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FLOODPLAIN DETERMINATION USING GEOGRAPHICAL INFORMATION SYSTEM (GIS) (A CASE STUDY OF OGUNPA RIVER IN IBADAN OYO STATE, NIGERIA)

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ABSTRACT: *Flood causes loss of life, destruction of public and private properties and disrupts the normal cultivating cycle. Floodplains are important land features that are highly discriminated from the neighboring uplands in terms of their hydrological and geomorphologic processes. Ogunpa 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. The aim of this project is to produce a floodplain map within River Ogunpa catchment. The geometric data for the river and flood plain were extracted from the Digital Elevation Model (DEM) using Geographic Information System. The Study analyzed the morphometric parameters of Ogunpa catchment area located in four local government of Ibadan which are Ibadan north local government, Ibadan south local government, Ibadan north east local government, Ibadan south north local government, determining areas which are prone to flooding. Data used were generated from topographical map of Ibadan scale 1:25,000 A triangular irregular network (TIN) was created to satisfy the Delaunay triangle criterion, which ensures that no vertex lies within the interior of any of the triangles in the network. Result obtained indicated that Ogunpa River exhibits high spatial variation in their properties. Ogunpa's water profile increases as the water flows downstream. The result revealed the flow direction of flood water in the area. The water profile increases as one move downstream along the length of the river. It was observed that most of the area was under medium hazard zone. The river has high tendency to flood due to its flat or low-lying terrain. Little or no provision has been made for surface drainage to aggravate the situation. Municipal waste refuse and eroded soil sediments contributes to the lower course stagnation of the river, resulting in poor drainage and tendency for flooding, the existing drainage basin are likely to induce high magnitude of flooding.*

KEYWORDS: Digital elevation model, Triangular irregular network, Flood plain, Flooding.

INTRODUCTION

Flood occurs annually from seasonal rain. Flood causes loss of life, destruction of properties. Floods are one of the most dramatic interactions between man and nature Ward (1978). There has always been a struggle between this force of nature and man's adequate efforts to control it. Physical exposure reflects the type of flood events that can occur and their statistical pattern at a particular site while human vulnerability reflects key socioeconomic factors such as the number of people at risk, the extent of any flood defense works and the ability of the population to anticipate and cope with the hazard. The important factors that influence damage are type of land use, characteristics of flood water including depth, velocity, duration, wave action and solid load and damage reducing actions taken by the occupants of the flooded areas. The extent to which flood characteristics are influenced depends very much on the nature of the modified surface, on the design of the hydrological system and on the climate. Flood simulation and

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damage assessment are being done using flood models. For this purpose, a hydrologic model is used to calculate the runoff from the rainfall and a hydraulic model to determine the water surface profiles at specific locations along the stream. Visualization of the flood simulation results, vulnerability or risk analysis and damage assessment can be done using GIS (Geographic Information Systems). GIS is used to develop and evaluate alternative plans that may facilitate compromise among interested parties. It provides more and better information for decision making situations. It allows the decision makers to identify a list, meeting a predefined set of criteria with the overlay process and the multi-criteria decision analysis within. In the years, period in 1980, Ibadan, the capital of oyo state went under the waters with an unprecedented flood which killed hundreds of people and destroyed properties, Ogunpa river which over flew its banks and resulted in deaths was channelized and believed a lasting solution had been found but surprisingly the river flooded again august, 2011.

MATERIALS AND METHODS

Study area Ogunpa River is located in Ibadan at a latitude of 3^0 35'and 4^0 10'N and a longitude of 7^0 2'and 7^0 4'E. Ibadan is the capital of Oyo State, Nigeria, in West Africa. Floodplain was generally the area contained by the upland valley walls and was defined by drawing or digitizing the most visual breaks between the flat lowland adjacent the river course and the upland areas. This graphic delineation process was facilitated by rather discrete lowland to upland changes in land use and land cover and topography. Different data types and sources were applied in a quest to give a robust expression to the outlined aims and objectives of this research using site visits, review of past reports and records of flooding in the area and so also to enable a closer view of the sampled area which cut across four (4) local government in Ibadan namely: Ibadan North, South, North East and South North local Government respectively.

Data access and sources

Data availability is of prime importance when using GIS. In the current study, map sheets provided information on a comprehensive body of secondary information related to environmental, (streams network and wetlands), socio-cultural (municipal and land use) and economic factor (road network). Also, existing literature were used extensively and the internet serve as a provider. Data acquired during the research were obtained by spatial and aspatial methods. The spatial methods of data acquisition are;

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.

Topographic maps

The topographical map of Ibadan was collected from the map department at Oyo state secretariat, Ibadan. The map was studied and the catchments area for the study area was delineated on the map, which was scanned, Geo-referenced and digitized thereby serving as a data base.

Aspatial mode of data acquisition

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

Data analysis

Prior the scanning and digitizing of the map sheet maps which were scanned, Geo-referenced and digitized thereby serving as a data base that makes up Ibadan topography, processing of the maps came to the stage of geo referencing where tic points were picked on the map sitting on the srtm and the necessary registering, geo- rectification and transformation were done in the arc-view environment.

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 cognizance contours, roads, and rivers, areas liable to flood etc.

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;

a. Areas liable to flood

b. Water bodies

c. Wetlands

d. Elevated areas

e. Roads

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.

Pre-processing of srtm imagery

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.

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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.

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.

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

Generating of Triangulated Irregular Network (TIN)

TIN was derived from the elevation data of a rasterized digital elevation model (DEM). TIN was used over a raster DEM in mapping and analysis; 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.

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. In selecting a susceptible floodplains area, the slope, elevation and aspect were generated clipped out of the study area using clipped analysts' tool from 3D analyst. Buffer zones were drawn around features of drainage and triangular irregular network (TIN) for developing terrain. Using this three-dimensional cross-section point, TIN model of the stream channel and floodplain was constructed. TIN created solely from vector data includes the stream channel and floodplain, but not the surrounding landscape. To best represent the terrain, the TIN includes areas both inside and outside the floodplain in order to give a sense of context. The grid (DEM) is the standard data model was used for small-scale representation of the general land surface. So in order to create a comprehensive TIN, a method to integrate relatively lower solution digital elevation model (DEM) data with comparatively higher resolution vector floodplain data was required. By combining the vector and raster data to form a TIN, the intended result was a continuous three-dimensional landscape surface that contains additional detail in stream channels. This approach was employed to form the TIN terrain model. Application of the approach consists of the following steps:

i. DEM was clipped to a manageable size. The TNRIS DEM has the same areal extent as a USGS 7.5-minute quadrangle map. Using the script Gridclip.ave, the DEM was clipped to the extent of any given polygon theme. The script requires a DEM and clipping polygon theme as inputs. The output is a clipped DEM.

ii. Raster to vector conversion on the clipped DEM to create a point shaped file of terrain elevations. This is performed using the script R2Vpoint.ave. In the conversion process,

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the DEM cells are converted to a point shape file, with each point attributed with the elevation of the cell.

iii. A bounding polygon was constructed from the cross-section endpoints. The script Boundary carries out this task. The script was used in the cross-section theme as input to create the bounding polygon theme.

iv. Any point from the DEM point theme that falls within the bounding Polygon was eliminated. First, the DEM point theme was intersected with the bounding polygon theme using the Theme/Select by Theme menu option in the ArcView view window. The selected points were deleted from the point shape-file using the Table/Start Editing menu option in the ArcView table window, followed by Edit/Delete Records.

v. From the cross-section theme, center point and bank stations were extracted in each cross-section in order to create a three-dimensional line theme consisting of the stream centerline and bank lines. The Avenue script Banklines.ave performs this task.

vi. TIN was created using three input data sources: the DEM point theme, cross-section line theme, and the centerline and banks line theme. TIN nodes are formed from the DEM points and the vertices of the cross-section lines. The stream centerline and bank lines are enforced in the TIN as break lines. The TIN was created using the Surface and Create TIN from Features menu item from the ArcView view window.

RESULT AND DISCUSSION

Using the results of the GIS analyses, fieldwork was initiated to determine the veracity of our predictions about potential reference in the floodplain.

Triangulated Irregular Network (TIN) of study area

A triangulated irregular network (TIN) is a digital data structure used in a geographic information system (GIS) for the representation of a surface. Figure 1 is showing topographic surfaces which are non-stationary i.e., the roughness of the terrain is not periodic but changes from one land type to another. A regular grid therefore was adjusted to the roughest terrain in the ARC-GIS model and was highly redundant in smooth terrain. It was apparent that, modelling these non-stationary surfaces accurately and efficiently adapting to this variation, while modelling the surface of a terrain as a sheet of triangular facets. Figure 1 is used in 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 non over lapping triangles. TIN determines which points are most necessary to an accurate representation of the terrain. The resulting triangulation satisfies the delavancy triangle criterion, which ensures that no Vertex lies within the interior of any of the circumstances of the triangle network. Values from 194.3-211.4>211.4-228>228.6>245.7 shows areas of high terrain which are classified as moderately vulnerable to flooding while values ranging from160-177.1>, 177.2-194.2>, 245.8-262.8>262.9-280 shows areas of very low terrain which are classified as highly vulnerable to flooding and easy access to water, excess water getting to this region without proper drainage can lead on flooding. Hence the steepness of the terrain reduces as the value reduces.

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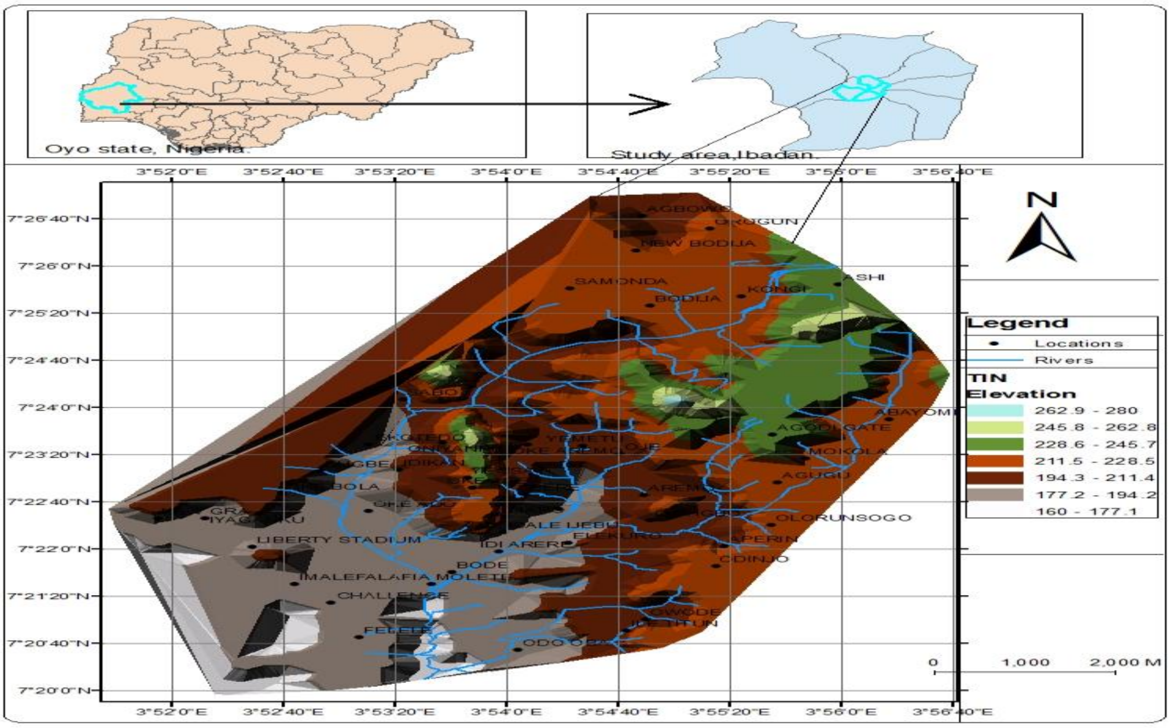

Figure 1: Triangulated Irregular Network of study area.

Aspect of study area

Figure 2 below, shows aspect map of Ogunpa catchment area, it 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. It's the first derivative of a DEM (figure 2). 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, 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 vector aspect, relief. It shows the degree direction of which the topographic slope faces. It shows the determinant of vegetation communities, habitat, and other biological and physical landscape characteristics. It shows the study area is sparsely vegetated going by the result from the legend of the map which ranges are considerably low.

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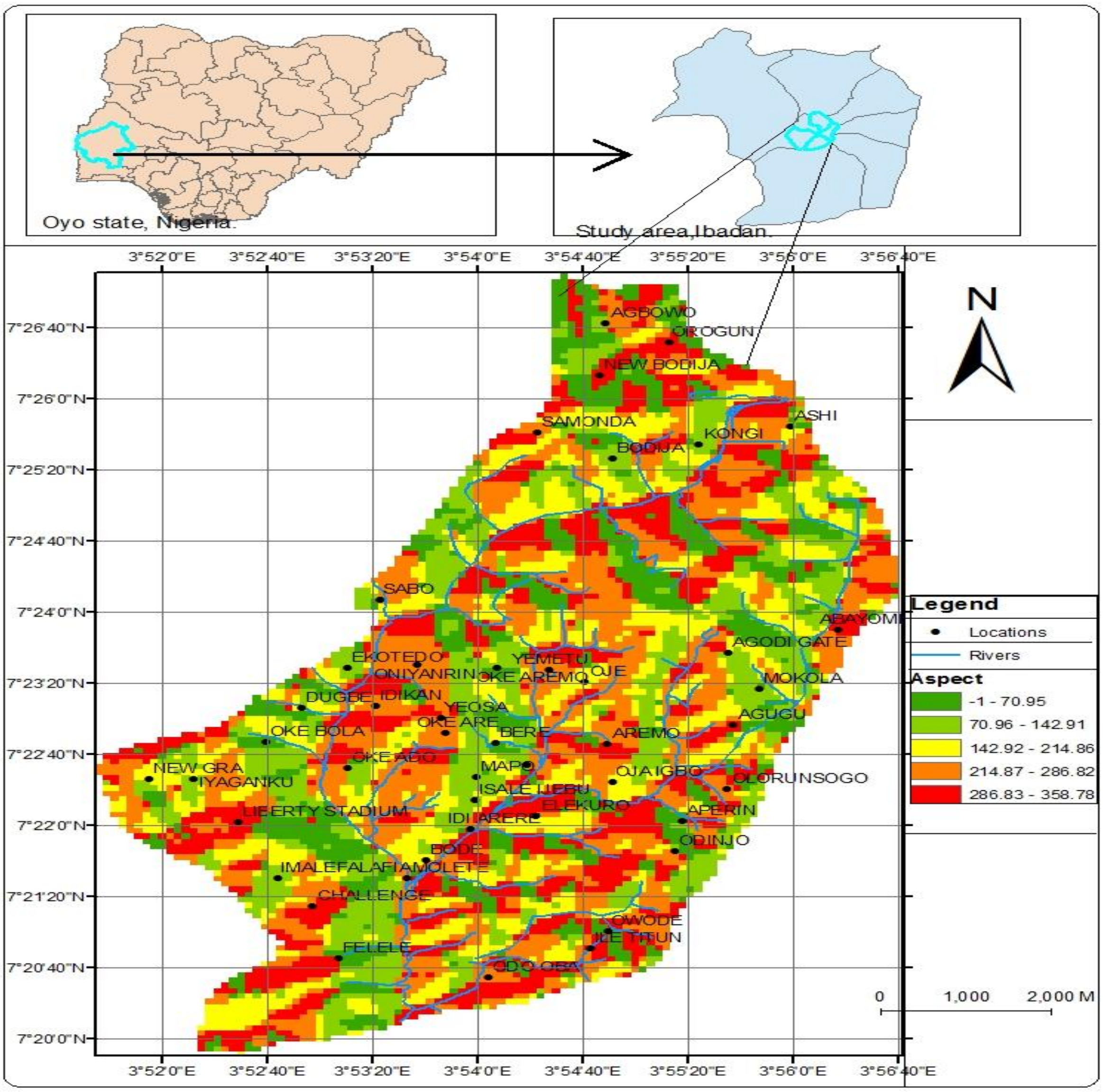

Figure 2: Aspect map of study area.

Slope of study area

Figure 3 below shows slope map of Ogunpa catchment area, the mean reference slope at each survey point was derived by land cover category. Slope was used to determine if the study area means were significantly different from one another and if some means were in homogenous groups. Overall, there was a significant variation in mean slope of the reference data by land cover category. Terrain slope under deciduous and mixed canopy was significantly steeper than other land covers. The other land covers (i.e., low grass, high grass, and scrub-shrub) did not exhibit significantly different mean slopes. As a set, slope was under-predicted as actual terrain slope increased (figure 3). Separate univariate linear models were computed between mean signed error and slope class and land cover class. The results indicate mean signed slope error varies by slope class when controlling for land cover. Slope was over-predicted for the lowest slope category and under predicted for the higher categories. This relationship was statistically significant for the high grass, scrub-shrub, mixed land cover, and deciduous. Slope

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characterize the percent of terrain slope, classified by 0-1.57, 1.58-5.88, 5.88-30.98 and >30.98 percent. It shows the steepness and direction of slope of study area in the descending order of the percent, giving us knowledge of direction of flow of water, Identifying areas at risk for flooding. The map shows the following information ranked by level of detail: Due to the very detailed legend with its exhausting unit area description (at least four levels of information for every unit area. First and second level, the percent of hazard or instability. The first level provides information concerning the confirmed or inferred degree of hazard or instability, by the use of colors and percent. green indicate a high degree of hazard. The second level of detail is provided by differentiation within green and lemon according to weather human life and hard structures are endangered (greens) or if the hazard is confined to loss of arable land and soils (lemon).Third level of information, suspected higher degree of hazard or instability If less than 50% of an unit area is suspected to a higher degree of instability the second character of the resulting polygon name (unit code) is "1"; if this is the case for more than 50% the second character is a "2".Fourth level of information type, evidence and corresponding degree of hazard or instability per unit area. The type of hazard is indicated on the map by corresponding erosion (deep or shallow).

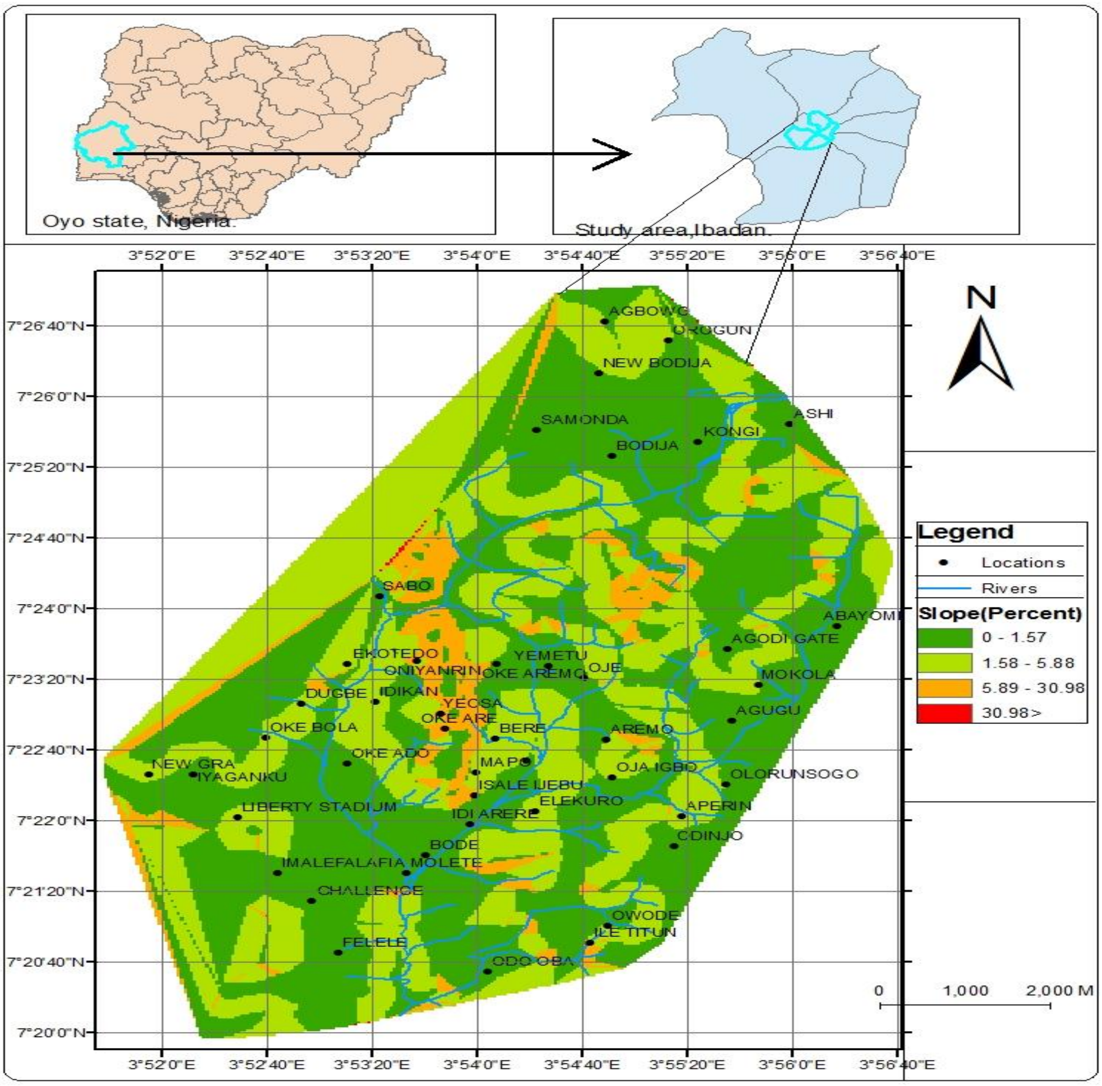

Figure 3: Slope map of study area

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Drainage of study area

Figure 4 below shows the converts of 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. Drainage of the study area shows watershed boundaries with the help of GIS, it shows the main river and its attributes helping us see the direction of the water flow. The area has high drainage which indicates high resistance, dense vegetation, low relief region, whereas regions of weak and impermeable soil material have sparse vegetation and mountainous relief. Gis has helped to know the drainage valve, which suggest moderate to high permeability of the terrain. Figure 4 shows that the streams are deflected from there straight path and follow somewhat transitional course. Steep rocky catchments with less vegetation will produce more runoff compared to flat tracts with more vegetation.

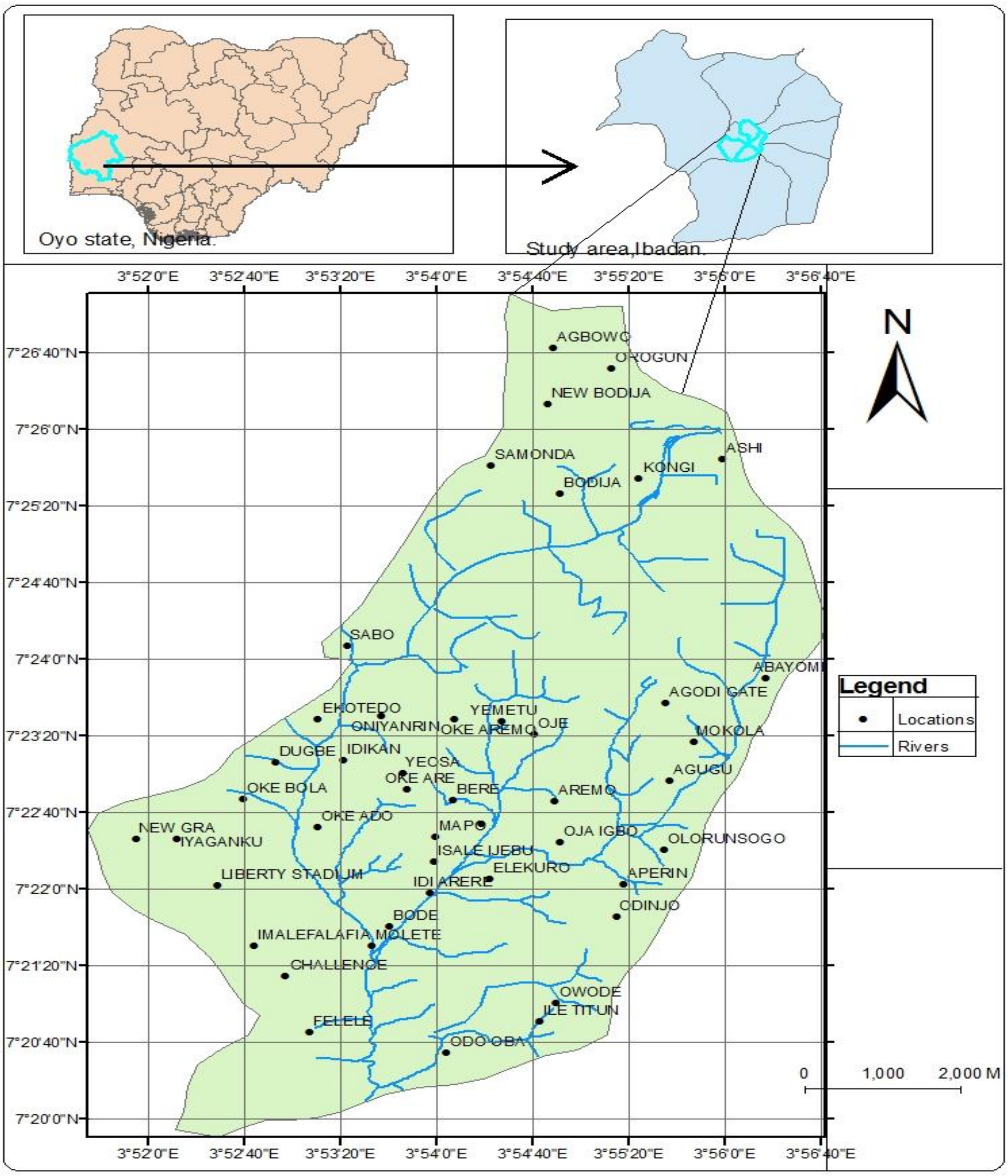

Figure 4: Drainage map of study area

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Natural Differential Vegetation Index (NDVI) of study area

Figure 5 below shows the natural differential vegetation index of study area. DTM which contain these numeric properties of the terrain and associated rules for interpreting them provide a fundamental component in the effective modeling and simulation of flood water motions of the study area. NDVI value ranging from high to low shows low vegetation activity on the study area.

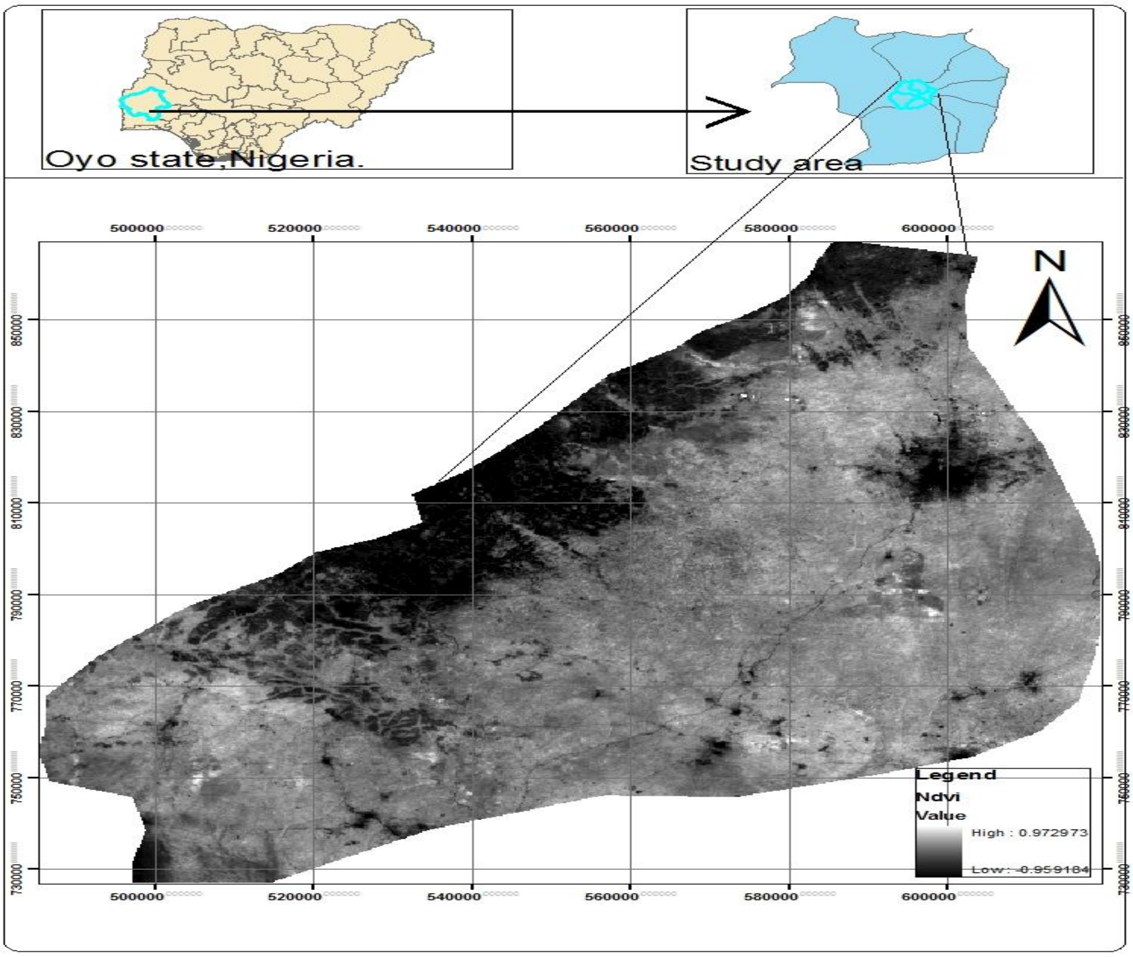

Figure 5: Natural differential vegetation index of study area.

Contour interpretation of study area

In figure 6 below shows flood interpolation taken by dividing the combined satellite mask image into regions of constant minimum flow, interpolated values were ensured of lying within the minimum and maximum flow bounds by interpolating each region independently. In each region, contours of equal flow are interpolated from the boundary points, at which the minimum flow is known. Each contour was interpolated using a flooding simulation extending from the next higher and lower boundaries. Regions having the minimum flow value or representing land that did not flood at the largest flow were not included and were used as the lower and upper limit of interpolation accordingly. The contour map was buffered out of the land use map

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showing areas of equal elevation symbolizing steeper areas and flatter areas measured in meters.

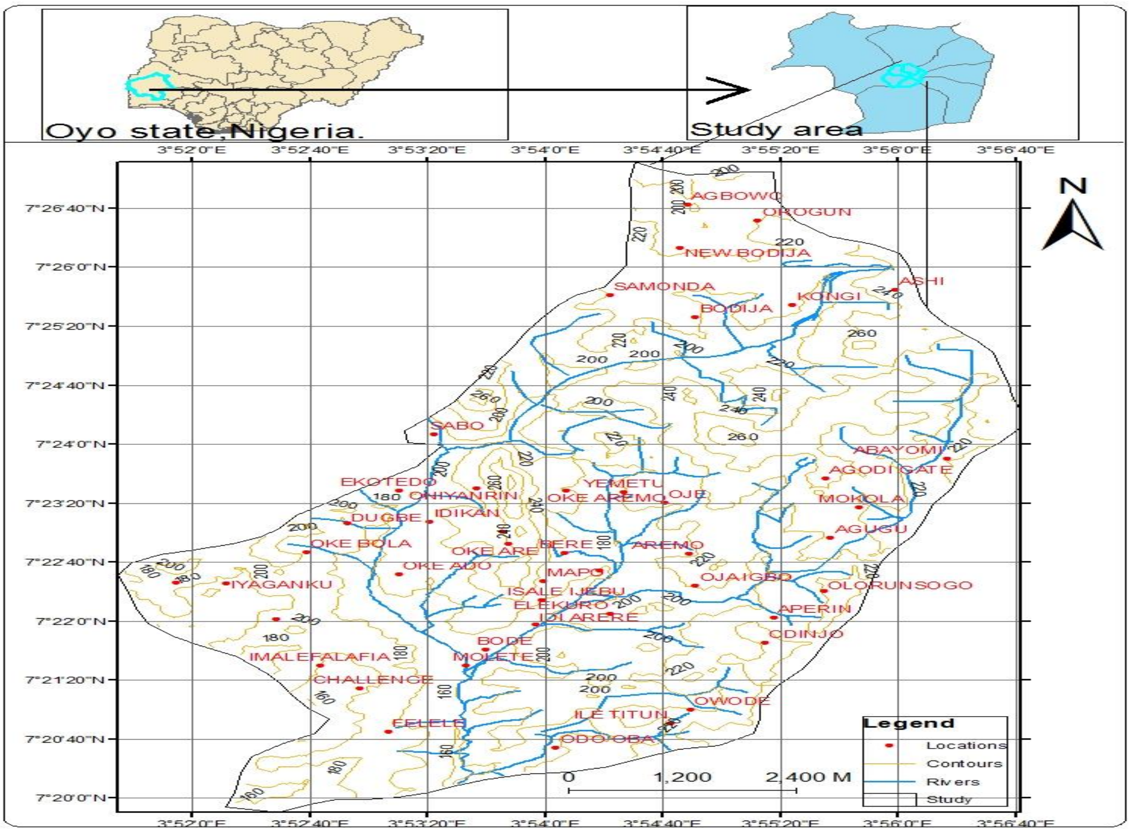

Figure 6: Contour map showing places of equal elevation of study area.

Elevation of study area

Figure 7 below shows elevation data, such as spot elevations at summits and depressions and break lines, can was included in the TIN model. Break lines represent significant terrain features like streams or roads that are indicative of a change in slope; In three-dimensional surface representation and modeling, the TIN is generally the; For each cross-section, the lateral and elevation coordinates of all points (black shade in Figure 7) are read and stored in an ArcView global variable. Using these values, the coordinates of the point possessing the minimum channel elevation are determined. Showing from the map there are multiple points possessing the same minimum channel elevation, the lateral coordinate of the channel center is calculated by averaging the lateral coordinates of all points possessing the same minimum elevation. From figure 7 the elevation value of 281 from the legend shows areas that are not susceptible to flooding and value 148 from the legend showing susceptible areas to flooding. It is observed that in the case of first order stream, there is maximum frequency and there is decrease in stream frequency as the stream order increases.

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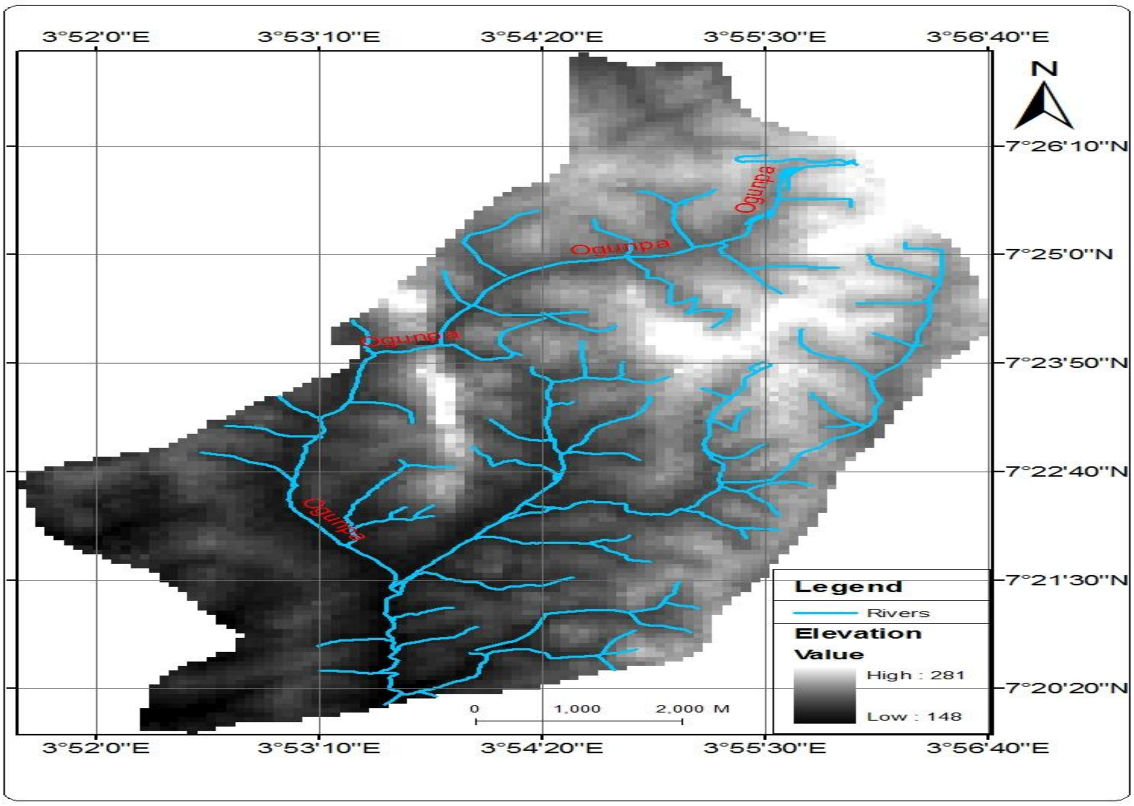

Figure 7: Elevation map of study area

Floodplain map

Hence, two things are known about the floodplain at each cross-section: water surface elevation and extent. In determining the lateral coordinates of the floodplain boundaries, the computed water surface elevation was used. The cross-section read from the left end of the cross-section to the right end. When the computed water surface elevation falls between the elevations coordinates of two adjacent points using water level of 180 meters and vegetal aggregation of 3.75 in figure 8 below and vegetal aggregation of 3.65 in figure 8 below the coordinates of these bounding points are noted. The extent of the flood masks of each flow provides a boundary line of equal flood extent. These interpolated pixels to obtain the flow at all other pixels in the image. Once the data was converted to polygons in the GIS it was clear that each Flood Unit contained small areas of floodplain that were inundated at the same particular flow. These areas were termed unique Ecological Units as they will have similar ecology due to their similar elevation and the fact that distribution of floodplain vegetation communities is strongly related to flooding frequency.For the upper course of the river, the water surface profile did not exceed the bank of the channel, and there was no indication of flooding in the area. For the middle and lower course regions, however, the water surface profile did exceed the bank of the channel, making these areas a frequent flood zone. Despite the topographical irregularities in the river bed slope (which is due to the impervious nature of Ibadan's geological surface), it was found that the Ogunpa's water profile increases as the water flows downstream. The water profile increases as one move downstream along the length of the river. The highest water elevations were measured at the lower course, which is due to the compilation and build-up of refuse in this particular region, as shown in Fi gure 8 below.

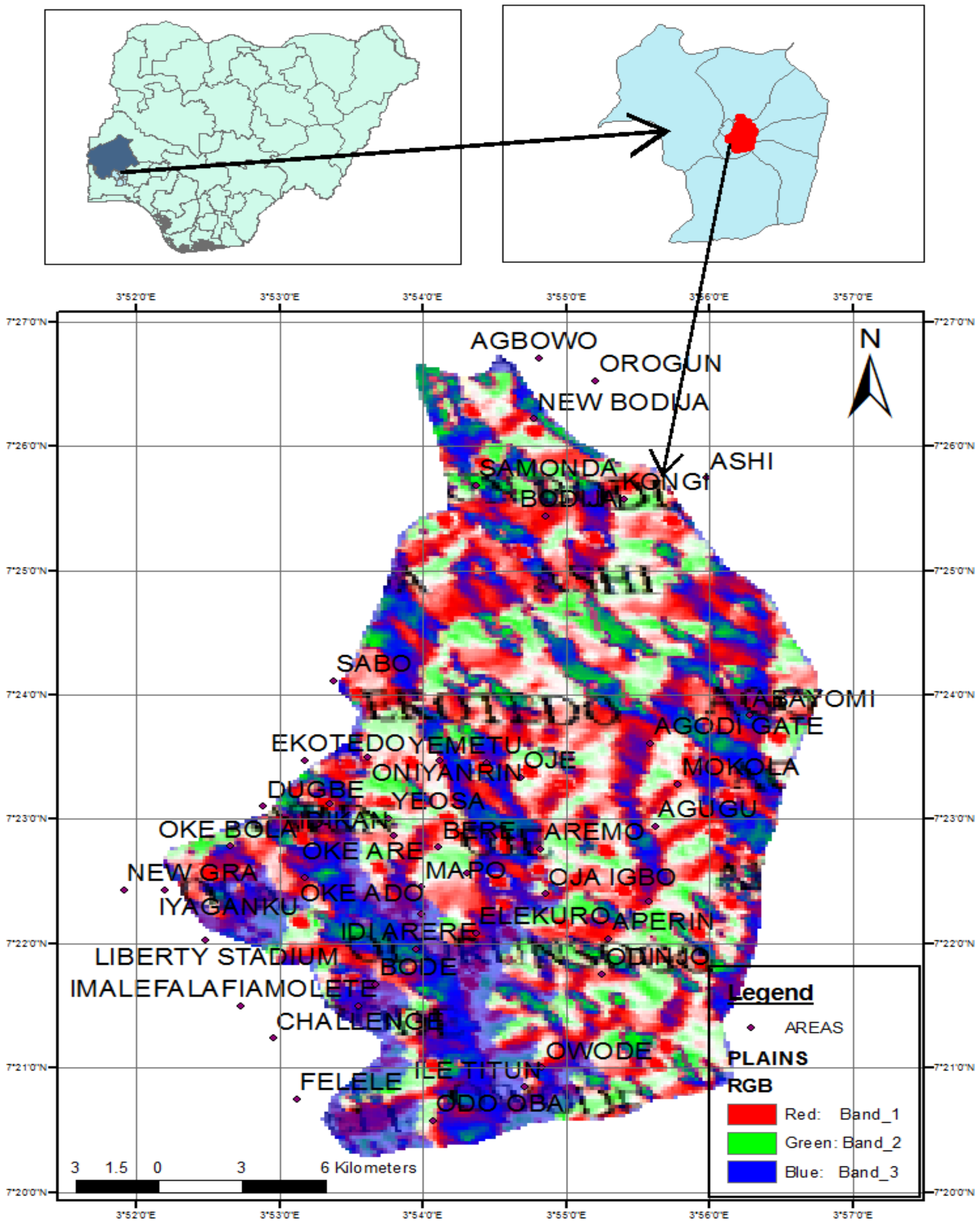

Figure 8: Floodplain map showing areas that are prior to flooding in Ogunpa catchment

CONCLUSION AND RECOMMENDATION

Ogunpa river basin has higher relief ratio, the higher erosive capacity and sediment yields which disposes the basin to higher flood peaks. Poor waste management combined with an inadequate drainage system (nonexistent water infrastructure) is a key factor in the frequent

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flooding of the River. However, the climate of this region cannot be overlooked as it greatly exacerbates the high probability of flooding in the region. Geospatial techniques were integrated for the mapping and analysis of flood extent and vulnerable areas. The study successively delineated the flooded areas, vulnerable and risk zones, by the flood if the water level get to 180 meters and vegetal aggregation of 3.75 and 3.65 in the study area The accuracy of the topographic information is very critical to identify of outlining floodplains in 3 Dimension. In this study, the 1/25,000 scale maps was used and it's refined enough for some other types of studies. The extent of the floodplain can be very sensitive to small changes in the Digital Terrain Model.

In this study, the use of GIS for the determination of floodplain has both potential to be an accurate improving and cost saving addition to civil engineering available tool. As seen in the project using accurate data and ARC-GIS can accomplish goals using computer technology that would otherwise take weeks and months. Controlled urban development by government agencies such as town planning authority through promulgation of edicts and laws. This is to reduce both the magnitude and frequency of flood being experienced in the basins. In this light, buildings already erected along 180 meters from the river are on floodplains and can be pulled down while areas yet to be built-up can be zoned for future development. Engineering construction such as building of micro dams, stream channelization and construction of embankments along main river channels to reduce flooding. Afforestation programmes to reduce flood incidents during rainy season by promoting infiltration process. This management effort will also aid in conserving water supply for dry season usage.Efficient waste management techniques to reduce flooding due to channel blockage and debris are pile-up. There should be a comprehensive mapping and inventory of all flood plains for proper planning, awareness and enlightenment of flood prone communities.

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