ASSESSMENT OF DRAINAGE BASINS IN AWKA NORTH AND AWKA SOUTH LGAS OF ANAMBRA STATE OF NIGERIA USING SATELLITE IMAGERY AND REMOTE SENSING TECHNIQUES

Nnamnso Peter Udoudo*, Ambrose Ndubuisi Ekebuike, Uchendu Chiedozie Kanayochukwu, and Ikwuagwu Onyedikachi Joshua
Department of Surveying and Geoinformatics, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria
Corresponding Author: environsurveys@gmail.com

Abstract

Drainage patterns are the traceable appearances in the stream network in which stream channels appear morphologically as they drain their contents and surroundings from the source streams to their outlets or destination streams (which may be Rivers, Lake, Sea, or Ocean) within the drainage basin. The low lying topographic area drained by a river and its tributaries in a stream system is referred to as the Drainage basin. Drainage systems therefore consist of networks of streams of different orders including springs, streams and rivers with their flood plain found within a given drainage basin. Remote sensing deals with acquiring a remote information from an object with the help of sensor devices without having any direct contact. The study area, which comprises Awka North and Awka South LGAs of Anambra state is one of the most populated and commercially developed areas or regions in the state. The area has a closely packed drainage network of stream tributaries with many first orders streams arising from the ground. Thus, the topography is not all that plain but undulating. This facilitates very high runoff after heavy precipitation or rainfall and gives rise to the deep erosion gullies. Some channels are used for residential buildings while others are used as waste dump sites thereby resulting in yearly floods and other environmental disasters. There is no proper zoning formula in Awka, where activity centers are zoned into different land uses, such as residential, agricultural, and industrial land use for proper environmental management. There is also no proper awareness of the dangers embedded in building within the flood plains and along the stream channels. As a result of this, residents are seen clustering along the drainage channels, disposing their wastes into it and causing series of divergence of water ways and flooding. This results in the blockage of the natural stream flow, and the consequence is disastrous in some cases. The aim of this study is to access the drainage network pattern in Awka North and Awka South using satellite imagery and remote sensing techniques. The objectives include; acquiring and processing a medium resolution satellite imagery of the study area, accessing the land use /land cover classification of the area to know the extent of water available for the study, 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. The methodology involved acquiring and processing a 30 arcsecond DEM (30m) data and medium resolution Landsat 8 Operational Land Imagery (OLI) satellite imagery, obtained from www.usgs.earthexplorer website and analyzing them using remote sensing and GIS techniques, in order to produce the drainage basin map of the study area. The result of the study showed that the drainage patterns within the study area are mainly closely packed dendritic with few parallel patterns. Recommendation included that efforts should be made to halt the blocking of the stream channels with building, while proper

land use zoning formula should be employed in the area. Thus, a proper assessment of the drainage pattern within the study area would help in management of its numerous watershed against pollution or dumping of refuse in to the stream channels.

Keywords: Drainage Basin, Mapping, Remote Sensing, Satellite Imagery, Stream Network, Topography

Introduction

Water on the surface of the earth flows from a higher to a lower elevation (as a result of the force of gravity) through its natural or man-made channels. The water channels are the confined pathways through which waters in fluidal form found on the earth surface (in form of springs, streams, rivers and so on) flow. There are source streams, where water seeps out of the ground or rocks and flows along a low lying path. One stream joins another and the linked-chain continues till it forms a network of streams joining each other and flowing with a combined force within the basin to a common destination via the trunk stream. According to Twidale (2004) 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 (Friend, Jones and Vincent, 2009; Howard, 1967). Drainage system and network is mostly studied through the field of science referred to as "Hydrology". 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. Ward and Robinson (2000) define Hydrology 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 is that aspect of science that involves the occurrence, distribution and the movement of water on, beneath and above the earth surface. It also covers the study of all the components of hydrological cycle. Hydrology therefore gives inside of 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.

Drainages channel or water way according to Nelson (2015) always develop along zones where rock type and structure are most easily eroded. This therefore creates the channel for water to flow or be drained. Thus, as soil particles are eroded along the lines of weakness, the eroded pathway gives rise to a channel for either a continuous or seasonal water flow depending on the water availability in the area.

Remote sensing is the gathering of an information about a remote object without making any direct physical contact with that object (Udoudo, Ekebuike and Ossai, 2023). 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 (Adjei-Darka, 2017; Canadian Centre for Remote Sensing, n.d; Lillesand, Kiefer and Chipman, 2008; Qihao, 2013). No man has ever gone to or reach the Sun, but through remote sensing techniques, its characteristics and features are studied. The use of satellite remote sensing technique, gives a more holistic hydrographic information than the ground method or technique when studying the water bodies (Ekpa and Ojinnaka, 2015;

Lillesand *et al.,* 2008). The use of remote sensing method therefore helps to obtain a larger and wider spectrum of information within a short time.

There are two divisions of remote sensing base on their mode of operation, which include the passive remote and the active remote sensing. Passive sensors reflect the energies projected by other sources. Example of this is the reflection of sun light by the moon (as the moon does not produce light of its own). Most sensor devices, like cameras produce their images through this means. Active sensors are those ones that produce their own energies, such as LiDAR. With this, they scan the objects in question and send back the reflected rays through the two-way traveling to the sensors to be processed so as to get the required information. This study therefore aims at accessing the drainage network pattern in Awka North and Awka South using satellite imagery and remote sensing techniques. The objectives include; acquiring and processing a medium resolution satellite imagery of the study area, accessing the land use /land cover classification of the area to know the extent of water available for the study, 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.

The Study Area

wka North and South LGAs which is the study area are LGAs location in Igbo land, within the eastern part of Anambra state of Nigeria. Anambra state is one of the states in the South-Eastern part of Nigeria (Figures 1 and 2).

The official and indigenous language of the area is Igbo language. As seen in Figures 1, 2 and 3, the area is located approximately within latitude between Latitudes 6° 04'N and 6° 28'N and Longitude 6° 55'E and 7° 11'E. There are however no larger water bodies in the area but several of the small streams are found meandering the entire region, most of which are covered by vegetation (gallery forest) thereby, impeding the visibility of the streams from the satellite imagery obtained for the land use/land cover classification.

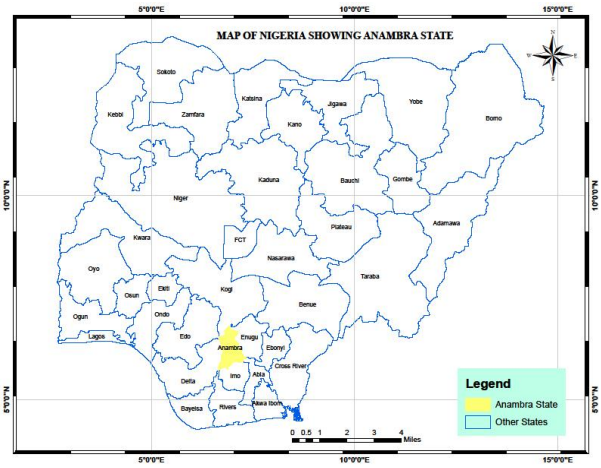


Figure 1: Map of Nigeria showing Anambra State
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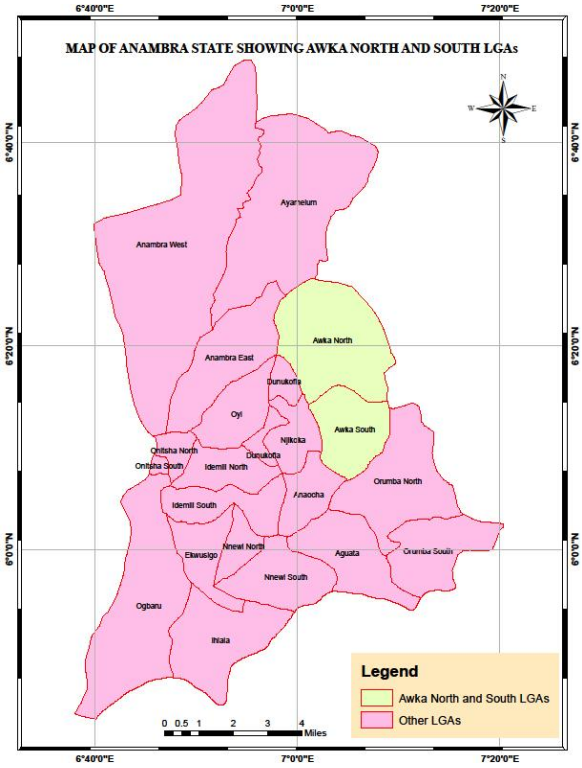


Figure 2: Map of Anambra state showing Awka North and South LGA

The area experiences two major seasons, the rainy and the dry season. The major wind masses are the South Monsoon trade winds from Atlantic Ocean and the North-Eastern trade wind, which is a dry wind coming into the country from the Sahara Desert. The highly humid wind blowing in from Atlantic Ocean results in seven months of rain occurring (April and October). That from November to March brings in dry season into the area and the entire country.

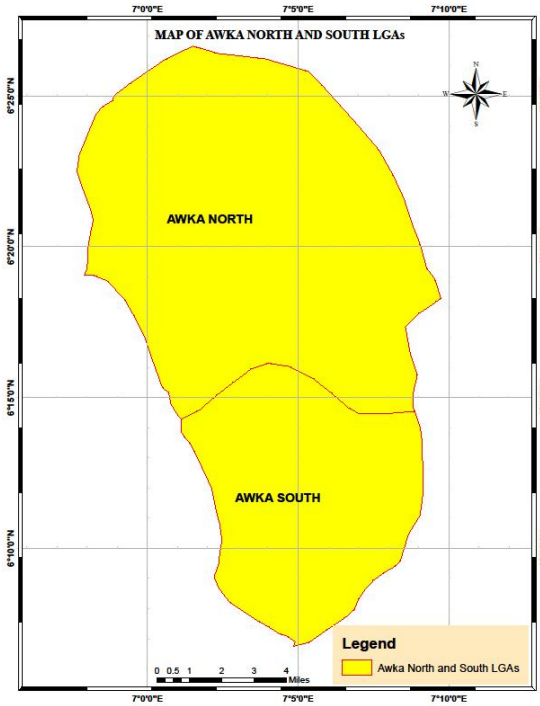


Figure 3: Map of Awka North and South LGA

Many first order streams are found in the area and in the rainy seasons, some locations are water logged which will dry up in the dry seasons. Thus, there are many seasonal streams that increase the drainage strength of the area during rainy season but dry off after the period of heavy rain. Because of this, the soil texture can be so muddy and wet during the rainy seasons.

The area is located in the Ecotom of the transition between the tropical rainforest and the wooden savannah grassland and is thus dominated mostly by the grassland and low forest vegetation that have scanty emergence of some taller trees. Along the stream valleys are some evergreen vegetation, otherwise called the "gallery forest".

Materials and Method

The methodology applied in this study involved the use of a remote sensing method to assess the stream network of the study area. The source of the satellite image was Landsat 8 OLI 2017 (Landsat 8 Land Operational Imager 2017) satellite imagery downloaded from www.earthexplorer.usgs.gov. Other data sources included the administrative boundaries of the Awka North and South LGAs, photographs and the Non-spatial data of the area which were collected through oral interviews. Processing and analysis of data, including band combination, image classification, accuracy assessment, displaying, processing, enhancing of the data were done using ArcGIS software. Microsoft office tool including MS-word and Microsoft Excel was used for statistical analysis, editing and arrangement of text.

Some of the analysis carried out in order to achieve the targeted aim included; the Land Use / Land Cover Classification Analysis (Supervised) to identify the different land cover and land use patterns in the area so as to ascertain the water bodies available for the stream network delineation and determination. The essence of this type of analysis is to show the hydrological and drainage activities taking place in the study area. The supervised classification was done by adopting the level one classification scheme of Anderson, Hardy, Roach, and Witmer (1976), where the LU/LC categories were grouped under five classes namely; Agriculture, Vegetation, Built-Area, Bare-Earth and Water Body.

The Watershed/Basin Analysis to identify and demarcate the watershed which is the traced edge of drainage basin in the area was carried out. This 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. The high elevation separating the watershed, otherwise referred to as the River Divides were also identified to help in delineating the watersheds by using different colours for their distinctiveness.

The Flow Direction Analysis too was done to show the direction of surface flow of streams within the area. This is a function of topography.

The Stream Network/Drainage Pattern Analysis also was carried to determine the drainage pattern in the area. This was to model the system to show the flow of surface water through the area.

Next analysis that follows was the Flow Direction Analysis, which was done to determine the direction of flow of each of the streams in the study area. At last, the Stream Order Analysis to identify and show the different order of streams in the area was done by adopting Strahler's stream ordering method.

Results and Discussion

In this study, the results are shown in forms of maps, tables, charts and discussions.

Land use and land cover (LULC) classification

Land use refers to the different uses to which man put land into including agricultural, waste disposal, industrial, residential, recreational, institutional, while Land cover on the other hand depicts the natural features covering the terrain surface including features such as water bodies, swamps, desert or sand dunes, bare land and forest or vegetation covers (Udoudo *et al.,* 2023). The classification scheme adopted was that of (Anderson, *et al.,* 1976).

This study shows that larger space of the study area is covered by vegetation, bare land and agriculture, while water bodies are seen in patches covered by the gallery forest. This type of forests are the evergreen forests lying on the both sides of the bank of stream. And if the wide of the stream is not large enough, the foliage of the trees at the opposite banks of the stream will interlock and cover the streams from visibility in and aerial photographs and satellite imageries. Gallery forests are always there along small stream channels due to the constant presence of moisture in the soil which causes their leaves to be evergreen (Figure 4). This therefore makes most of the streams in the area to be hidden from satellite imageries. In that case, those small stream channels and their connectivity are only mimic, seen and analysed from satellite image classification as "vegetation". This is because the study area does not have large open water bodies to be openly seen through aerial views. The classification analysis also shows built-up areas which are found in patches of human settlements. Also identified from the image classification is the presence of bare lands (Figure 4).

DEM creation for topographic extraction

Extraction of the topographic details of the study area to trace the stream network became unavoidably very necessary. This is because the available streams in the study area were hid from aerial views, such as google earth image and visibility in the satellite imageries. This was largely due to the interlocking of foliage and branches of the gallery forest dominating the two sides of the streams. In order to extract the topographic details of the area and to delineate the stream network, the Shuttle Radar Topographic Mission (SRTM) image of the study area was downloaded online from www.earthexplorer.usgs.gov for processing and then analyses.

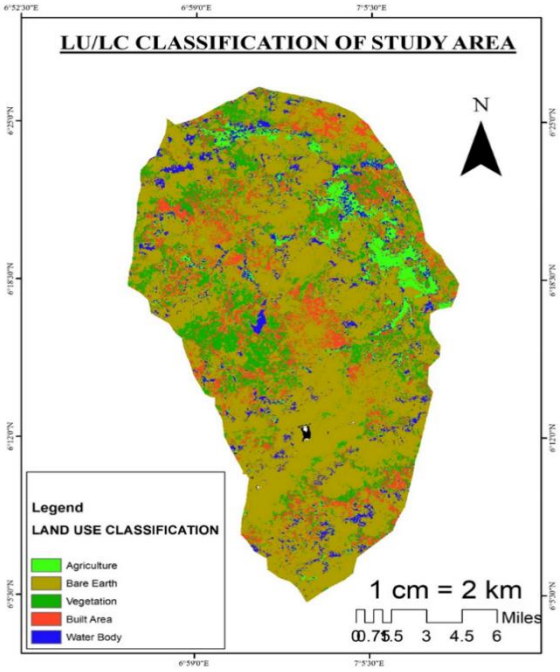


Figure 4: Land Cover Classification Map of Awka North and Awka South LGAs

For the drainage map and stream flow network of the study area to be created, some processing steps with ArcGIS were taken on the SRTM imagery including; carrying out the Mosaic of the Raster Data, Filling Sinks or Depression in the Dem, Clipping 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 (Figures 5, 6 and 7). All these jointly worked to give the required stream network and basin demarcations required.

Clipping of area of interest

To focus the analysis to a desired area of interest, the following steps were carried out using the study area shape file to clip out the area from the DEM imagery (Figure 6).

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

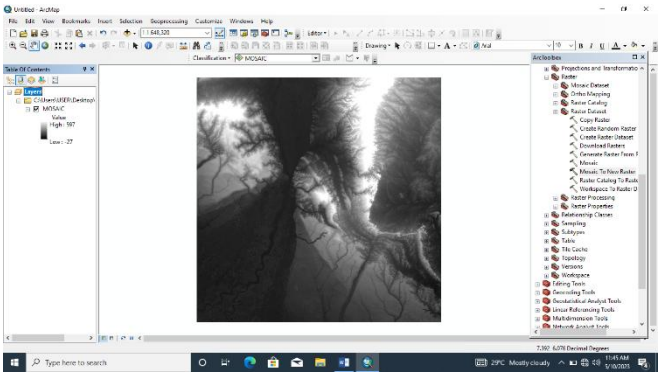


Figure 5: The Mosaic DEM imagery in ArcGIS

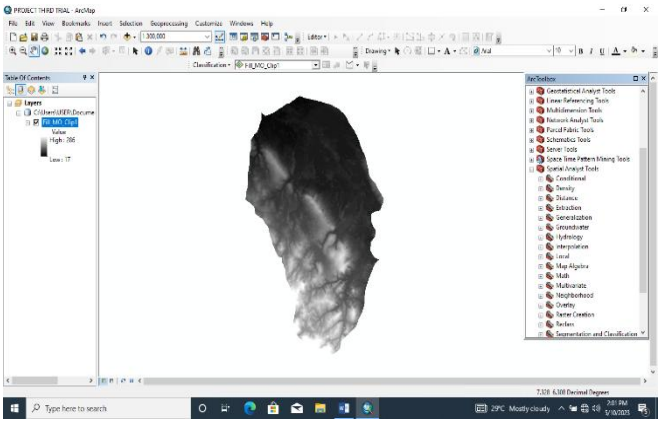


Figure 6: Clipped image of the study area from the filled DEM in ArcGIS

Basin flow in the study area

The tool was used to determine and delineate the different watershed or river basins that are within the study area raster. The different basins were shown in different shades of colour so as to differentiate one basin from the other (Figure 6).

1. Click 'Spatial Analyst Tool'

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

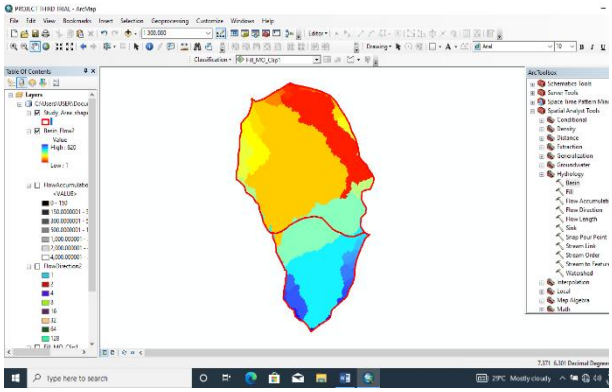


Figure 7: Basin Flow image in ArcGIS

After this, conversion of the basin flow raster into polygon was produced (Figure 7). The steps are as 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'.

Drainage basin in Awka North and Awka South LGAs

The pattern of stream network in the study area as identified by the study is shown in figure 8 below. Stream network analysis, also known as Drainage pattern analysis was done using ArcGIS software in a GIS environment, from the SRTM image to model the flow of surface water within the basin. The result of the analysis shows that the stream network within the study area consists of mainly dendritic patterns while few streams toward the North-Eastern part of Awka North have parallel arrangement or patterns (Fig.8). Drainage basins in Awka South is in a region having homogeneous bedrock material beneath it, and this influences the surface geology to have a similar resistance to weathering. This gives rise to the dendritic pattern of stream network found in the area.

The few network patterns within the upper right corner of Awka North with parallel arrangement depicts the underlying fault lines and the soil texture pattern in the area.

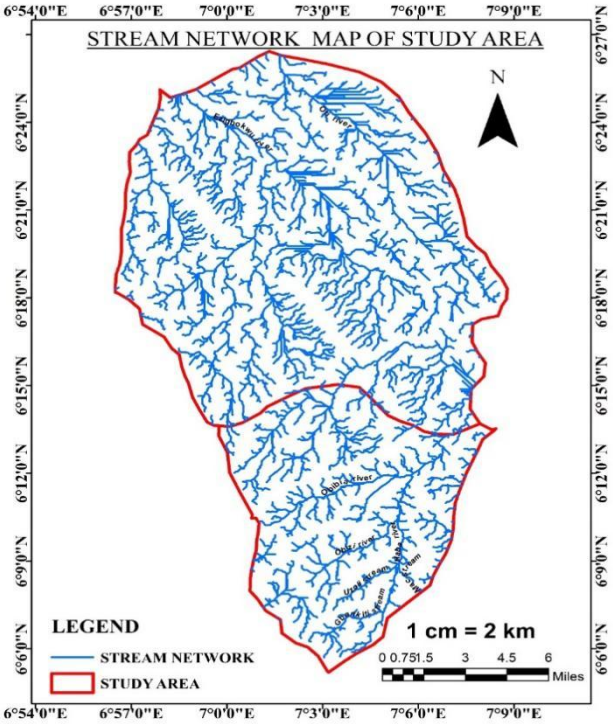


Figure 8: Stream Network Map of Awka North and Awka South LGAs

Watershed and drainage basin identification and demarcation

The Basin or Watershed analysis was done with the ArcGIS software to define the stream networks and the areas in which they drain within a particular drainage basin. This analysis shows that there are many different small or first order streams within the identified basins. Many of these streams do not have any particular name known state wise, nationally or internationally, but the local names given to them by the individual communities which they pass through. In this case, the research reveals that one stream for instance bears different names as

it flows across different communities. The different watersheds or traced edge of the basins have "River Divides" separating each drainage basin from the other one. As shown in Figure 9, each of the drainage basins are identified by delineating them with different colours to show their distinctiveness.

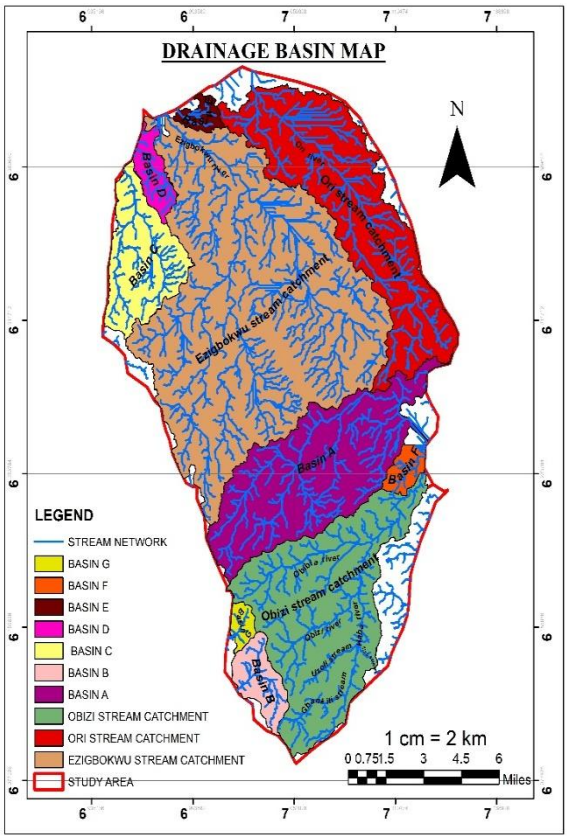


Figure 9: Drainage Basin Map of Awka North and Awka South LGAs

The analysis showed Ten (10) major basins or watershed in the area including; Ezigbokwu stream catchment, Obizi stream catchment, Ori stream catchment and seven other basins which we named as basin A, B, C, D, E, F and basin G because their name could not be known due to the fact that they are local streams and have different names through the different communities they pass through.

Obizi stream catchment which is the largest basin in Awka South have an interesting connections of different streams within its basin which include; Obibia river, Uzoli stream, Gbankiti stream, Mac stream and Haba river. These streams make up the network that drains many communities located within Obizi river catchment. In Awka North LGA, Ezigbokwu drainage basin or stream catchment is the largest and has the highest number of stream network in the region, and therefore drains a larger area of land across many towns and communities within Awka North.

Conclusion

The aim of this study was to assess the drainage networks in Awka North and Awka South LGAs using satellite imagery and remote sensing techniques. From the Land use/Land cover classification carried out in the area, vegetation and forest dominated the area and few patches of water bodies were seen though there are network of small and first order streams in the area not visible through satellite imageries. The invisibility of the streams was as a result of the gallery forest at the bank of those small streams where their leaves and branches interlocking from both sides of the banks covered the surface of the streams.

The analysis from the study showed that ten major drainage basins or watersheds drain the area. They include Ezigbokwu stream catchment, Obizi stream catchment, Ori stream catchment and seven others we named with letters of the alphabets, from A to G, as basin A, B, C, D, E, F and G, because their name could not be known due to the fact that they are local streams and have different names through the different communities they pass through. In some of these communities visited, the local people were reluctant to give us the local names of these small streams. According to some of them in their traditional belief, those streams are owned by some deities and their names should not be reveal to strangers anyhow. Since those streams are not identified in the national or international gazettes and archives, we have to number the basins from "A" to "G".

This study has also revealed that the prevailing drainage pattern within the study area is dendritic and very few parallel patterns existing in different watersheds within the north-eastern part of the Awka North. This should be as a result of the homogeneous bedrock material within the zone, which gives rise to few hard and elongated rock faults. This resulted in the few parallel arrangements that are found within the area.

This study recommended that scientist should research, developed and invent a satellite imagery with the electromagnetic spectral band that can pass through leaves of vegetation to trace all the smaller stream networks underneath the trees despite their foliage and canopies. Also, some local streams have name that has not entered into the national or the international gazette and archives. More efforts should be made by the international bodies to name those streams for identifications and other purposes. Efforts should be made by the government to ensure that the gallery forests are not deforested for timber and agricultural purposes.

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