SELECTION OF SUITABLE DRAINAGE PATTERN USING REMOTE SENSING AND GIS TECHNIQUES IN BAUCHI METROPOLIS, BAUCHI STATE, NIGERIA

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Abstract-*This paper describes how Remote Sensing and GIS techniques were used in the selection of suitable drainage pattern in Bauchi town. The satellite imagery of the study area was captured using Google earth software, the imageries were glued using CorelDraw Suit 1.2 to produce a single map of the area which was geo referenced using ILWIS (Integrated Land and Water Information System) 3.3 and then exported to Arc View GIS 3.2a. The scanned topographical sheet 149 (Bauchi N.E) of the study area was sourced and geo referenced using ILWIS 3.3, the area of interest, that is, area of Bauchi town was sub mapped and the contours in the sub mapped topo sheet were digitized using ILWIS 3.3 which was also exported to Arc View GIS 3.2a. Furthermore, analysis maps of the study area were generated from the digitized contours in sequential order using ILWIS 3.3, which include Digital Elevation Model (DEM), Flow Direction Map, Flow Accumulation Map, Slope in Percentage, Aspect Map as well as the Optimal and Suitable Drainage Patterns of the study area. The optimal and suitable drainage patterns were exported to Arc View GIS 3.2a to form overlays. In the Arc View GIS environment, simultaneous approach of digitations was applied whereby the glued satellite imagery of the study area was digitized to obtain the built-up areas and roads, digitizing the sub mapped topo sheet to generate the contours was also done. At the end, overlays of built-up area, roads and contour as well as optimal and suitable drainage patterns of the study area can be produced. Recommendations were made on the use of GIS and remote sensing to reduce the effect of flooding.*

***Keywords*:** Contour Lines, Digitizing, Flooding, Geographic Information System (GIS), Remote sensing.

1.0. INTRODUCTION.

Flood usually occurs due to poor drainage system within and around the area in question. (Mazumber, 1983).The essential principle of any type of land drainage is to provide an open, adequate and readily accessible channel through which the surface or subsoil water can flow. The physical surface of the earth (land) is in constant change, abundant water resources give rise to new growth, cities expand, what was one forest is converted to farm land. Man causes some of these transformations; others are merely the result of the changing of the seasons (Wikipedia, the free encyclopedia). Therefore land is one of the basic natural resources that require a total preservation and management for the sustainable survival of the survivors on it. The factors that bring about land

degradation are too many which include water flooding, desertification, erosion, etc. but here, only one will be treated which is water flooding, and the means of solving the problem is by the suitable selection of drainage pattern through the application of flow accumulation analysis by the use of Remote Sensing and GIS. Floods are among the most devastating natural disasters in the world, claiming more lives and causing more property damage than any other natural phenomena (Akintola, F. O. 1978).

Hence, there is the need to explore new approaches in solving these peculiar flood problems by employing flow accumulation analysis through the use of remote sensing and GIS. Various establishments and professionals have defined GIS from different perspectives. There is, however, consensus on the basic tenets of GIS, its effectiveness, qualities and characteristics. In its simplest form, geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts (Microsoft Encarta 2009).

Bauchi town is the headquarters of Bauchi State with administrative and commercial activities carried out in the city. Like many other cities of Nigeria, Bauchi has rapid increase of population which results in the need of shelter by the dwellers. However the issue of flooding has continue to serve as a setback to the town especially during the raining season, where by water use to overflows into houses and even to rooms of some residence especially those residing within the lower elevation of the area thereby creating large scale damage to properties and sometimes even lost of lives. Some of the major areas that are experiencing flood hazards in the case study area include: Doya quarters, Kofar dumi, Bayan bata, Karofin madaki, Rariya and Wunti roundabout.

Bauchi town, located at latitude 10°17' North and longitude 9°49' North, is the dominant urban center in the state. It covers an area of about 1662.118 sq.km, and most of the 398,190 inhabitants of Bauchi local Government area live within the city and its environs. The town lies within the undifferentiated basement complex with older granite (out crops) and young granites out crops. Basement complex as the

crystalline rocks of the area are located in the area of high relief with relatively runoff and low infiltration rate (offodile, 1983).

It composes of shallow soil which include sandy, clay and loamy soil type in iron pan, underlie by crystalline rocks, hills, mountains, which include rock elements on slope of hills and mountains, boulder accumulations with little or no soil.

The area under study is of tropical continental (Sudan) climate. This type of climate consists of two seasons; a rainy/wet season and a dry season. The rainy season mostly start from April or May and ends in October. Also during this season, humidity is high to about twelve percent in February to about sixty eight percent in August and temperature is high about 32°c (90°f) (Burnette 1965). The dry season usually start from November to April. This is a long period of dry weather with high temperature during the day and low temperature at night. Average temperature during this season is about 21°c (about 70°f) (Burnatte 1965). Mean daily maximum temperatures range from 29.2°c in July and August to 37.6° in March and April. The mean daily minimum ranges from about 11.7°c in December and January to about 24.7° in April and May. There is a severe harmattan period from December to February. This is the period when the North-East trade winds begin to blow South wards in to the country from the Sahara belt. At this period it is generally cooler than normal with less humidity and visibility at certain times is restricted as a result of airborne dust.

Vegetation in the study area is the savannah type with sporadic thorny bushes, shrubs and isolated trees. It is generally characterized by undifferentiated mixed wood lands, particularly mixed acacia (Bain, A.D. 1926).

The study area is characterized by dendritic drainage pattern base on the natural topography of the area. A dendritic drainage pattern tends to develop where a whole drainage basin is made up of the same type of rock. Dendritic drainage resembles the shape of a tree, with the smallest tributaries being the outermost twigs and the main river channel forming the trunk. In a dendritic drainage pattern, tributary streams generally join at an acute, or less than 90 degree angle forming Y-shaped junctions.

The aim of this paper is to select suitable drainage pattern through the following objectives: To generate the buildup areas as well as the contours of the study area, to design the digital elevation model (DEM) of the study area, to produce analysis maps of the study area, to show the natural drainage pattern of the study area, and finally to select suitable drainage pattern of the study area.

2.0. MATERIALS AND METHODOLOGY

2.1.0 INSTRUMENTS USED.

These include the following:

2.1.1 SOFTWARE; (i)Arc view GIS 3.2a, CorelDraw suites X3, (ii)Google Earth software package, (iii)Integrated Land and Water Information System (ILWIS) version 3.1 and 3.3 Academic, (iv)Microsoft Windows XP Professional Version 2002, service pack 2, and (v)PDF Suite 9.0

2.1.2 HARDWARE; (i)Garmin Handheld GPS receiver 76CSx, (ii)HP printer model D1663, (iii)Laptops: HP pavilion G6, with 64 bit – 4.00 GHz processor and ZINOX Intel Pentium Dual CPU T3400 Laptop with 232GB internal memory, 956MB installed ram, 32 bit – 2.16 GHz processor.

2.2.0 DATA USED: (i)Coordinates (Northing, Easting) of some roundabout within the case study area was obtained using hand held GPS (Global Positioning System) Garmin receiver 76CSx. The coordinates were used to georeferencing the glued imagery. (ii)Glued Satellite imagery from Google Earth with a resolution of 0.6m.

(iii)Scanned Topographical map of Bauchi N.E. which covers the case study area at a scale of 1:50,000 having a contour interval of 10m.

2.3.0 DATA ACQUISITION

A. SCANNED TOPOGRAPHICAL SHEET: The scanned topographical sheet 149 (Bauchi N.E. Edition 3, 2008) at a scale of 1:50,000 covering the case study area was sourced.

B. GLUED SATELLITE IMAGERY: The glued satellite imagery of the study area was sourced by the following procedures:

1. Capturing the Google Earth imagery of the study area.

i. Google Earth was launched.

ii. In 'my place' on the Google Earth window, 'BAUCHI' was searched as shown in figure below.
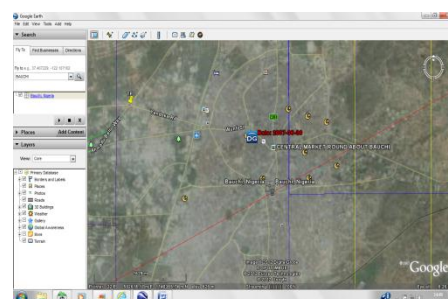
(Google Earth window showing Bauchi Town).

iii. The imagery was zoom- in and capturing was started from the top left hand side of the study area.

iv. From the menu bar, 'file' was clicked and 'save' was selected to save the imagery in the folder created for saving the imageries. The imagery was given identification number as '01s1' i.e imagery1, strip1.

v. After the whole process 1688 imageries were captured and saved in Joint Photographic Experts Group (JPEG) image format.

2. Gluing the satellite imagery.

Coreldraw(suit X3) software was used in glueing the captured satellite imageries as shown below.

(GLUED SATELLITE IMAGERY)

C. GROUND TRUTHING: This is the identification of features on ground. It is a field survey which is undertaken to check the interpretation. During ground truthing, the following information was identified:

The coordinates of some roundabouts in the study area were recorded using Handheld GPS receiver 76SCx, which were used as controls for Georeferencing the glued satellite imagery. The coordinates were tabulated as follows:

S/N	Roundabout(s)	Easting(m)	Northing(m)	Accuracy(m)
1	Dogon yaro Roundabout	588489	1138948	±3
2	Eagle Roundabout	589225	1140259	±2
3	Awalah Rounabout	592114	1143786	±2
4	Nasarawa Roundabout	590803	1139363	±4

Some places that are experiencing flooding within the case study area were identified as follows; Doya quarters, Kofar dumi, Bayan bata, Karofin madaki, Rariya and Wunti roundabout.

Also the coordinates of the flooding areas were recorded as:

Affected areas	N	E
Rariya	1139903	593551
Doya quarters	1139829	593802
Bayan bata	1140453	591960
Kofar dumi	1138822	593832
Karofin madaki	1139372	593142
Wunti market	1140423	591436

2.4.0 DATA PROCESSING.

2.4.1 GEOREFERENCING AND SUB MAPPING THE CASE STUDY AREA FROM THE TOPOGRAPHICAL SHEET.

The following sets of coordinates from the topo sheet were used for Geo referencing the topographical sheet.

Easting	Northing
585000.00	1160000.00
605000.00	1160000.00
605000.00	1135000.00
585000.00	1135000.00

Sub mapping is the process of cutting particular portion from the whole map. In this project, sub mapping was done as follows:

On the Georeferenced topo sheet, the row and column numbers of the top left hand side and that of the down right hand side of the area of interest were recorded as '1464,504' and '543,855' respectively. On the ILWIS window 'operations' was selected from the menu bar, 'raster operation', and 'sub map' were selected. Then 'sub map of raster map dialog box' appeared. In the 'sub map of raster map dialog box', the recorded row and column of the top left hand side and the down right hand side were input, output map name was written as 'Bauchi sub map' and the raster map (Georeference topo sheet) was selected. Then 'show' was clicked. By clicking 'show', map list of 'Bauchi sub map' was automatically appeared. In the display options-map list as color composite, the color bands i.e. red band, green band and blue band were balanced as 1, 2 and 3 respectively. 'Ok' was clicked and then 'Bauchi sub map' was displayed automatically as shown in figure below:
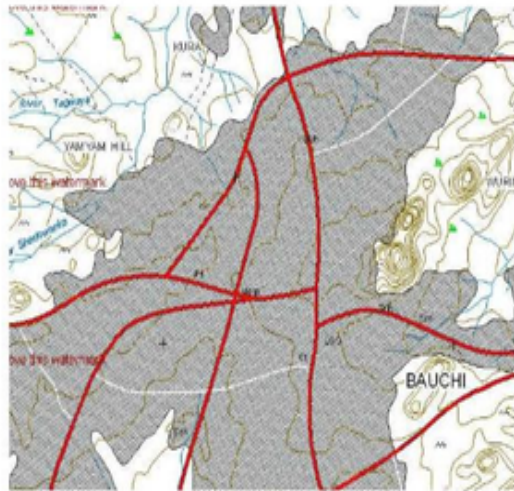
Figure-2.4.1: Sub mapped topo sheet.

2.4.2 CONTOUR DIGITIZATION.

Digitization is the process of converting the analogue map in to digital format. The contours were digitized as follows:

Goto 'Bauchi sub map window',click file icon and select 'create segment map', then 'create segment map dialog box' appeared. In the 'create segment map dialog box', output map name was inputted (typed) as 'study area contour', and the domain value was selected. By doing this the map is ready for digitizing. In the menu bar 'insert mode' was selected and with the 'insert mode' each contour was digitized (traced), the contour values were written as required.
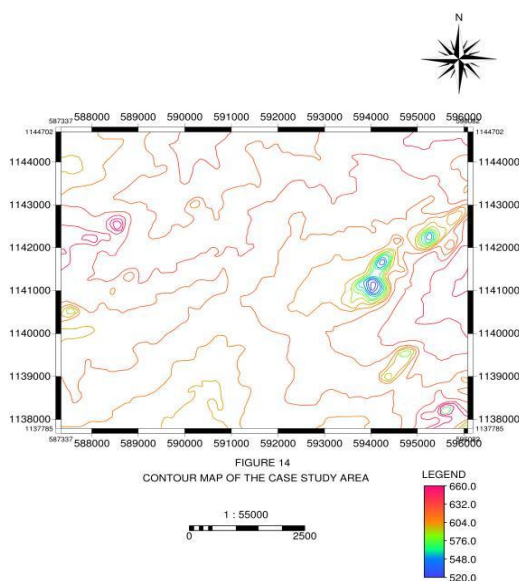
Figure-2.4.2: Contour map of the case study area

2.4.3 GENERATION OF DIGITAL ELEVATION MODEL (DEM).

Digital elevation model (DEM) was generated using contour as input. The process involved the following:

i. In the ILWIS window 'operations' was selected from menu bar, 'interpolation and then 'contour interpolation.

ii. In the 'contour interpolation dialog box', the 'contour map' of the case study area was inputted, the output map name, and the georeferenced map was also inputted, 'show' was clicked then display options-raster map appeared and by clicking 'ok', the digital elevation model of the case study area appeared automatically on the ILIWIS environment.

iii. Then 'file' was clicked and 'create layout' was selected then the save view as dialog box appeared and the map view name was inputted to create layout which include scale, border line, coordinate, legend. Figure below show the digital elevation model (DEM) of the case study area.
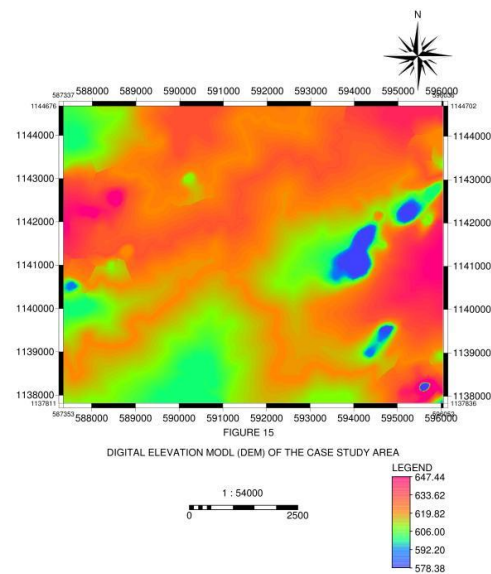

Figure-2.4.3: Digital Elevation Model (DEM) of the study area

2.5.0 PRODUCTION OF ANALYSIS MAPS.

2.5. 1 PRODUCTION OF FLOW DIRECTION MAP.

This involves the following steps:

i. Go to 'Operation' from the menu bar, selected 'DEM hydro-processing', 'flow determination', 'flow direction' and then the 'flow direction dialog box' appeared.

ii. On the 'flow direction dialog box', the digital elevation model (DEM) of the study area was inputted; the method as steepest slope and the output raster map name was inputted as 'flow direction map' and then 'show' was clicked.

iii. Then the display option-raster map dialog box appeared and 'ok' was clicked, then the flow direction map displayed automatically.

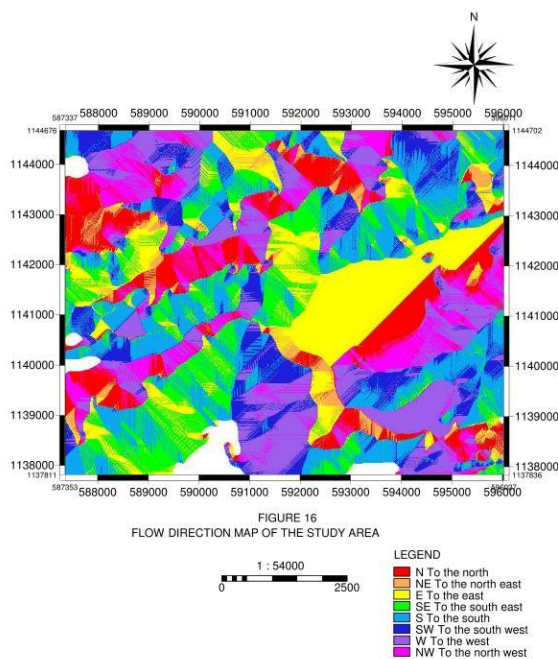iv. Then layout was created as in digital elevation model (DEM). Figure below show flow direction map.

FIGURE 16
FLOW DIRECTION MAP OF THE STUDY AREA

1 : 54000

LEGEND
N To the north
NE To the north east
E To the east
SE To the south east
S To the south
SW To the south west
W To the west
NW To the north west

Figure-2.5. 1: Flow Direction Map of the study area

2.5.2 PRODUCTION OF FLOW ACCUMULATION MAP.

The cumulative counts of the number of pixels that naturally drain into outlets is perform in flow accumulation map. Its operation shows the drainage pattern of a terrain.

The process of generating flow accumulation map is the same as that of flow direction, but the input of the operation is the output map of the Flow direction operation. The output map contains cumulative hydrologic flow values that represent the number of input pixels which contribute any water to any outlets (or sinks if these have not been removed); the outlets of the largest streams, rivers etc. will have the largest values. Figure below show flow accumulation map.
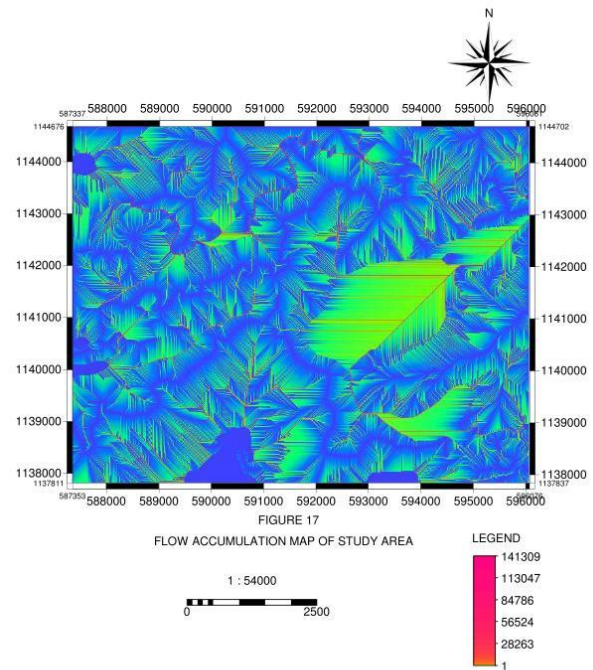

FIGURE 17
FLOW ACCUMULATION MAP OF STUDY AREA

1 : 54000

LEGEND
141309
113047
84786
56524
28263
1

Figure-2.5. 2: Flow Accumulation Map of the study area

2.5.3 PRODUCTION OF SLOPE AND ASPECT MAP.

The characteristics of flow accumulation which include slope and aspect maps were determined. They are created by the use of separate raster objects for each of these terrain characteristics in the ILWIS 3.3 software environment as follows:

Calculation of slope maps in percentages:

(1) Height differences in X-direction were calculated as: start the 'filter operation', select the Digital Elevation Model as the input map and select 'linear filter' dfdx. Call the output map as 'DX'.

(2) Height differences in Y-direction were calculated as: start the Filter operation again, select the Digital Elevation Model as input map and select linear filter dfdy. Call the output map as 'DY'.

(3) To calculate a slope map in percentages from these maps 'DX' and 'DY', the following expression was typed on the command line of the Main window:

SLOPEPCT = 100 * HYP(DX,DY)/ PIXSIZE(DEM)

HYP is an internal Mapcalc/Tabcalc function.

Function PIXSIZE returns the pixel size of a raster map; for DEM

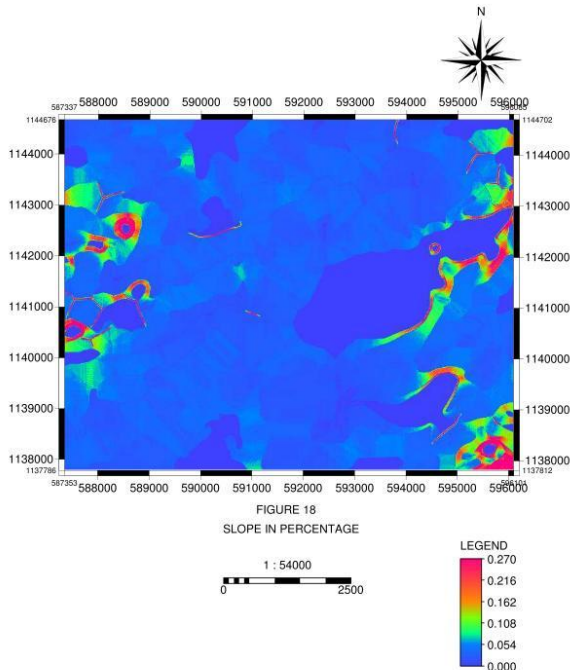SLOPEPCT is the output map name of the slope map in percentages.

Figure-2.5. 3a: Slope in Percentage

Calculation of aspect map:

An Aspect map shows to which side a slope is directed, an aspect value of 0 means that the slope is facing the North, 90 facing the East, 180 facing the South and 270 facing the West, etc.

To calculate a classified aspect map, the following expressional procedure was used:

ASPECTR = ATAN2(DX,DY) + PI

To coznvert the radians into degrees, the following expression was typed:

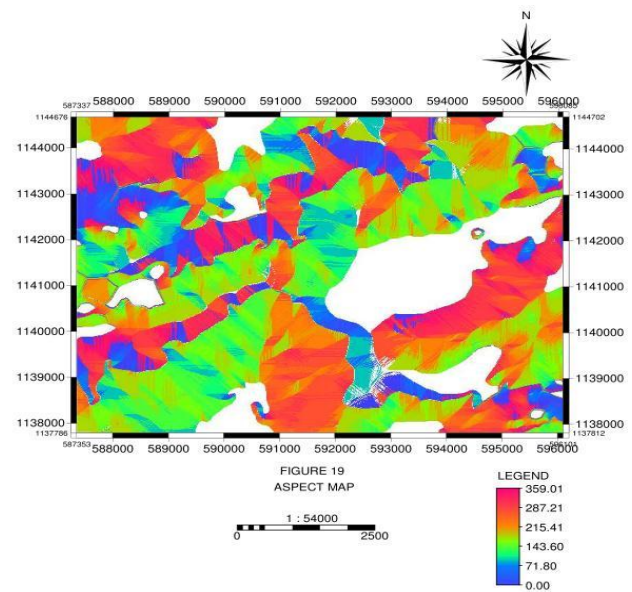ASPECTD = RADDEG((ASPECTR))

Figure-2.5.3b: Aspect Map

2.5.4 STREAM NETWORK PRODUCTION

This involves the production of optimal and suitable drainage network.

Optimal drainage pattern production involved the following:

i. Operations was Clicked from the menu bar and DEM hydro-processing, network catchment extraction, and drainage network extraction were selected, then the drainage network extraction dialog box appeared.

ii. In the dialog box appeared, the 'flow accumulation map' was inputted, the name of the output map was also inputted and 'show' was clicked, then the optimal drainage network appeared as shown in figure below.
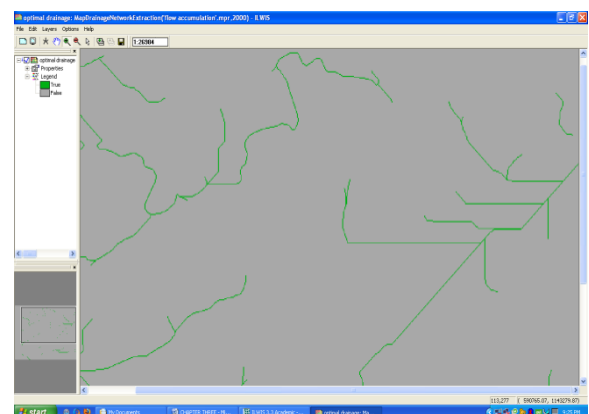

Figure-2.5.4a: ILWIS window showing the optimal drainage network.

Suitable drainage pattern production involved the following:

This involved the same procedure followed as in the production of optimal drainage pattern. But the input map is the optimal drainage map. The suitable drainage network is subjected to edition which gives room for the selection of suitable drainage pattern. Hence the stream pattern can be altered to suite the area under study.
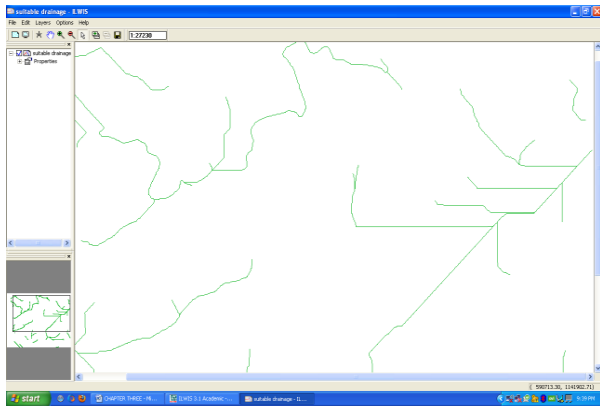

Figure-2.5.4b: ILWIS window showing the suitable drainage network.
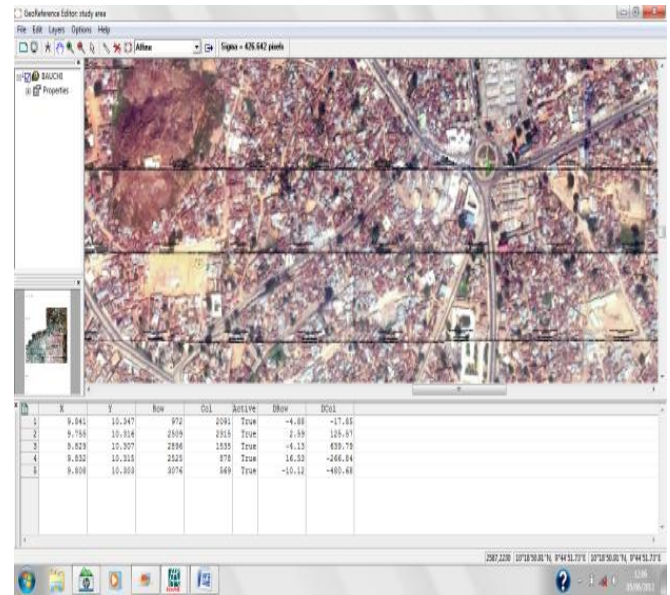
2.5.5 IMPORTING THE SATELLITE IMAGE TO ILWIS ENVIRONMENT.

The same processes were followed as in importing the scanned topographical sheet.

2.5.6 GEO-REFERENCING THE SATELLITE IMAGE IN THE ILWIS ENVIRONMENT.

It involved the following process:

i. In the ILWIS environment 'file' was clicked, 'create' was selected and 'geo-reference' was selected and clicked. Then the geo-reference dialog box was appeared.

ii. In the 'geo-reference dialog box', the geo-reference output name was written, coordinate system was selected i.e. Northing and Easting, georef. Tie points was selected and then 'OK' icon was clicked.

iii. The image was zoom in, the cursor was place at the center of the roundabout and clicked then 'add tie points dialog box' was appeared and the coordinate of the roundabout was imputed as shown in figure below.

(ILWIS window showing how the satellite imagery was georeferenced).

(iv) The process was repeated until the entire coordinates of the four roundabouts were inputted.

3.5.7 EXPORTING THE SATELLITE IMAGERY AND CONTOUR MAP FROM ILWIS ENVIROMENT.

i. The items to be exported were saved in the computer C drive.

ii. In the file menu of the ILWIS environment, 'export' was selected and clicked then the 'export dialog box' appeared.

iii. In the dialog box, the image was selected with the file format as 'Erda.LAN' and the output file name was typed and 'OK' was clicked.

2.5.8 DIGITIZING IN ArcView GIS 3.2a.

In the ArcView GIS, built-up area, major road, minor road and foot path were digitized simultaneously on the satellite imagery as follows:

i. ArcView GIS 3.2a was lunched, then the 'add data dialog box' appeared and 'yes' was clicked.

ii. Then the 'add theme dialog box' appeared, then 'C drive' was clicked to select the new folder (i.e. were the exported image from the ILWIS was saved) and then data source was typed as 'image data source' then the image was selected from the folder and 'OK' was clicked. The same processes were repeated in exporting the optimal and suitable drainage network from ILWIS to ArcView.

iii. 'Image' was clicked in the ArcView environment, and then 'view' was clicked from the menu bar and 'new theme' was selected, the 'new theme dialog box' appeared, then on the feature type 'line' was selected and 'OK' clicked.

iv. Then the same 'new folder' in the 'C drive' was selected and the theme name was typed as 'built-up area' and OK was clicked. The same process was done to create the theme for minor road, major road, foot path and contour.

v. The 'built-up area' was selected and 'theme' from the menu bar was clicked, 'start editing' was selected and then 'draw line' from the standard tool bar was selected to start digitizing the built-up area as shown in figure below.
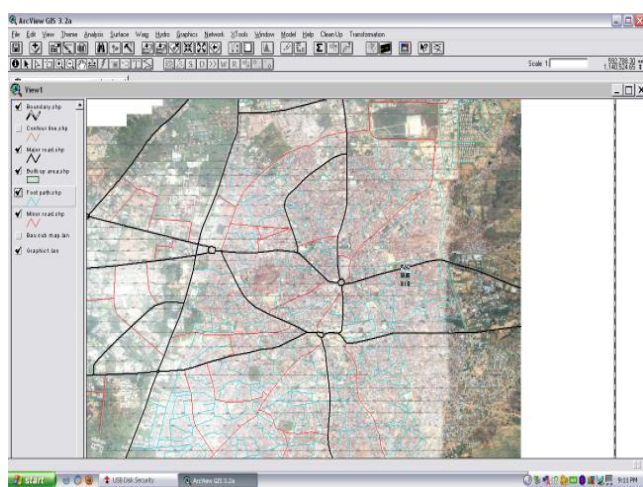
(ArcView GIS window showing how satellite imagery was digitized).

vi. The process was repeated to digitize the major road, minor road and the foot path as shown in figure below.
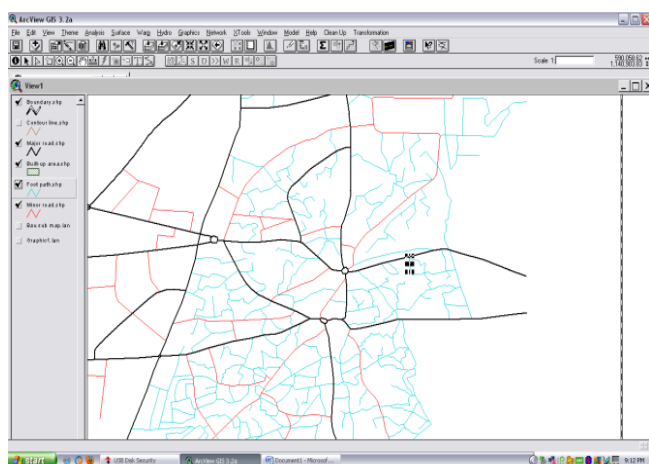

Figure-2.5.8 : Arc View GIS window showing the digitized major road, minor road and footpath.

2.5.9 INPUTTING THE CONTOUR VALUES IN THE ARC VIEW GIS ENVIROMENT.

i. 'Add theme' was clicked from the main menu bar, then on the 'add theme dialog box', the exported contour map from the ILWIS environment was selected and 'OK' was clicked.

ii. On the ArcView window 'theme' was clicked and 'auto level' was selected then the 'auto level dialog box' appeared and 'OK' was click to input the contour values on each contour.

3.0 ANALYSIS AND DISCUSSION OF RESULT

This chapter discusses the results achieved in the previous chapter as well as the analysis of the entire outcome to reach the final objective.

 Figure 2.4.3 shows the Digital Elevation Model (DEM) of the study area and is obtained as a result of contour interpolation from digitized contour. This DEM is showing the nature of the topography of the study area using different sets of colours to represent different levels of the topography. It is used in this project for the creation of flow accumulation (Figure 2.5.2), slope map in percentage (Figure 2.5.3a), aspect map (Figure 2.5.3b) and other analysis that produced optimal and suitable drainage pattern in Figure 2.5.4a and Figure 2.5.4b respectively. Figure 2.5.2 , which is the flow accumulation map shows the different levels of accumulation of water in the study area using different colours, red shows the highest level of accumulation while blue shows no accumulation. Figure 2.5.3a, which is the slope map in percentage shows the level of slope in percentage at different places within the study area. Figure 2.5.1 (flow direction map), shows to which direction water take their ways, different colours show different direction of flow which can either be East, West, South, etc. Flow direction is calculated for every central pixel in input blocks of 3 by 3 pixels, each time comparing the value of the central pixel with the value of its 8 neighboring pixels. The output map contains flow directions as N (towards North), NE (towards North East), etc. In a (sink-free) Digital Elevation Model (DEM), the Flow direction operation determines into which neighboring pixel any water in a central pixel will flow naturally. Figure 3.5.3b is the aspect map. It also shows the direction of flow using number values from 0 to 359.01. The Drainage Network Extraction operation extracts a basic drainage network. The output raster map will show the basic drainage as pixels. A threshold value, i.e. a value for the minimum number of pixels that are supposed to drain into a pixel to let this pixel remain as a drainage in the output map; the larger you choose this value, the fewer drainages will remain in the output map; a threshold raster map that contains variable threshold values. A threshold map can for instance be based on geological units, on height values, or on an internal relief map, etc. Depending on the flow accumulation value for a pixel and the threshold value for this pixel, it is decided whether true or false should be

assigned to the output pixel. If the flow accumulation value of a pixel exceeds the threshold value, the output pixel value will be true; else, false is assigned. To limit the number of output streams and reduce calculation time for the Drainage network ordering operation, you can specify the minimum drainage length (in meters); then, only external streams with a length greater than this value will remain in the output drainage network. Figure 2.5.4a is the optimal drainage pattern generated using flow accumulation as an input. It shows the areas where there is highest accumulation of water in the study area and where the water naturally supposes to flow. Figure 2.5.4b (suitable drainage pattern) is the same with the optimal drainage pattern, and its input is optimal drainage pattern, but it is subjected to edition.

From the above discussion we can therefore observe that some eastern parts of the study area are in lower elevation, hence these areas may experience flood problem. A good overlay of build-up area and the optimal drainage network will provide the idea of the structures that were built on the natural water ways. As mentioned in the above discussion, suitable drainage pattern is subjected to edition, so this gives room for the analysis and selection of suitable ways of the drainages within the study area. This selection was made with the consideration of the analyses maps such as flow direction map, flow accumulation map, etc. As well as the consideration of built-up areas and the roads in order to avoid excessive property demolition during the drainage construction.

4.0 CONCLUSION AND RECOMMENDATION

GIS and remote sensing are the key to this project where by maps such as those showing the buildup area within the case study area, the Digital Elevation Model (DEM) of the case study area, the slope and aspect maps, the flow accumulation map, the Optimal and the Suitable drainage networking map of the study area were produced.

From the above conclusion, I can finally recommend that:

i. Improper planning and poor designing of layout are among the major causes of flooding, therefore government is hereby advised on making proper planning and good designing of layout to minimize the effect of flooding.

ii. Further hydrological analysis and other analysis should be made to improve on the current situation of using GIS and remote sensing for analysis to minimize the effect of flooding.
iii. Extensive effort should be made for the implementation of this, and any kind of project which is important in order to see their positive effect.

iv. Finally, adequate GIS equipment should be provided for the students this will enable them to have the knowledge and training on making use and doing analysis with such equipment.

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