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

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Abstract: - Streams are the channels through which water flow on the surface of the earth, from higher to lower elevations, or from the source, through intermediate to the trunk or destination. They are mostly natural (though there could be man-made) channels forming network of drainage systems on the surface of the earth. At the sources, water is seen oozing or zipping out from the soil or rocks, which gets larger with the channel length. The hierarchical position that a particular stream possesses in the stream connectivity or network within its basin is the order it is described to have. Thus, stream order is the hierarchical position a particular stream occupies in the stream network that it is found. Some source streams may be momentarily dry valleys or seasonal streams, containing water only during heavy rainy seasons. Others may have permanent water flow all year round. Awka North and South LGAs of Anambra state, the study area for this research has several of the "source or lower order" stream networks than the higher orders. Ignorance of the negative effects of building residential structure across the stream channels results in yearly floods, deep erosions, collapsing of buildings and loss of both lives and properties in the area. Little or no efforts has been made by the regulatory bodies and town planners to rescue this situation in the area. To assess the drainage network in the area and provide basic information of the stream orders to help in tackling all these environmental problems, this study aimed at providing environmental solution through acquisition, processing and interpretation of Shuttle Radar Topographic Mission (SRTM) and satellite imageries of the area using GIS technique. The objectives included acquisition of the required satellite imageries of the area, processing them to trace out the stream networks, assessing their flow directions and production of a stream ordering map of the area. Some recommendations made included the need for putting into consideration the flow channels before approval be given for siting of buildings and other structures in the area so as to avoid blockage of the stream channels and their corresponding consequences.

Key Words— ***Stream Ordering, Drainage Pattern, Stream Network, Satellite Imagery, SRTM.***

1.0 INTRODUCTION

Streams form the natural routes on the surface of the earth through which flood waters are channeled after precipitations. Thus, after rain or down pour, water found on the surface of the earth flows through confined pathways, from their sources to their destinations (which may be oceans, lakes or seas). [5] has defined a stream as a body of water that carries rock particles and dissolved ions and flows down slope along a clearly defined path, called a channel. He equally pointed out that streams may vary in width from a few centimeters to several tens of kilometers.

The aspect of science that deals with the study of the movement of water within the earth is known as hydrology. According to [10], Hydrology is the science that deals with the waters of the earth, their occurrence, distribution and circulation, their chemical and physical properties and their interactions with the environment. Hydrology therefore gives insight on the hydrological cycle which covers all aspects or phases of water found on, below or above the surface of the earth and their movements or circulations [9].

Water on the surface of the earth flows from a higher to a lower elevation through its natural or man-made channels, and within the flow process, one stream joins another and the linked-chain of flow forms a network of streams joining each other and flowing together within their basin to a common destination or trunk stream [9]. According to [8], a stream network is a spatial arrangement of streams known as drainage pattern. [3] has defined drainage pattern of a river

network to mean the arrangement in which a stream erodes the channel of its network of tributaries. [1], [4], has pointed out that the regional geological characteristics of an area can easily be identified and interpreted through their drainage distribution patterns. Drainage networks are formed when several streams make interconnectivities with each other as they flow from their sources and within their channels to the trunk streams. [5] has opined that Drainage channel tends to develop along zones where rock types and structures are most easily eroded. A drainage pattern pertaining to a terrain is a mesh of interconnected streams [7].

Different drainage patterns of stream flows are in existence depending on the underlying geological formation of the channel area. [7] has pointed out that a typical drainage is an arrangement of river segment in a drainage basin and that it has several contributing identifiable features such as leaf segments, intermediate segments and bifurcations. Some of the patterns are identified to include; Dendritic, Trellis, radial, Centripetal, Parallel, Reticulate, Violent and Deranged [3], [5], [7].

As one stream joins another, the size and the width (and sometimes the depth) of the resulting stream becomes bigger, wider and deeper than the individual streams forming it. This is due to superimposing of their flow strengths on each other. The flow volume of water passing through any point in a stream channel is referred to as the Discharge [5]. Within the channels in the basin, the streams are arranged in hierarchies. The hierarchical position of the streams within the drainage network, as they flow through their basin to their trunk stream is referred to as the stream order. The order of any stream in the network is the hierarchical order occupied by that stream within the network. Different methods of stream ordering are used for numbering of streams. According to [7], different methods of stream ordering mostly used are Horton (1945), Strahler (1952), Scheideggar (1965) and Shreve (1967). A stream originating from a source without joining any stream yet is a first order stream. 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. And the point where two streams meet is called a junction [7].

However, when a stream of lower order joins a higher order, the higher order is maintained. By this method, it means that any braided stream (which is a single stream that branches or divides to give many small island and then join again to continue as a single stream), will maintain the same stream order throughout the braided region because, the braided area is still seen as one stream.

Satellite imageries are those imageries taken from space with the earth orbiting satellite or sensors. It is an advancement in photogrammetry and aerial photography. Many types of satellite imageries are in use, including Shuttle Radar Topographic Mission (SRTM), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Satellite Altimetry, Google Earth, Landsat Imageries etc.

SRTM according to [6] is a kind of international research effort that obtained earth's terrain data from 60° N to 56° S, in order to generate a high-resolution digital topographic database of Earth. It collects elevation data over 80% of earth's land area during an 11-day Space Shuttle mission. And with a horizontal resolution of 3 arc sec, SRTM represents the best quality, freely available digital elevation models (DEMs) worldwide [6].
According to [2], Shuttle radar topographic mission (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. The processed SRTM 90 m digital elevation model (DEM) for the entire globe was compiled by Consultative Group for International Agriculture Research Consortium for Spatial Information (CGIAR-CSI) and made available to the public via internet mapping interface [2].
SRTM image which is used to extract the topography of the earth surface can be downloaded online from www.earthexplorer.usgs.gov

This study aimed at assessing/tracing the stream networks and their hierarchical orders within the study area and thus, it makes use of SRTM to acquire the elevation data since streams are formed at the lower elevations in a basin. The objectives of the study include acquisition of the required satellite imageries, processing them, tracing out the stream networks within the area, finding out their flow directions and producing a stream ordering map of the area.

2.0 THE STUDY AREA

The study area is Awka North and South LGAs of Anambra state of Nigeria. Anambra state is one of the states in the South-Eastern part of Nigeria (Figure 2.1, 2.2 and 2.3). Igbo language is the official and indigenous language of the area. The area is located approximately between Latitudes 6° 04'N and 6° 29'N and Longitude 6° 55'E and 7° 11'E. There are many first order streams in the area forming network of streams which drain the area. Though some of the streams originate from other LGAs and flow through the study area, our concentrations are only limited to the administrative boundaries of Awka North and Awka South LGAs.

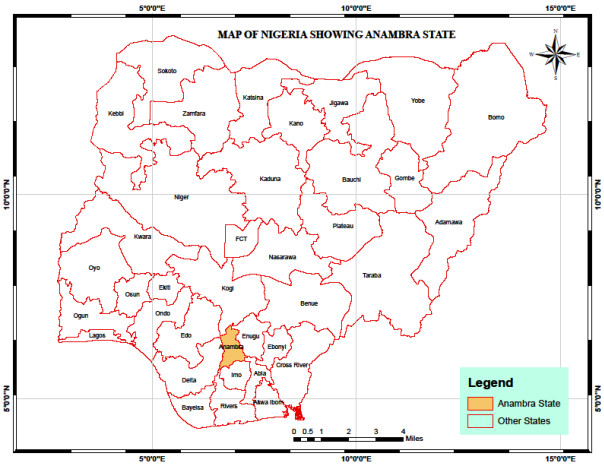


Figure 2.1: Map of Nigeria showing Anambra State

Most of the streams in the area are however seasonal streams. Such are only seen flowing during the heavy rainy seasons and will dry off completely during dry seasons, and thereby leaving the dry channels. Yet, they will leave dry valleys which are usually identified as steams by satellite imageries captured in the rainy season as first order streams.

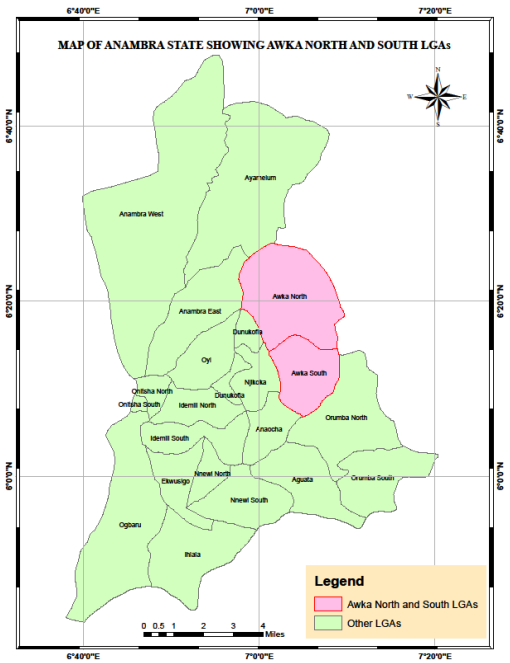


Figure 2.2: Map of Anambra state showing Awka North and South LGA

There are however no larger water bodies in the area but several of the perennial streams are found meandering and draining the entire region. Most of such streams are hidden by some vegetation (gallery forest) thereby making the visibility of such streams impossible from the satellite imagery obtained for the land use/land cover classification.

The area experiences two major seasons, the rainy and the dry season. The major wind masses are the South Monsoon winds from the direction of Atlantic Ocean and the North Eastern dry wind coming into Nigeria from the Sahara Desert. The moist and highly humid wind blowing in from Atlantic Ocean results in about seven months of rain occurring between April and October. The rest of the five months from November to March faces dry season with dry weather with temperature of about 27 to 30 degree Celsius [9].

There are several of interconnected network of streams in Awka North and South forming the study area. Some locations in Awka are water logged especially those low lying areas close to some streams. But some of those areas will also be completely dry in the dry seasons. This implies that the soil texture can be so muddy during the rainy seasons and very hard during the dry seasons.

The area is located in the Ecotom of the transition between the tropical rainforest and the wooden savanna grassland and is thus dominated mostly by the grassland and low forest vegetation. Along the stream valleys in Awka, are some evergreen interlocking vegetation otherwise called the "gallery forest" [9].

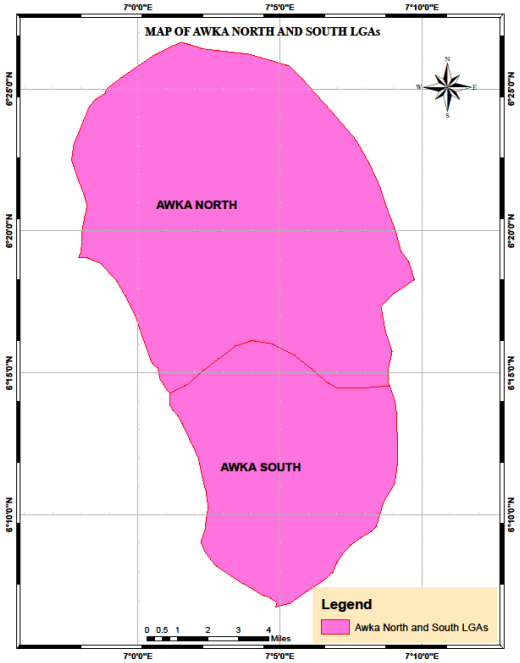


Figure.2.3: Map of Awka North and South LGA

3.0 MATERIALS AND METHODS

The methodology employed in this study involved the use of SRTM and Satellite imagery to obtain the required target. Thus the satellite imagery of the area was downloaded and processed in a GIS environment to get the expected outcome. Landsat 8 OLI 2017 (Landsat 8 Land Operational Imager 2017) and Shuttle Radar Topographic Mission (SRTM), which were downloaded from www.earthexplorer.usgs.gov

were the two major satellite imageries used for this study. the Google earth images was just used for viewing. Other data sources included the shapefiles of the administrative boundaries of the Awka North and South LGAs (gotten from the department of surveying and Geoinformatics, Nnamdi Azikiwe university, Awka), photographs and the Non-spatial data which were collected through oral interviews. Processing and analysis of data were done with ArcGIS Pro. The steps included band combination, image classification and accuracy assessment and enhancement of the data. Microsoft office tool (including MS-word and Microsoft Excel) was used for statistical analysis, editing and production of text.

Some of the analysis carried out in order to achieve the aim included; the Watershed/Basin analysis to identify and demarcate the watershed which is the traced edge of drainage basin in the area. The watershed or basin analysis was done to define and trace out the stream networks, the areas drained by particular streams, as well as the edges of the basins within the identified drainage systems. River divides were identified to help in delineating the watersheds.

The Flow Direction Analysis was equally carried out to show the direction of surface stream flow within the area. The drainage pattern analysis was then done to determine the drainage pattern in the area. This stream network analysis was done to model the system to show the patterns of stream network in the area. Next was the Flow Direction Analysis, and this was done to determine the direction of flow of each of the streams in the basin as they drain out their contents through their highest order or trunk streams. The Stream Order Analysis to identify and show the different stream orders in the area was finally done.

4.0 RESULTS AND DISCUSSION

The results in this study are shown in form of diagrams including maps, tables and charts. Others are presented in form of discussions.

4.1 LANDUSE AND LANDCOVER (LULC) CLASSIFICATION

Landuse refers to all uses to which man put land to. Such include agricultural, recreational, institutional, waste disposal, industrial and residential. Landcover on the other hand portrays the natural features on the earth surface, such as water bodies, vegetation (forest), swamps, desert or sand dunes, bare land [9]. The LULC classification in this study showed that 13% of the study area was as agriculture, 33% as vegetation, 27% as Built area, 26% as Bare land and 1% as water body. The 1% of water body from the classification result here is a confirmation that most of the water bodies in the area are covered by gallery forest and that there are less open water bodies within the study area (Fig. 4.1).

CLASSIFIED	BAND FEATURES	FREQUENCY
CLASS 1	AGRICULTURE	13
CLASS 2	VEGETATION	33
CLASS 3	BUILT AREA	27
CLASS 4	BARE LAND	26
CLASS 5	WATER BODY	1

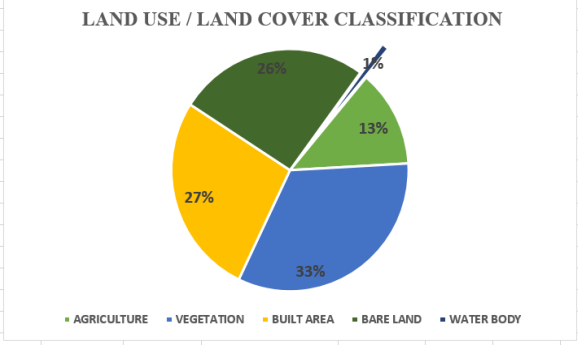


Figure 4.1: LULC Classification Pie-chart

4.2 TERRAIN TOPOGRAPHY EXTRACTION FROM DEM

Since both the google earth image and satellite image classification of the area could not reveal the true aerial coverage of water bodies and the streams (due to the present of interlocking gallery forests along the banks of the streams as earlier stated), the SRTM of the area was unavoidably used. This was able to trace the low lying topographies and the stream networks contained in them through its digital values.

In order to do this, the SRTM image of the study area was downloaded online from www.earthexplorer.usgs.gov . This was processed and then analyzed to extract the results as terrain details.

For the drainage map and stream flow network of the study area to be created, some digital image processing steps were taken on the extracted SRTM imagery. These included making a Mosaic of the Raster Data, Filling Sinks or Depression in the DEM, clipping of area of interest with the clipping tools, extraction of the Flow Direction of the Raster Cells, Flow Accumulation analysis, Determination of Basin Flow, Raster Calculation / Map Algebra, and finally carrying out the Raster to Polyline Conversion process (Figure 4.2, 4.3 and 4.4, 4.5, 4.6 and 4.7). All these helped to extract the stream network and to carry out drainage basin demarcation within the area.

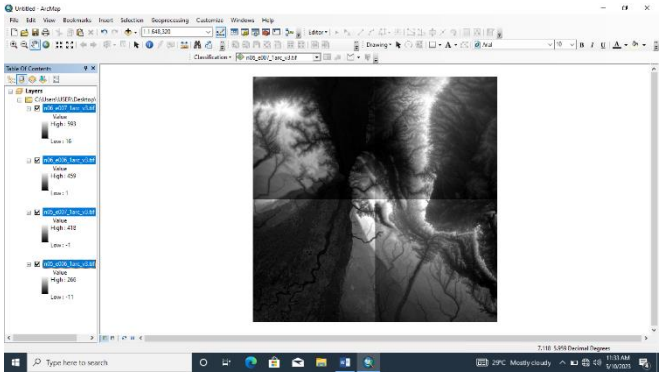


Figure 4.2: The DEM imageries before mosaic

4.2.1 MOSAIC OF THE RASTER DATA

Four Raster images were downloaded to cover the study area. As shown in Fig.4.2 and 4.3. The four imageries were mosaic or overlapped together so as to form one continuous image covering the study area (Fig. 4.2). The steps are as follows;

1. Click 'Data management tool'
2. Go to 'Raster', then 'Raster processing' and click on 'Mosaic to new raster'
3. Select the four imageries, Set "Output Raster" to the desired output name and location.
4. Click "Run."

4.2.2 FILL SINKS OR DEPRESSION IN THE DEM

After the DEM data was merged together, the first step to take was to fill out areas of void values or sinks or depression (that is, such areas where a cell of low values is surrounded by high elevation values). If that was not done, such data could have caused distortions during processing. Thus, the filled sink helped to ensure proper delineation of the basins and streams to avoid a derived network being discontinuous. The steps for this (Fig. 4.3), are as follows:

1. Click 'Spatial Analyst Tool'
2. Click 'Hydrology' then, 'Fill'
3. Add the mosaic image as input, select output location.
4. Click 'Environment', go to 'Raster analysis', select 'same as layer mosaic' and click 'OK'
5. Then click 'OK'

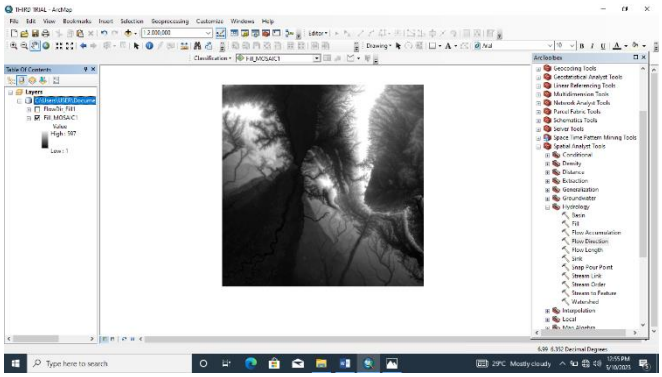


Figure 4.3: Filled mosaic image of the raster DEM

4.2.3 FLOW DIRECTION OF THE RASTER CELLS.

The flow direction tool was used to determine the potential direction of flow of water based on the elevation values of the pixels of the raster in order to determine where the direction of flow for each cell in the raster data drains as it makes its way downstream (Fig. 4.3).

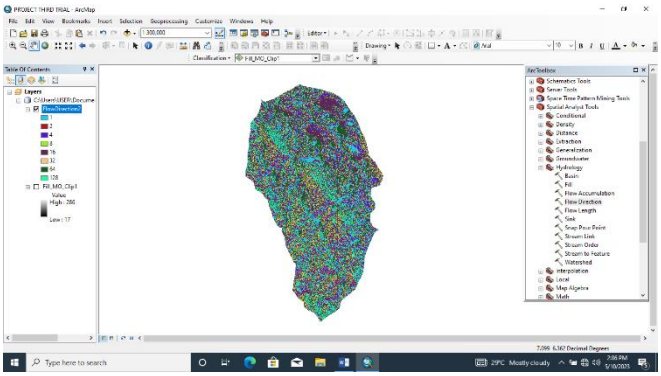


Figure 4.4: Flow Direction of the Study area.

The following steps were taken;

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'

4.2.4 FLOW ACCUMULATION

This very tool helps to calculate the flow into each cell by identifying the upstream cells that flow into each down slope cell. This value for each pixel is the sum of all flows from upstream of that pixel (Fig. 4.5). The steps are as below:

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

After that, click on the flow accumulation layer and go to properties.

1. Click 'Symbology Tab' and select classified.
2. Set the number of classes as **7** and click 'Classify' the values as 150,300,500,1000,2000,4000 and the lowest value.
3. Click 'OK'

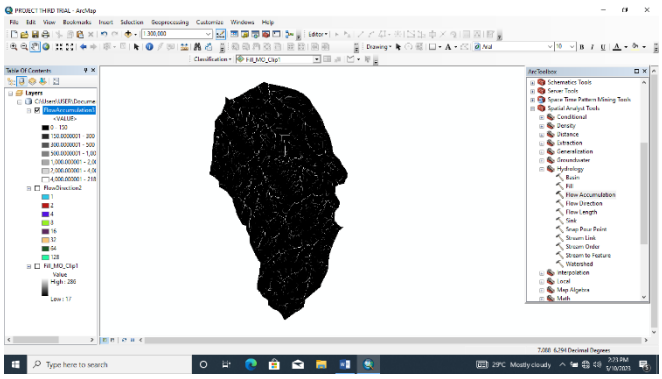


Figure 4.5: Flow accumulation image in ArcGIS

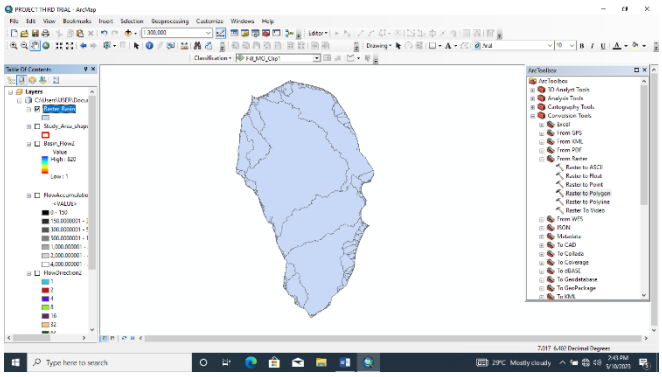


Figure 4.6: Raster to polygon image in ArcGIS

4.2.5 RASTER INTO POLYGON CONVERSION

This step followed immediately. To do this, follow the steps below:

1. Click 'Conversion Tool'
2. Go to 'From Raster' and click 'Raster to Polygon'.
3. Add the basin flow as the input raster and set the output polygon features and location
4. Click 'OK'

4.2.6 RASTER CALCULATION / MAP ALGEBRA

Raster calculation (Fig. 4.7) was done so as to calculate the elevation value difference between the high and low values of the raster data so as to assess the flow accumulation. The value for raster calculation is set at (flow accumulation >150). This means that where the flow accumulation cell has a value greater than 150, it will make those output cells null (0). And where the flow accumulation cells are less than 150 in value, it will make the output cells to have a value of 1. The steps are as follows:

1. Click 'Spatial Analyst tool'
2. Go to Map Algebra, click on 'Raster calculator'
3. Choose the 'flow accumulation' layer and set it to be greater than 150
4. Set the output raster
5. Click 'OK'

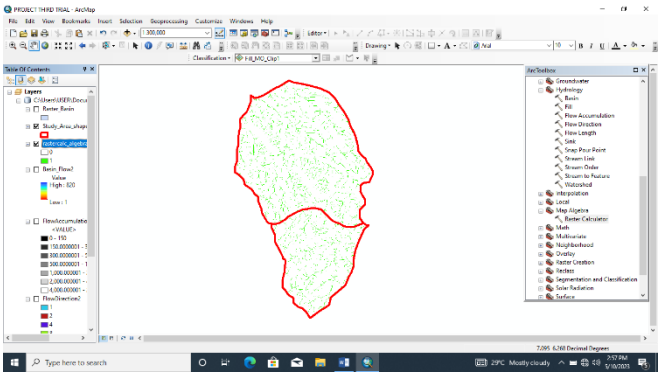


Figure 4.7: Map algebra image

4.2.7 RASTER TO POLYLINE CONVERSION

This final processing tool displays the stream network (Fig. 4.8) which is the goal of our study. This tool was used to convert the stream raster to polyline so that the stream network values in the raster data can be converted to vector polyline, which then shows the network of the streams as a line shape on the map of the study area.

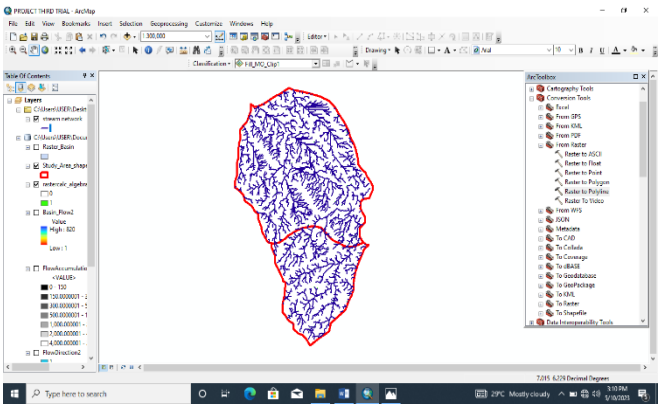


Figure 4.8: Raster Calculation / Map Algebra

The steps for Raster Calculation / Map Algebra are:

1. Click 'Conversion Tool'
2. Go to 'From Raster' and click 'Raster to polyline'
3. Set the map algebra as input raster and also the output polyline features as Stream
4. Click 'OK'

4.3 STREAM ORDER ANALYSIS

The Obizi river basin was used for the stream order analysis. This analysis involves assigning a numeric order to links in a stream network using Strahler stream ordering method in ArcGIS environment. This process identifies and classifies types of streams based on their numbered tributaries from first order to the highest order within the river basin.

The stream order analysis as seen in Fig.4.9 below showed that Obizi river basin has 175 first-order streams, 42 second-order streams, 8 third-order streams, 3 fourth-order streams and 1 fifth-order stream.
Apart from the north-eastern part of the Awka North LGA that had few parallel stream network, all other network of streams was found to be dendritic in form (Fig. 4.9).

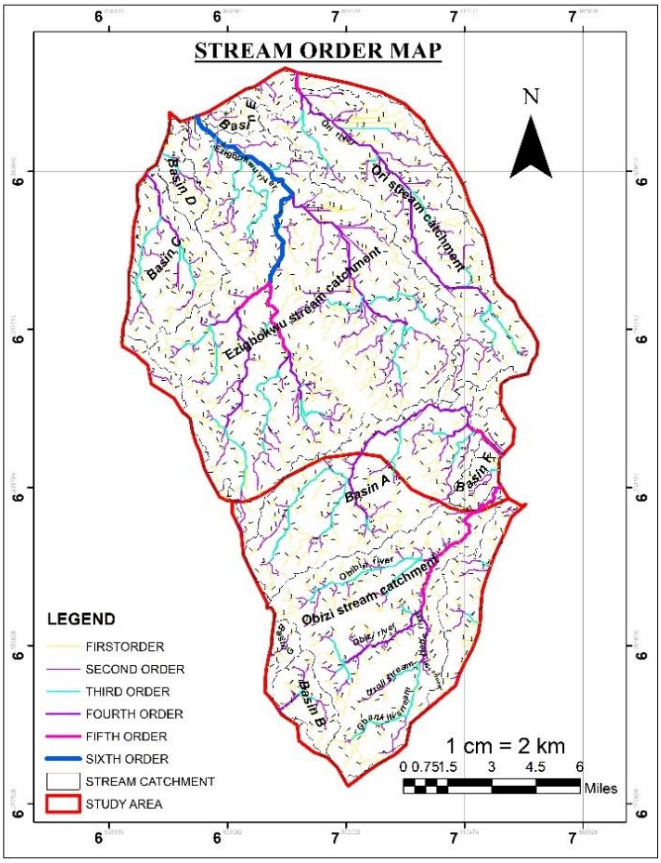


Figure 4.9: Stream Order Map of the Study Area

Stream Order (i)	Stream Numbers (Ni)	Bifurcation Ratio
1	175	4.17
2	42	5.25
3	8	2.67
4	3	3
5	1	-
MEAN BIFURCATION RATIO = 3.77		

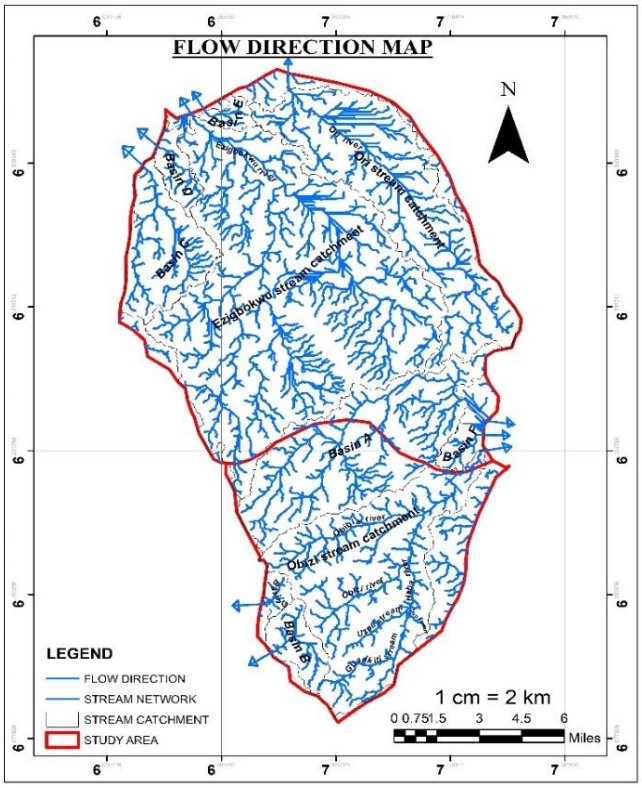


Figure 4.10: Stream Flow Direction Map

4.4 CALCULATION OF BIFURCATION RATIO

Bifurcation ratio which, is the ratio that shows the number of streams of a particular order in the catchment to the number of streams in the next higher order within the same catchment was calculated. The Bifurcation ratio of the Obizi river basin (as shown in Table 1) was calculated using the formula Bifurcation Ratio = Ni/Ni+1.

Table 1: Bifurcation Ratio Calculation Table

Bifurcation ratio has no unit.
Where Ni = Total number of streams in a given order, and Ni+1 = Total number of streams in the next higher order.
The study, shows that there are 229 number of streams of different orders draining the area. The mean bifurcation ratio of 3.77 here shows that that the area is well networked with streams and will have influence on the rate at which erosion occur during heavy precipitation.

5.0 CONCLUSION

The aim of this study was to assess the stream ordering and flow pattern in Awka North and Awka South LGAs of Anambra state of Nigeria, using satellite imagery and remote sensing techniques. From the Landuse/Landcover classification carried out in the area, very small area was found to be water, because 13% of the study area was seen to

be agriculture, 33% as vegetation, 27% as Built-up area, 26% as Bare land and only 1% was water body). The availability of the first order streams and other water bodies were not that visible (as it is shown by 1% only). This is because the study area has no open water body and the few first order streams are hiding from aerial visibility by the presence of gallery forests along the banks of the small streams. This gives rise to evergreen vegetation along the meandering stream channels, and was classified under vegetation.

From the analysis, ten major drainage basins were found in the area. They all had many streams and tributaries. They included Ezigbokwu stream catchment, Obizi stream catchment, Ori stream catchment and seven others. We named these other seven with alphabetical letters form "A" to "G" because they had no single and common names but names given to them by the individual communities in which they passed through.

The stream order analysis of the area from the study has also revealed that 5th order is the highest stream order in the region (Figure 4.9). The network of streams within the ten drainage stream catchments in the basin has 175 first-order streams, 42 second-order streams, 8 third-order streams, 3 fourth-order streams and 1 fifth-order stream which gives a total of 229 connecting streams with ten different trunk streams or outlets.

This study has equally shown that dendritic drainage pattern is the dominating stream network system (Figures 4.9 and 4.10). There are however very few parallel arrangements of stream flow. This is found at the north east of the area, and exactly the northern part of Ori catchment basin. Some of the streams in the area, mostly the first order stream and few second order streams are seasonal streams.

The study has made some recommendations. The town planning and regulatory bodies should not base their viewing decisions only on the aerial photographs and google earth images of the area for allocation and zoning of activities centers to users. Most of the residential buildings are built on the first order stream channels, especially those that are seasonal in nature. This normally results in high rate of flooding and collapsing of buildings during heavy rain fall, as the channels will contain water to their full capacities. Also, the names of some of the streams has not been captured into the national or international gazette and archives. This makes it difficult for researchers to identify their names. More stream naming efforts should therefore be made by the Local Government Council and State authorities in charge of water resources so as to harmonize the different names given to some streams by the individual communities they pass through. Thus, instead of a particular stream, which passes through about seven communities having seven different names, the Local Council and State authorities involved should make a deliberate effort to harmonize them to have only one name for easy identification, just as we have a single name for "River Niger" in Nigeria though it passes through different states in the country.

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