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ASSESSMENT OF STREAM NETWORK PATTERN IN ABAK AND ESSIEN UDIM LGAs OF AKWA IBOM STATE OF NIGERIA USING REMOTE SENSING AND GIS TECHNIQUES

Nnamnso Peter Udoudo[1], Ambrose Ndubuisi Ekebuike[2] Samuel Chukwudi Igwe[3], Francis Okoli[4], James Silas[5]

[1-5]Department of Surveying and Geoinformatics, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

Corresponding Author: environsurveys@gmail.com

Abstract:

The focus of this research is on the application of Remote Sensing and Geographic Information System (GIS) techniques to carry out a hydrological analysis in Abak and Essien Udim Local Government Areas (LGAs) of Akwa Ibom State of Nigeria. Most of the hydrological studies in Akwa Ibom are focused on more developed area and not in Abak and Essien Udim LGAs, resulting in building residential and other structures on stream channels, and experiencing the negative environmental consequences yearly. This study examines the hydrological features within this small hydrological unit which contributes her content and precipitation at the long run to a much larger basin (Cross river Basin). Methodologically, the study employed the GIS approach by analyzing the source data downloaded online from remote sensing imageries. The Landuse/Landcover classification result shows 34.11% Built-Up area, 33.65% Farmland., 26.30% Vegetation (Forest Land), 3.50% of Bare Land, and 2.44% of Water Bodies. Also, the stream network is dominated with dendritic pattern having 283 First order streams (where most are seasonal with dry valleys during dry seasons), 128 Second order streams, 61 Third order streams and 4 Fourth order streams in the area. Few smaller drainage units or basins exist in the area which contribute its content to Cross River basin. The study has also made some recommendations to the management authorities to ensure proper sustainable management and use of the hydrological resource within the area to avoid environmental degradation. Houses and other structures also should not be built across the stream channels to avoid blocking the water ways which may result in collapse of the buildings, erosion and environmental degradation.

Key Words— *Stream Network, Watershed, Hydrological Analysis, Remote Sensing, GIS.*

1.0 INTRODUCTION

Water channels are the confined pathways through which waters in fluidal form on earth surface (in form of springs, streams, rivers and so on) flow [15]. This is mostly studied through the aspect of science known as "Hydrology". Hydrology, according to [16] is defined to mean the science that deals with the waters of the earth, including their occurrence, distribution, circulation, their chemical and physical properties and their interactions with the environment. Thus, hydrology deals with the scientific study of both the

distribution and movement of water through its different channels, which may be springs, streams, rivers or other water ways and storages on the earth [15]. On the surface of the earth, liquid waters, flow from a higher to a lower elevation (as a result of the force of force of gravity) through their natural or man-made channels. Hydrology of an area is fully understood by studying its parameters including precipitation, water storage surface runoff, etc. which feed the flowing streams. [12], has used precipitation, soil moisture, snow and ice, evapotranspiration, stream flow, and water storage as parameter to study hydrology. These parameter, give the state of water availability in an area which leads to the volume of water available for stream flow in a region. [12], has also pointed out that streamflow is the most dominant mechanism by which moisture is transported from the global land areas to ocean, and also provides most of the water used for municipal and industrial supply, irrigation, energy production and many other purposes.
In the stream network, one stream joins another and the linked-chain continues till it forms a network of streams joining each other and flowing with a combined or super-imposed force within the basin to a common destination via the trunk stream [15]. The knowledge of hydrology, especially that of the stream flow network in an area is crucial to identify some hydrological complexities of water availability or deficiency, including floods, droughts, and erosional activities in any hydrological unit.
According to [13], river patterns or the spatial arrangement of channels in the landscape, are determined by slope and structure, which also provide clue of underlying structure, and this have proved significant in the search for minerals. The river drainage and distribution pattern of an area is very important as it helps to both identify and interpret the regional geological characteristics of such area [5]; [7].

The search for mineral deposit in an area could easily be determined by the pattern of stream flow that characterize the region as it shows in some cases the underlying bedrock. According to [3], drainage systems and the hydrologic morphometry of any nation is a veritable resource among the core dataset usually captured when producing a topographic map of a country, whereas sufficient knowledge of the spatial pattern and distribution of stream and their watersheds are inevitable if proper planning of water resources are to be undertaken. The river drainage and distribution pattern of an area is very important as it helps to both identify and interpret the regional geological characteristics of the area [5]; [7]; [13].

On the surface of the earth, water flows down the lower topography in response to the gravitational pull. This flow is usually confined within a channel, which based on its hierarchical position could be first, second, third, or higher others. The channels could be springs, streams, rivers, etc. As the channel flows, one stream joins another and the linked-chain continues till a network of streams joining each other and flowing with a combined force within the basin to a common destination via the trunk stream is formed [15].

Drainage channels always develop along zones where rock type and structure are most easily eroded [9]. The channels depending on the precipitation in the area can be seasonal or permanent streams. Seasonal streams will dry off during severe dry seasons while the permanent streams flow all year round.

Drainage channels are found within the watershed or river catchment. According to [3], the term watershed is normally used interchangeably with river catchment and is defined as an area of land that drains all its streams and rainfall to a common destination. Watershed therefore is a topographic unit that channels all its precipitation to a common outlet known as trunk stream which could be sea, Ocean or Lake.

Mapping and presentation of the patterns of stream flow could be done through the ground-based hydrographic survey, but the use of remote sensing and GIS techniques provides a quicker means for studying the patterns through which the stream network are interconnected within a hydrological unit.
Remote sensing which enables distance objects to be studied is a reliable source of information especially when the direct contact with the object of study is very difficult or the object is very large to be covered within the given time (if the ground based survey is to be employed). Studying or gathering an information about a remote object without a physical contact is remote sensing. Remote sensing is also defined as the acquisition of an information about an object through remote means, involving the use of instruments called sensors, without getting into a direct physical contact with the object in which its information is demanded [1]; [8]; [11]; [14]; [15]. A quicker and more holistic hydrographic information can easily be obtained by the use of satellite remote sensing technique than the ground method or technique when studying the water bodies [4]; [8]. As far as the distance of the sun and other planetary bodies are from the earth surface, they can easily be studied through remote sensing means by making use of sensors. With remote sensing, a wider and a larger spectrum of an object can be studies.

One of the remote sensing imageries that helps to extract topographic information is the Shuttle Radar Topographic Mission (SRTM). It is a kind of Digital Elevation Model (DEM) that has a global coverage. [6], has pointed out that SRTM has created an unparalleled data set of global elevations that is freely available for modeling and environmental applications, and that the global availability (almost 80% of the Earth surface) of SRTM data provides baseline information for many types of the worldwide research.
Unavailability or total lack of information about river channel and the stream connectivity of the streams within the watershed can lead to poor environmental management, erosion, flooding and collapse of buildings built on the water ways [15]. There are different types of stream networks. Including Dendritic, Trellis, Rectangular, Radial, Centripetal, parallel etc. All these have different structures, but Dendritic is the most common network pattern.
This study, shows the pattern of stream network in the study area with their drainage basins. This is necessary because the drainage information is very vital for a proper hydrological management of the study area.
The knowledge of the Landuse and Landcover (LULC) of any hydrological unit is equally important to have an insight whether the region has water bodies or not. This can easily be done through LULC classification. According to [14], Landuse refers to the different uses to which man put land into including agricultural, waste disposal, industrial, residential, recreational, institutional etc, while Landcover depicts the natural features covering the terrain surface including such features as water bodies, swamps, desert or sand dunes, bare land and forest or vegetation covers.
Classification of LULC can be supervised or unsupervised. The level one classification scheme according to [2], categorizes LULC into five classes namely; Agriculture, Vegetation, Built-Area, Bare-Earth and Water Body.

This study aims at assessment of the stream network and distribution pattern in Abak and Essien Udim LGAs of Akwa Ibom state of Nigeria through remote sensing and GIS techniques.
The objectives of this study include; acquiring and processing a medium resolution satellite imagery of the study area, accessing the drainage network pattern of the area using satellite imagery and remote sensing techniques, and production of the drainage network map of the study area.

2.0 THE STUDY AREA

The study area is made up of two LGAs in Akwa Ibom state, which are Abak and Essien Udim LGAs. Akwa Ibom state is one of the states found in the Niger Delta region of Nigeria, having its southern boundary with the Atlantic Ocean (Fig.2.1). It is one among the 36 states of Nigeria, and occupies part of the Bight of Bonny. The two LGAs of study share their borders with Obot Akara and Ikot Ekpene LGAs in the North, Etim Ekpo, Ukanafun and Oruk Anam LGAs in South, Ikono and Uyo LGAs in the East, and finally, Ika LGA and Abia state in the West.

Figure 2.1: Map of Nigeria showing Akwa Ibom State

Geographically, the two LGAs of study stretch themselves between latitude 4°50'N and 5°12'N and longitude 7°28'E and 7°52'E (Fig. 2.2, 2.3). The LGA Headquarters of Abak is also in Abak, while the LGA Headquarters of Essien Udim is in Afaha Ikot Ebak.

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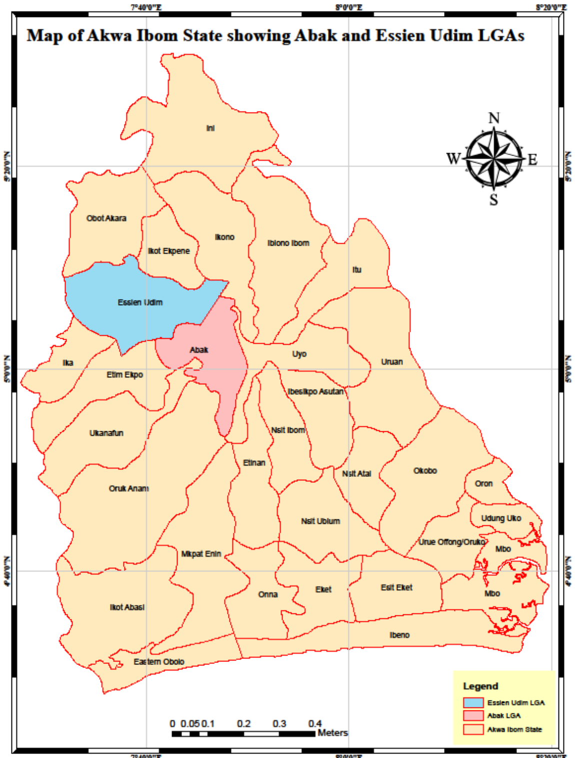

Figure 2.2: Map of Akwa Ibom State showing Abak and Essien Udim LGAs

The region is cold and humid as it is closer to the influence of Atlantic Ocean. The average temperature range is between 26^{o}C and 27^{o}C.

Rainfall and humidity is high in the area, where there is about 8-9 months of rainfall and about 3-4 months of dry season yearly. Due to its proximity to the Atlantic Ocean, there are always some spots of rainfall even in dry seasons, including the months of December and January whereas other parts of Nigeria will still be experiencing severe harsh and dry weather.

The two LGAs in study are in the rain forest zone of the country, and thus has characteristics tropical rain forest ecosystem vegetation. The area is very rich in biodiversity as a result of its hydrology, thick vegetation and forest especially when the bushes are undisturbed.

The area has several range of topographic features, such as lowland, plains, undulating hills, river valleys, and wetlands which gives rise to its hydrological complexities.

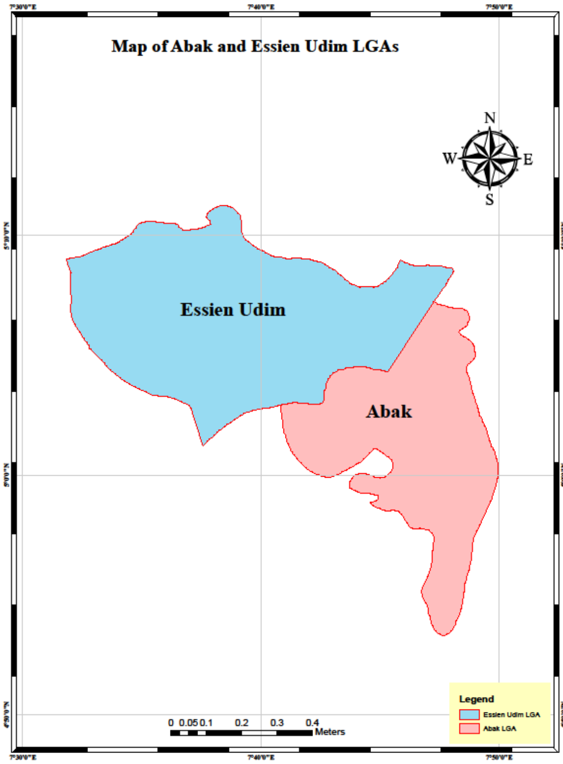

Figure 2.3: Map of Abak and Essien Udim LGAs

The area also has several hydrological features including streams, and wetlands which play a vital role in the local climate, hydrology and contribute to the overall drainage pattern in the area.
The people of the area are mostly crop farmers, traders and fishermen. Industrially, the area has bases much in agriculture and fishing activities. The Official language of the area is Annang Language although there are some local dialects. The indigenous language of the area ins Annang language.

3.0 MATERIALS AND METHOD

The methodology applied in this study involved the use of a remote sensing and GIS techniques to carry out some hydrological analysis in the area so as to get the stream network and drainage basins of the study area. The sources of the data were satellite images including Landsat image and Shuttle Radar Topographic Mission (SRTM) imagery downloaded from www.earthexplorer.usgs.gov. Other data sources included the administrative boundaries of Akwa Ibom state, Abak and Essien Udim LGAs, and the non-spatial data of the area which were collected through oral interviews.

The software applied in the study was ArcGIS which is a powerful GIS tool for conducting a comprehensive hydrological analysis. Microsoft office tool (MS-word) was also used for editing and arrangement of text.

The two major remote sensing data sources for this study are the Landsat OLI image of the study area and SRTM image downloaded from www.earthexplorer.usgs.gov which were imported into the ArcGIS environment and the clip tool was employed to clip out the desired area and to focus on the area of interest.

The Landsat image was classified with ArcGIS to get the LULC feature classes. Some GIS activities performed in ArcGIS on the clipped SRTM image to obtain the expected hydrologic outcome included;

importation of data, conversion of Raster File to Network of Streams, Fill sinks, Flow Direction Analysis, Flow Accumulation Analysis, Stream Link Analysis, Drainage Basin Analysis, Stream Order Analysis, Flow Length Analysis, and Watershed Delineation Analysis.

3.1 Image Classification Process/DEM Extraction

Classification of satellite imageries help in grouping the LULC features into different categories for easy identification and analysis. It can be done by either supervised or unsupervised method. The level one LULC classification scheme designed by [2], which groups LULC into five classes including Agriculture, Vegetation, Built-Area, Bare-Earth and Water Body was adopted for this study. A clipped stage of the image classification with ArcGIS done in the study is shown in Fig. 3.1.

3.11 Topographic Extraction from DEM Creation

Tracing of the stream channels has to do with the topography of the terrain. Streams will tend to flow down the slope from a higher to a lower elevation in response to the force of gravity. This has to be undertaken before the hydrological analysis could be carried out. Thus, the SRTM data, which is a global topographic image, has to be imported in so that the area of interest could be clipped out.

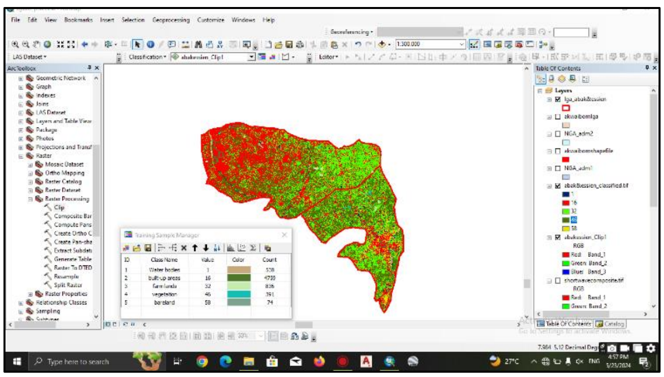

Figure 3.1: Clipped out Landsat image of the study area in ArcGIS

3.12 Clipping of the Area of Interested

Clipping the interest area from the whole downloaded image, was done so as to calve out and focus on the desired locations.

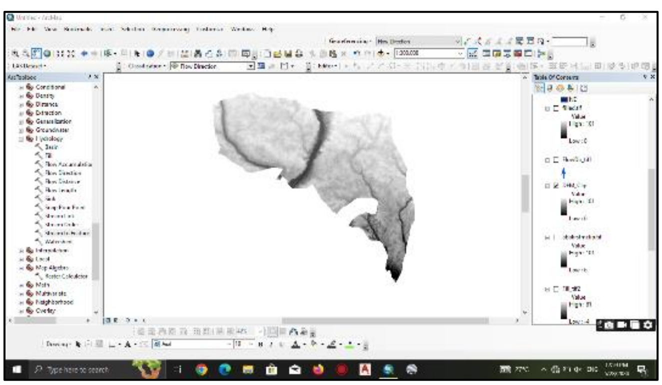

Figure 3.2: Clipped out SRTM image of the study area in ArcGIS

SRTM, Landsat and some other satellite imageries has global coverage and without clipping or cutting out area of focus, concentration will not be centered properly on the area of interest. Steps for the clipping are as follows;

1. Click on "Add Data" to add the downloaded images of the study area from saved folder to the ArcGIS environment
2. Go to Data Management Tool
3. Raster, then Raster processing
4. Click on 'Clip'
5. Set input raster to the filled mosaic image
6. Set study area shape file as clip extent
7. Click OK

3.13 Fill Sinks

This was also done to the added DEM image. These steps were involved here:

1. Open Spatial Analyst toolbox.
2. Locate the "Fill" tool in the "Input your DEM raster" and choose an output location.
3. Run the tool to fill in the DEM.

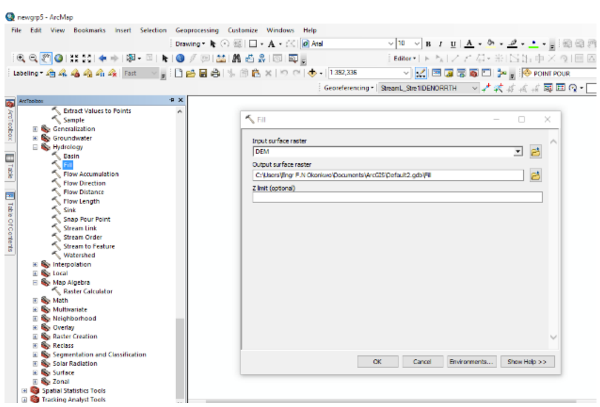

Figure 3.2: Filling the Sink in ArcGIS Environment

3.2 Some Hydrological Analyses in the Study Area

To assess the intricate patterns of stream or water flow in the region, some hydrological analysis was carried out, including Flow Direction Analysis, Flow Accumulation Analysis, Stream Link Analysis, Drainage Basin Analysis, Stream Order Analysis, Flow Length Analysis, and Watershed Delineation Analysis.

3.21 Flow Direction Analysis

This helped to show the direction in which water flows within the hydrological region. Thus it portrays the direction or the pathway that water will flow in the hydrological unit using their pixel values. This is clearly shown through its SRTM, which utilizes the DEM and algorithms for establishment of the route for water flow. In ArcGIS 10.5, the following steps were involved:

1. Click 'Spatial Analyst Tool'
2. Click 'Hydrology' then, 'Flow Direction'
3. Add the filled image as input, select output location.
4. Then click 'OK'

3.22 Flow Accumulation

Flow accumulation analysis is the analysis that helps to calculate the quantity of flow or flow accumulation into each cell. The value of each cell is the sum of all flows into it from upstream, thereby pointing out the inflow quantity of water into a particular region. The steps are:

1. Click 'Spatial Analyst Tool'
2. Click on 'Hydrology' then, 'Flow Accumulation'
3. Add the flow direction image as input raster
4. Select output location.
5. Click 'OK'
6. Click on the flow accumulation layer
7. Go to properties
8. Click 'Symbology Tab'
9. Select classified
10. Set the number of classes
11. click 'Classify'
12. Click 'OK'

3.23 Stream Link

This helps to delineate network of streams. It uses the flow accumulation raster to sort out pixels representing stream locations. The links form the connecting junctions of stream segments, which helps in delineating stream networks, and shows the section of a stream in the larger stream network delineated within the hydrological unit for easy management or assessment. It involves the following clicked steps:

i. Analysis Toolbox
ii. Stream link
iii. Flow Direction
iv. Indicate output
v. Run or Ok

3.24 Drainage Basin Analysis

Drainage Basin or River basin shows the hydrological unit where all its precipitation and runoff from its chains of stream network drains all its content to a common trunk or outlet. It is a hydrological depression area, or a low basin topographic unit drained by a river and its tributaries. It shows where all the water within a landscape unit flows to a common trunk. There may be many watersheds within a drainage basin. Basins, which are low topographic hydrological units are formed by tectonic forces or by erosional forces. Drainage basin forms a political unit of development in many nations. Steps are:

1. Arc Toolbox
2. Spatial Analyst Tool
3. Clicked on hydrology
4. Select Basin Flow
5. Add flow direction in input raster
6. Select desired output location and name it.
7. OK.

3.25 Flow Length

A stream flowing from its source will merge its content into another water body at a junction. The distance that the stream flows before meeting with another stream is the flow length of such stream. To achieve this involves the following steps:

i. Click on Spatial Analyst toolbox.
ii. Click on Flow Length" tool
iii. Put flow direction raster
iv. Insert output location for raster flow length
v. Click on Ok to input distance along the flow path

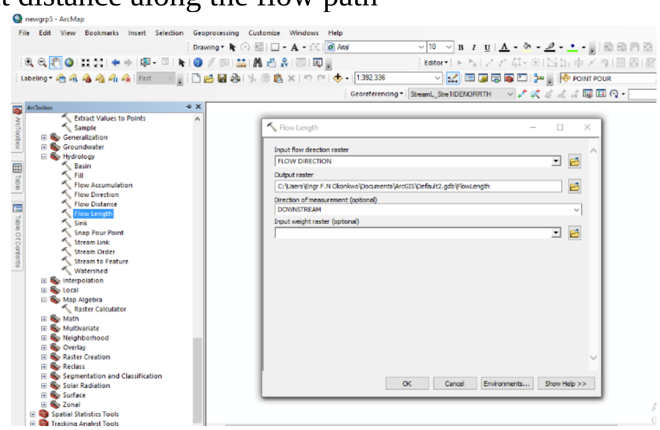

Figure 3.3: Flow length Process in ArcGIS

3.26 Stream Order Analysis

The stream order of any stream or river in the stream network within a given basin is the hierarchical order it occupies within the basin. Many methods are used for the ordering system but Strahler's method is the most commonly used method because of its simplicity. Stream just emerging from the source is regarded as the First Order stream. When two of such join, they form a Second Order as the resulting stream, and so on. The steps include:

1. Click Spatial Analyst toolbox
2. Input the stream link raster
3. Click Stream Order
4. Specify output location for stream order raster
5. Ok the tool to assign order to streams

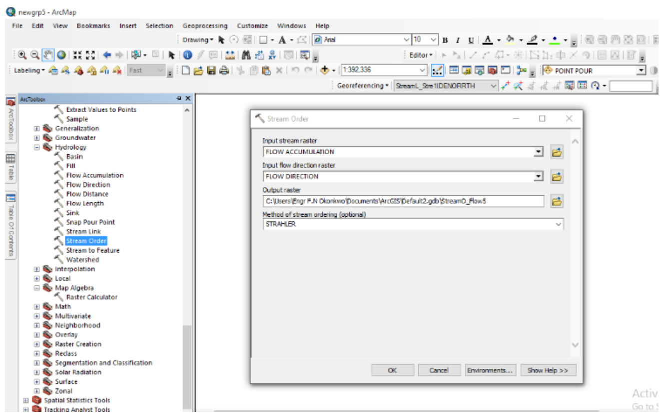

Figure 3.4: Stream Order Analysis Process in ArcGIS

3.27 Watershed Delineation

Watershed describes the traced edge of a river basin. It delineates the outer edge of a basin to specify the entire areas or units that drain their precipitation and runoff into a particular water body. The steps are:

1. Select a point in the river network
2. Click on Spatial Analyst toolbox.
3. Click on Watershed
4. Input flow direction raster and the chosen point
5. Select output location for the watershed raster
6. Ok to delineate the watershed

4.0 RESULTS AND DISCUSSION

The results in this study are shown in forms of discussions, maps, tables, and charts, to enable complex hydrological processes to be visualized. To achieve a reliable, effective, efficient and sustainable environmental management and planning in a complex a hydrological unit like Abak and Essien Udim LGAs, the intricate structure of the stream flow must be well presented because it gives insight for water resources utilization and management if sustainable use is to be achieved.

4.1 Landuse/Landcover Classification

Figures 4.1, 4.2 and 4.3 show the result of image classification of the study area. They show five different colours used to classify the LULC features into classes. The different colours used here for the LULC classification and the classes they represent are; Blue, Deep Brown, Light Green, Deep Green and Yellow colour, which represent Water bodies, Built-Up Areas, Farmland, Vegetation, and Bare Land respectively.

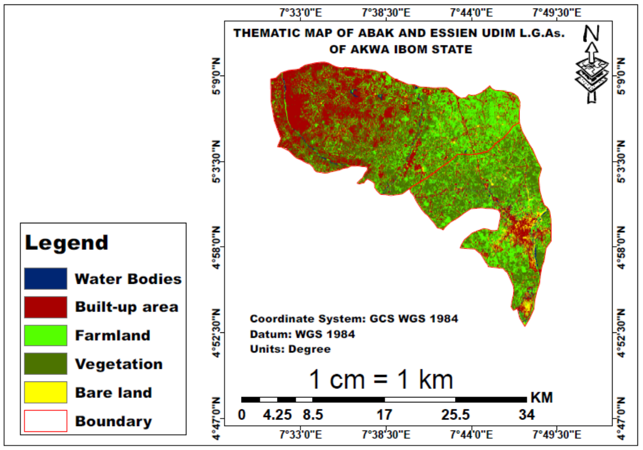

Figure 4.1: Landuse Landcover Classification Map of Abak and Essien Udim LGAs

This study shows that the largest feature is Built-Up area consisting of 34.11%. the second largest feature class is Farmland constituting 33.65%. This is followed by Vegetation (Forest Land) taking 26.30%. Next to it is Bare land which is 3.50%. The smallest of all the feature class is the Water Bodies occupying only 2.44% (Fig.4.2). The bar-chart that further describe the different feature classes is shown in Fig.4.3.

The interpretation of the different sizes of the feature class here (Fig. 4.1, 4.2, 4.3) indicate that built up area and Farm land dominate the entire region with larger percentages. Farm land is slightly less than Built-up Area with just 0.79%. The indication of this is that the area is a semi, -urban area where farm land measures nearly equally with the residential areas. The people of the region are therefore mostly farmers by occupation.

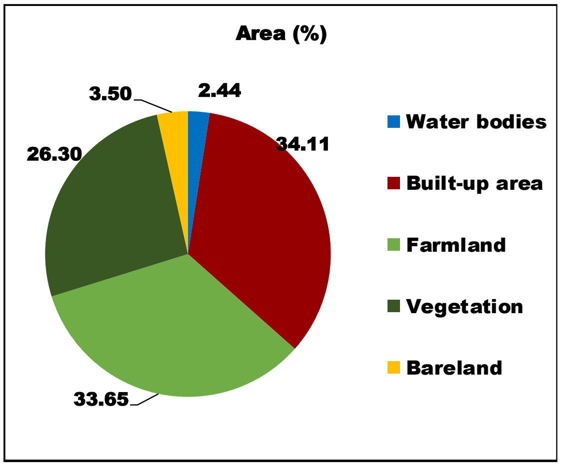

Figure 4.2: Pie-Chart of the LULC Classification of Abak and Essien Udim LGAs

Vegetation is third largest size with 26.30% and representing the height of 2.65 in the bar-chart (Fig. 4.2 and 4.3).

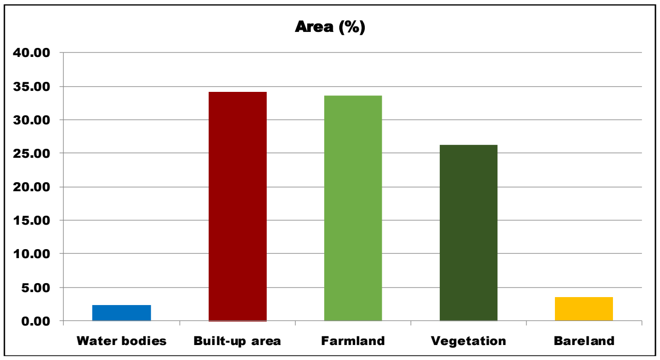

Figure 4.3: Landuse Landcover Classification Map of Abak and Essien Udim LGAs

The area is therefore rich in timber and wood production. Secondary forest and thick forest belong to this very category.

Second to the smallest is the Bare Land, which represent roads, sand open field and other bare land recreational spaces. This has only 3.50% and is represented with the height of 0.8 in the bar-chart. The water bodies form the least of all the LULC features in the area with 2.44 % and the height of 0.7 in the bac-hart. This actually shows that there are water bodies in the area for this study, though not much. The few streams that are found here are mostly the first and second order stream. The few streams here also indicate that there are some gallery forests along the stream lengths. These are the evergreen small forests that are normally found at the banks of a stream due to the presence of yearly supply of water. These kind of forests always make those streams that are not wide enough to be invisible from the satellite imageries, which are in most cases remote sensing picture images from the space. The implication of this is that most of such areas will be seen, identified and classified as vegetation and not as water bodies during image classification. The presence of the gallery forest is a useful tool in identification of the first order stream channels from google Earth imageries because they will show deep green vegetations even at dry seasons due to the constant water supply [14].

4.2 Stream Network in The Area

The interconnectivity of the streams within a hydrological unit forms a network of interconnected streams that drains out the area.

This interconnectivity is referred to as the stream network. There are different patterns of stream network arrangement. The commonest one is the dendritic stream network. The network pattern in the region as seen in Fig.4.4 is dendritic. This is a result of the underlying rock structure. The implication of this is that the drainage basins in Abak and Essien Udim LGAs are in a region having homogeneous bedrock material beneath them. Thus, the surface geology here has a similar resistance to weathering and thereby giving rise to dendritic network arrangement.

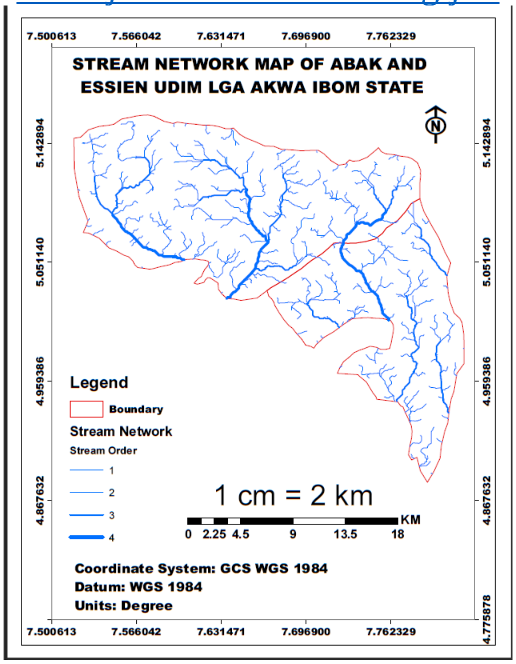

Figure 4.4: Stream Network in the study Area

4.3 Drainage Basin in the Area

The different drainage basins in the study area are shown with different coded colours for visual understanding and interpretation (Fig. 4.5).

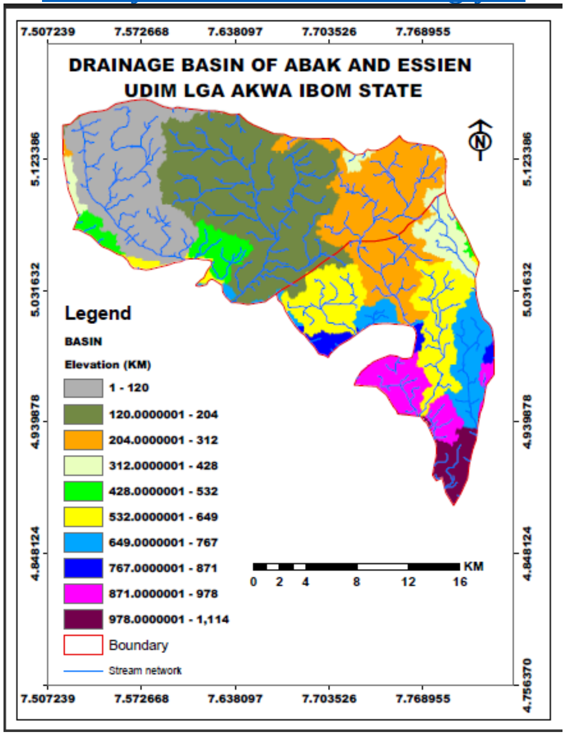

Figure 4.5: Drainage Basins in the study Area

The basins show how the flow and precipitation in the area are drained as it reveals the distribution, size and shapes of the different basins within the region. Some are larger (with more tributaries) while some that has few tributaries are smaller. These different colours sub-basins show the localized catchment within the main basin.

4.4 Stream Order Analysis

The stream order shows the order or the hierarchy of streams based on their flows as they join one another at certain points and increase in sizes.

Different methods of stream ordering are used for numbering of streams. [10], has pointed out different methods of stream ordering commonly in use to include Horton (1945), Strahler (1952), Scheideggar (1965) and Shreve (1967). When a stream originates from a source without joining any other stream yet, it is regarded as a first order stream.

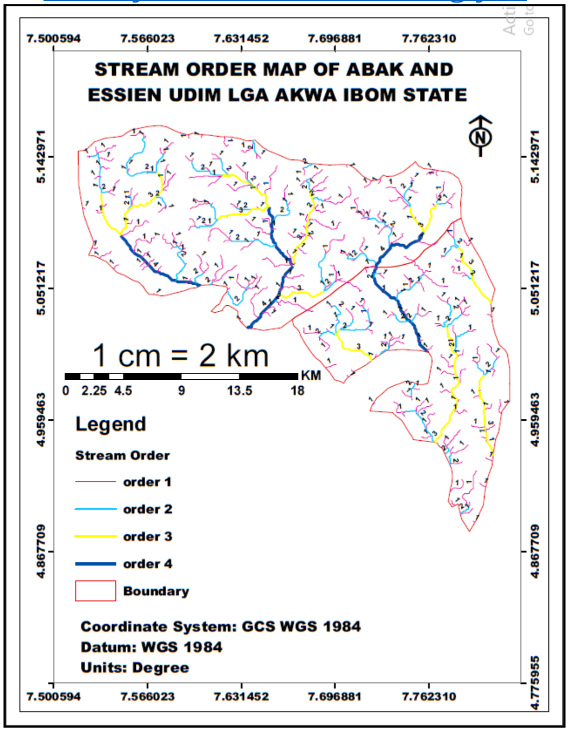

Figure 4.6: Stream Order Map of the study Area

When two first order stream meet, the resulting one is a second order stream. Two second order will join to form the third order and so on. That meeting point where two streams meet is called a junction [10].

The stream ordering in the study shows that the highest stream order in the place is 4th order. The study reveals that there are 283 First order streams, 128 Second order streams, 61 Third order streams and 4 Fourth order streams in the area. Most of the First order streams are seasonal streams are dry valleys during dry seasons. The high number of the first order stream in the region shows that there are much erosional activities in the area (Fig.4.6).

4.5 Stream Outlets in the study Area

The study has shown that there are many drainage outlets in the region. Almost all the streams in the area flow towards the South East direction. The implication of this is that the entire stream network in the area may likely belong to a single larger basin.

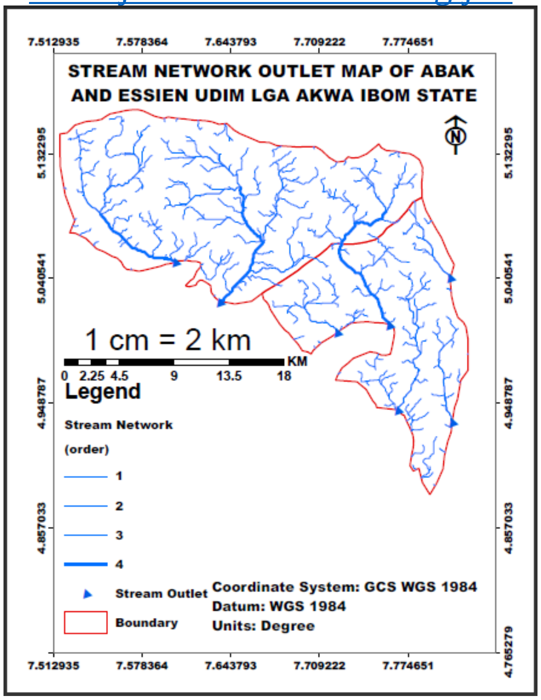

Figure 4.7: Stream Outlets in the Area

Thus the flow direction of nearly all of the streams seem to be toward same direction. This is because the study area is just a small hydrological unit, and the streams through their outlets still continues in other LGAs outside the boundaries of our study area. Only two trunk streams flow towards the South (Fig.4.7). The major outlets constituting higher orders are 7 in number. There are however few smaller outlets at some boundaries point of the two LGAs forming the study area.

4.6 Watershed Delineation

The different watersheds in the area are shown with different colours as seen in Fig. 4.8.

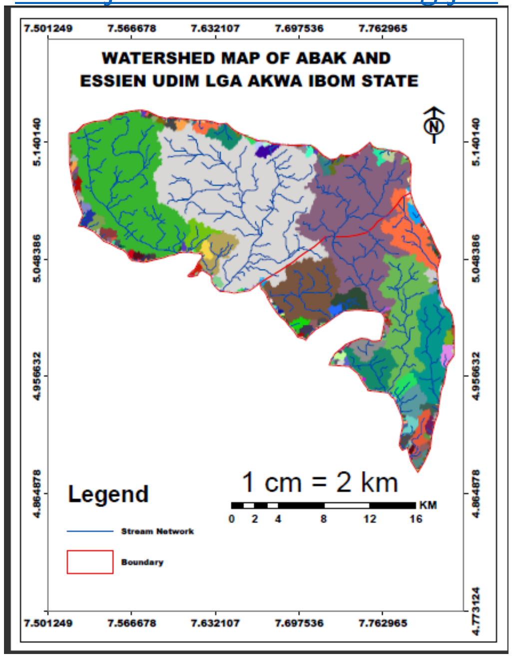

Figure 4.8: Watershed Map in the Area

The different watersheds here show the edges of the smaller drainage basins in the area. There are 8 local basins in the area that are easily identified (Fig.4.8). Other are minor one that are very small in sizes.

5.0 CONCLUSION

Application of remote sensing and GIS has proven to be a very reliable and useful tool in the study of the patterns of stream network and interconnectivity in any hydrological unit. This study assessed the stream network and distribution pattern in Abak and Essien Udim LGAs of Akwa Ibom state of Nigeria through the use of remote sensing and GIS techniques. This method has yielded a good and efficient result as it has given a valuable insight into the hydrological features and characteristic in the region. The satellite image classification of the study area has revealed that built-up area and farmland are the most dominant LULC feature class in the area. Built-up area was 34.11%, showing that the region has much of human settlement and high population. Farmland was 33.65%, indicating high potential that the area may be used for high agricultural production if modern and mechanized agriculture is enhanced. However, as the built up area is much indicating high population, strategies should be adopted to avoid over exploitation of the forest resources which will result in deforestation. 26.30% of the area was for vegetation, indicating that the area is rich in biological species. Forest products including the Timber and non-timber forest products are also available in the area. Bare land was small with just 3.50%. The classification equally revealed that the small percentage of the feature class in the region was the water body, constituting only 2.44%. This study focused on the pattern of flow of this 2.44% which was the water bodies.

The pattern of stream network in the area as revealed by the study is mainly dendritic. This is as a result of the underlying geological formation or rock structure in the area which have homologous resistance to weathering. The entire area belongs to one larger basin but have some smaller sub- basins within, which drain its contents towards the south-eastern part of the study area., indicating that they have a common outlet if the streams are trace down beyond the boundaries of the two LGAs under study. The highest stream order in the study area is the 4th order stream, which are 4 in number. There are also 283 1st order streams (most of which are seasonal in nature which will leave dry valleys during dry seasons), 128 2nd order streams, and 61 3rd order streams in the region. With this stream network structure, there is active erosional activities during heavy precipitation. This calls for proper land management to avoid the negative erosional effect in the area. Being a small environmental and hydrological unit, the area has few sub-watersheds which are identified with different colures to show the drainage basins within the area. These are important as they show how water are drained within the area.

This study recommends that a more detailed research on the hydrological features of the area should be carried out with higher resolution satellite imageries, to provide more insight into the hydrological characteristics and challenges in the area. A comprehensive effort should also be made by the government to ensure that the watershed and the basins within the area are not misused. As it is revealed by the study that some of the streams are seasonal in nature, efforts should be made to avoid building houses and other structures to block the water ways. The gallery forest along the stream banks should not be destroyed to avoid exposing the land to erosion. Due to the localized nature of the basins identified in the study, no name has been given to them as most of the streams has no single name but different names they are called by the individual communities they pass through.

REFERENCES

[1]. Adjei-Darka, P. (2017). Remote Sensing and Geographic Information Systems for Flood Risk Mapping and Near Real-time Flooding Extent Assessment in the Greater Acrra Metropolitan Area. KTH Royal Institute of Technology, School of Architecture and Built Environment. Stockholm, Sweden.

[2]. Anderson, R. J., Hardy, E. E., Roach, J. T. and Witmer, R.E. (1976). A Land Use and Land Cover Classification System for Use with Remote Sensor. Geological Survey Professional Paper 964. United States Government Printing Office, Washington. pp. 1-28.

[3]. Bello, I. E., Adzandeh, A., and Rilwani, M. L. (2014). Geoinformatics Characterisation of Drainage Systems Within Muya Watershed in the Upper Niger Drainage Basin, Nigeria. *International Journal of Research in Earth & Environmental Sciences*. Vol.2 (3), pp.18-36.

[4]. Ekpa, A. U. and Ojinnaka, O. C. (2015). Near Shore Bathymetry Evaluation using Remote Sensing Method. *Journal of Environmental Issues and Agriculture in Developing Countries*, Volume 7, Number 2, August 2015 ISSN: 2141-2731.

[5]. Friend, P.F., Jones, N.E., Vincent, S.J. (2009). Drainage Evolution in Active Mountain Belts: Extrapolation Backwards from Present-Day Himalayan River Patterns, in: Fluvial Sedimentology. VI. John Wiley and Sons, Ltd, 305-313.

[6]. Gorokhovich, Y. and Voustianiouk, A. (2006). Accuracy assessment of the processed SRTM-based elevation data by CGIAR using field data from USA and Thailand and its Relation to the Terrain Characteristics. *Remote Sensing of Environment*. 104 (2006) 409 – 415.

[7]. Howard, A.D. (1967). Drainage Analysis in Geologic Interpretation: A Summation. American Association Petroleum Geologist Bulletin. V.51 No.11. pp-1246-2259.

[8]. Lillesand, T.M., Kiefer, R.W., Chipman, J.W. (2008). Remote Sensing and Image Interpretation: 6th Edition, Hoboken NJ. John Wiley and Sons. Hoboken.

[9]. Nelson S. A. (2015). Streams and Drainage Systems. Tulane University. pp 1-18. http://www.tulane.edu/~sanelson/eens1110/streams.htm

[10]. Pradhan, M. P., Ghose, M. K.,and Kharka, Y. R. (2012). Automatic Association of Strahler's Order and Attributes with the Drainage System. *International Journal of Advanced Computer Science and Applications*. Vol.3, No.8. pp.30-34.

[11]. Qihao W. (2013), Introduction to Remote Sensing Systems, Data, and Applications. *Remote Sensing of Natural Resources*, ResearchGate. https://www.researchgate.net/publication/299708984

[12]. Qiuhong, T., Huilin, G., Hui, L., and Dennis, P. L. (2009). Remote Sensing: Hydrology. *Progress in Physical Geography*. 33(4). pp.490-509.

[13]. Twidale, C.R. (2004). River Patterns and Their Meaning. *Earth-Science Reviews*, 67(3-4), 159-218.

[14]. Udoudo, N. P., Ekebuike, A. N., and Ossai, E. N. (2023). Hydrographic Mapping of Coastal Area of Ibeno LGA of Akwa Ibom State of Nigeria using Remote Sensing Method. *International Journal of Progressive Research in Science and Engineering.* Vol.4 No.07, pp. 27-33.

[15]. Udoudo, N. P., Ekebuike, A. N., Nwopi, T. C., Agulonu, A. K. (2024). Stream Order and Flow Pattern Assessment in Awka North and South LGAs of Anambra State of Nigeria using Shuttle Radar Topographic Mission (SRTM) and Satellite Imageries. *Environmental Review Journal* Vol. 9 (3). pp. 165-172.

[16]. Ward, R. C. and Robinson, M. (2000). Principles of Hydrology. 4th Ed. *McGraw-Hill*. UK.