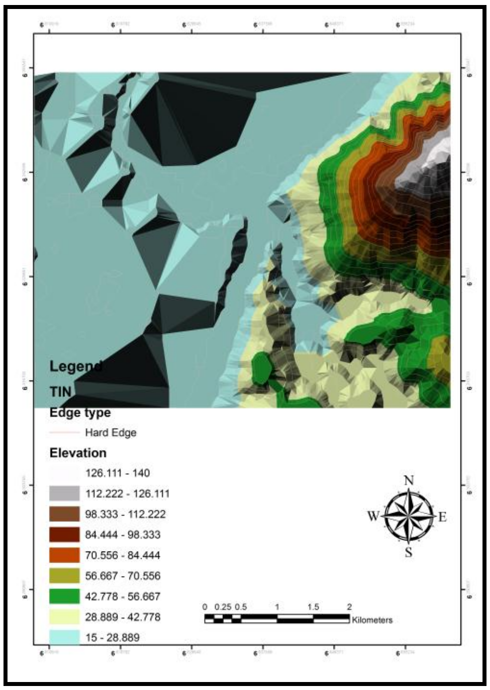

Fig 3.1 Triangulated Irregular Network (TIN) of Study Area

3.2 Generation of Surface Roughness Vector Models

Aspect (Terrain Angles of inclination and Azimuth) map, Slope, Hill-shade with contour were created for the study area. The shaded relief (Hill-shade) (figure 4.3) was created from surface raster of the area with an Azimuth angle of light source measured clockwise from north and altitude directly overhead. Slope represents the rate of change of elevation for each DEM cell. Its the first derivative of a DEM (figure 4.5). Aspect determines the downslope direction of the maximum rate of change in value from each cell to its neighbors. It can be thought of as slope direction (figure 4.4). Li et al., (2005) documented that the complexity of a terrain surface may be described by the concept of its roughness and irregularity which are characterized by different numerical parameters or descriptors such as roughness vectors (slope, aspect, relief, etc).

The Slope algorithm

The rates of change (delta) of the surface in the horizontal (dz/dx) and vertical (dz/dy) directions from the center cell determine the slope. The basic algorithm used to calculate the slope is:

$$slope\_radians = \text{ATAN} \left(\sqrt{([dz/dx]^2 + [dz/dy]^2)} \right)$$

Slope is commonly measured in degrees, which uses the algorithm:

$$slope\_degrees = \text{ATAN} \left(\sqrt{([dz/dx]^2 + [dz/dy]^2)} \right) * 57.29578$$

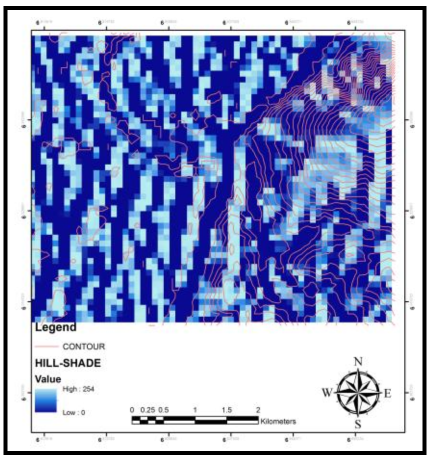

Figure 3.2: Hill-Shde with Contour Map

3.3 Generating the Digital Terrain Model (DTM)

DTM which contain these numeric properties of the terrain and associated rules for interpreting them provide a fundamental component in the effective modelling and simulation of flood water motions of the study area. A perspective view of the environment was modelled showing the flow kinematics (motion) (figure 3.5).

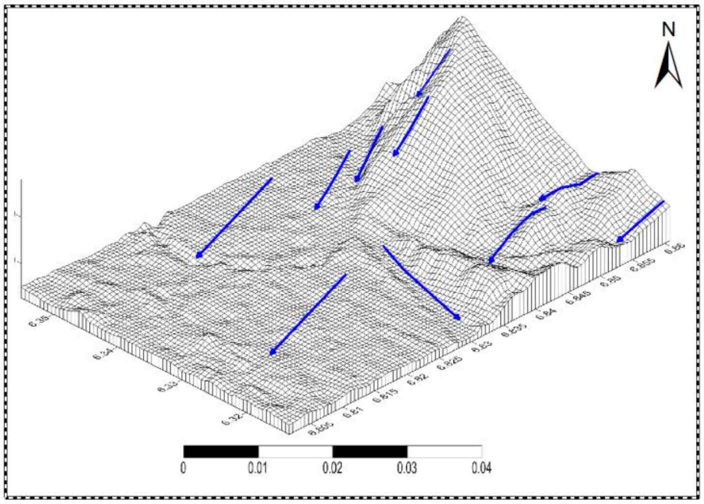

Figure 3.5: Perspective View of Krigged and Flow Model

3.4 Floodplain and Landuse Classification

Classification of wetland and floodplain was carried out in the study area. Results shows that mojority of the area is covered by floodplain. Water body, wetland and builtup areas were also show on the map produced (figure 4.12). The landuse map is depicted in figure 3.6.

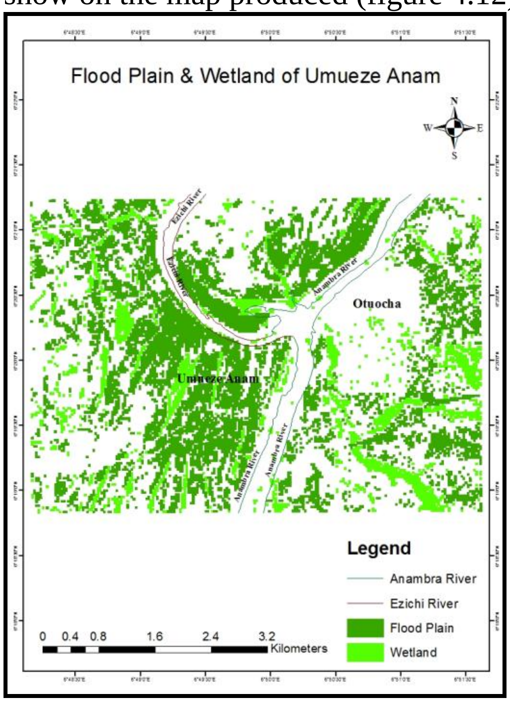

Figure 3.6: Floodplain and Wetland Map

4. CONCLUSION AND RECOMMENDATION

The research work was sucessfully carried out. In the study, topographic data was used to model flood kinematics in Umueze Anam and environs. Result reveal flow direction of flood water in the area. This have shown that the numerical terrain descriptor method is effective in modeling flood water motions. The following recommendations are hereby put forward:
1.Drainage shold be put in place to take up flood waterfrom the surface to avoid spread during raining season.
2. Validation shoild be carried out for the rain-fed flood water motions modeled in Umueze Anam in the wet season.

REFERENCES

1. Tom J. Coulthard and Marco J. Van De Wiel. (2007): Quantifying fluvial non linearity and finding self organized criticality? Insights from simulations of river basin evolution. ScienceDirect; Geomorphology 91 (2007) pg- 216-235.
2. Adger, W. N., Hughes, T. P., Folke, C., Carpenter,S. R. and Rockstrom, J. (2005): Social ecological resilience to coastal disasters, Science, 309, 12 August.
3. Jens H. Christensen, Ole B. Christensen (2002): Severe summertime flooding in Europe. NATURE | VOL 421 | 20 FEBRUARY 2002 | www.nature.com/nature
4. Manfred Mudelsee , Michael Börngen , Gerd Tetzlaff & Uwe Grünewald: No upward trends in the occurrence of extreme floods in central Europe 2003; nature: International Weekly Journal of Science
5. Independent Evaluation Group (2006), Hazards of Nature: Risks to Development. An IEG Evaluation of World Bank Assistance for Natural Disasters, World Bank, Washington, DC, page 48.
6. Pender. G, (Proceedings of the Institution of Civil Engineers; Water Management 159; Pg 3-8. Paper 14426).
7. Ian Douglas, Kurshid Alam, Maryanne Maghenda, Yasmin Mcdonnell, Louise Mclean and Jack Campbell, 2008; Unjust waters: climate change, flooding and the urban poor in Africa. Environment and Urbanization 2008 20: 187.
8. Erege Uchechukwu (2011): An SCS Curve Number & GIS Approach to Rainfall Surface Runoff Estimation in Ogun Sub-Watershed
9. Etuonovbe Angela Kesiena (2011): The Devastating Effect of Flooding in Nigeria**;** FIG Working Week 2011Bridging the Gap between Cultures Marrakech, Morocco, 18-22 May 2011
10. Baiye, E., 1988. Numan in the Throes of Floods, in: The Guardian, Thursday, October 8, pp: 9
11. Akinyemi, T., 1990. Stemming the Tide of Lagos Floods, in: The Guardian, Friday, July 20, pp: 7
12. Nwaubani, C., 1991. Ogunpa River Leaves Bitter Aftertaste in Tragic Course Through Abeokuta; in: The Guardian, October 21, pp: 9

13. Edward-Adebiyi, R., (1997). The Story of Ogunpa, in: The Guardian, Saturday, May 17,pp: 5.
14. Sibley, D. (1995) Geographies of Exclusion: Society and Difference in the West. Routledge, London, Uk
15. Ian Douglas, Kurshid Alam, Maryanne Maghenda, Yasmin Mcdonnell, Louise Mclean and Jack Campbell, 2008; Unjust waters: climate change, flooding and the urban poor in Africa. Environment and Urbanization 2008 20: 187
16. Nwilo. P, Nihinlola. O, and Ayila. Adzandeh (2012): Flood Modelling and Vulnerability Assessment of Settlements in the Adamawa State Floodplain Using GIS and Cellular Framework Approach. Global Journal of HUMAN SOCIAL SCIENCE Volume 12 Issue 3 Version 1.0 February 2012. Global Journals Inc. (USA) Online ISSN: 2249-460x & Print ISSN: 0975-587X
17. Mason, S and A Joubert (1997), "Simulated changes in extreme rainfall over southern Africa", International Journal of Climatology Vol 17, pages 291–301