https://dx.doi.org/10.4314/ijs.v25i3.4

ASSESSMENT OF STREAM ORDER AND DRAINAGE PATTERN OF FLOOD PRONE AREAS OF EBONYI STATE, SOUTHEASTERN NIGERIA

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(Received: 23rd May, 2023; Accepted: 24th November, 2023)

ABSTRACT

This study evaluates stream order and drainage pattern of flood in Ebonyi state, Southeastern Nigeria. The drainage network within Ebonyi State was identified using the Shuttle Rader Topographic Mission (SRTM), the stream order and flood drainage pattern with the aid of the Digital Elevation Model (DEM), and the Topographic analysis of Spatial Analyst on Hydrology. The data was acquired using Geometric Positioning and the LANDSAT downloaded from the United States Geological Survey (USGS) Earth Explorer 2019 and Thematic Mapper (TM) 2009. The result shows that the map of the eastern part of Ebonyi State houses the Cross River basin as a main consequent river draining to the Atlantic Ocean. The drainage gets darker down the slope as more volumes of water move into the traversing drainage channels in their corresponding orders. As flood magnitude increases, the velocity decreases because more water from different river orders or tributaries has been added to the adjusting river channels. It proves that consequent rivers like the Enyim River of Izzi, Iyiokwu River of Abakaliki, Alcor River of Ikwo, Iyere River of Afikpo South, and Esu Umuchimaewuze River of Ohaozara Local Government areas slope down through the adjourning tributaries when the basin is saturated. The map legend shows a thick blue outcome indicating that the flood originates from the Enyim River of Izzi, Iyiokwu River of Abakaliki, Alchor River of Ikwo, Iyere River of Afikpo South, and Esu Umuchimaewueze River of Ohaozara. Therefore, urgent adjustments and construction of drainage systems are needed to accommodate more water volumes.

Keyword: Stream, Flood, Drainage, Landsat, Ebonyi.

INTRODUCTION

Over the years, there have been cases of flood in Ebonyi State, especially in some LGAs like Izzi, Ikwo, Ebonyi, Ohaozara, and Afikpo South LGA (Oginyi, Nwankwo, Nweboko, Agada, 2013). The cases of unprecedented flood disasters as recorded in Oginyi *et al.,* (2013), where properties worth millions of naira were lost in the Abakaliki metropolis. In 2015, crops like rice, yams, and cassava were chocked in the lower river basins of Izzi, Ikwo, and Abakaliki LGAs of Ebonyi State causing unexpected poverty, loss of lives, and unnecessary theft. Nwankwagu and Nkwede (2016), identified the impacts of floods to farmers in Ebonyi State, and explained the causes of flooding in the study area are heavy rains, careless habits of inhabitants through, throwing of solid refuse dumps on water ways leading to drainage blockage, while Onu and Onu (2020) assessed the Coping Strategies for Flood in Ebonyi State to ascertain the impact of the devasting flood and its effects from time to time. In line with the management of flooding, Lindsay *et al.,* (2019), opined that drainage and river directions characterized the structure of the stream network, which allow the identification of confluence points and individual network that links stream order. Stream order allocates geometric designations that indicate the watershed drainage system and where the stream segment lies (Clayton *et al.,* 1972). In Ebonyi State, the major consequent river, the Cross River Basin, cannot get filled up during the rainy season, but its environs and beyond get chocked up by flood that endangers the entire populace. The drainage network is the fundamental hydrologic and geomorphic areal unit through which a detailed description of the geometry of landforms where data are collected, organized, and analyzed (Chorley, 1969). The systematic description of the geometry of a drainage basin and its stream channel requires measurement of linear aspects of the drainage network, areal aspects of the drainage basin, and relief (gradient) aspects of the

channel network and contributing ground slopes (Alfa *et al.,* 2019; Salvi *et al.,* 2017). Therefore, this study undertook a systematic examination of different stream order segments traversing through the watershed in Ebonyi state, their roles and actions as they empty into the main river, the Cross river, and invariably x-ray the importance of these tributaries that contribute to flooding in the study area to proffer sustainable ameliorative measures

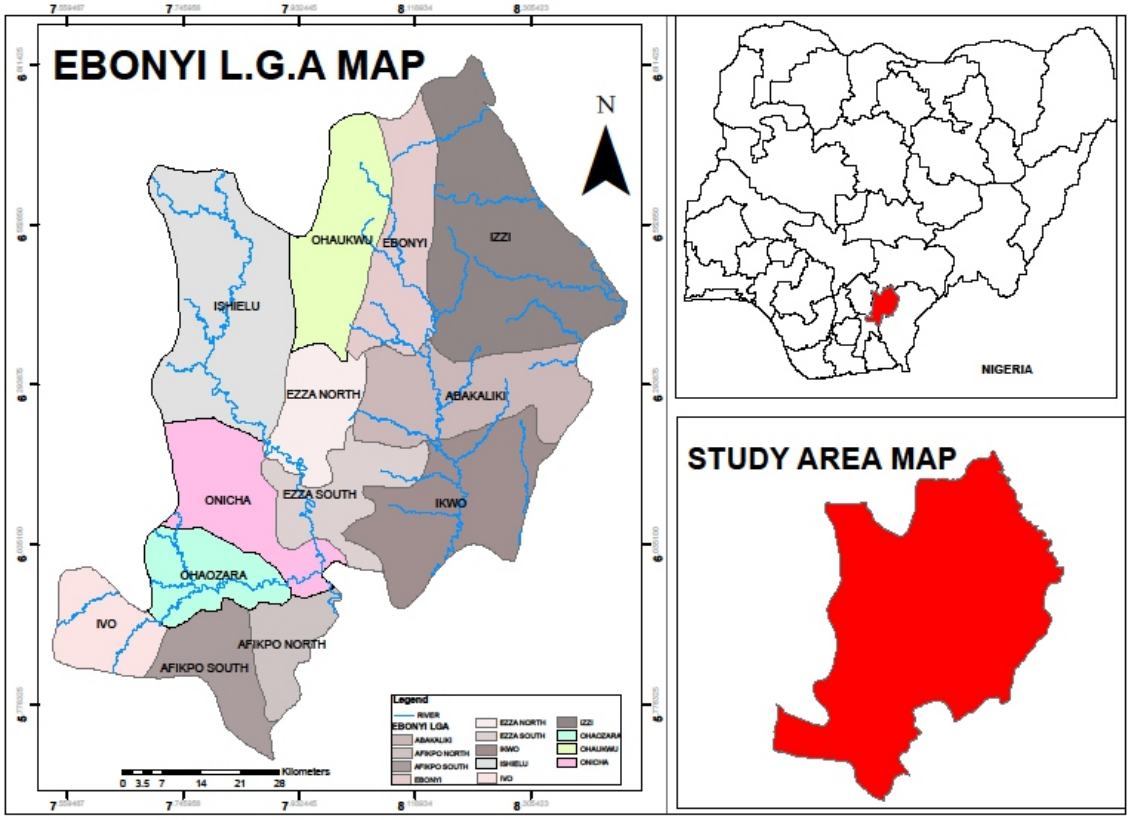

Figure 1: Ebonyi state map showing the study area (source: authors GIS Map).

MATERIALS AND METHODS

Study Area

Ebonyi State lies between *N 6° 10' 40.7028", E 7° 57' 33.4296*". Ebonyi State is in the South Eastern part of Nigeria. It comprises thirteen local government areas: Abakaliki, Afikpo North, Afikpo South, Ebonyi, Ezza North, Ezza South, Ishielu, Ikwo, Ivo, Izzi, Ohaukwu, Ohaozara, and Onicha LGA. The State is bounded in the North by Benue State, East by Cross River State, West by Enugu State, and South by Abia State. The National Population Census (NPC) of 2006 shows that Ebonyi State had a total population of 2,176,947. The State has been growing at a phenomenal rate of 5% per annum (NPC, 2006). The State slopes from North to South, the entire area is drained by the Cross River Basin that accepts all the tributaries of the whole rivers within the watershed. It has 400 ft as its highest contour and 100 ft as its lowest contour above sea level. It falls within the Asu-River Geologic Group (Lower Cretaceous), Eze-Aku shale formation, and Nkporo Formations. The State consists of hydromorphic soils of reddish-brown gravel and pale-coloured clayey soil, shallow in-depth, and of the shale parent material. Its topography is largely a tableland; the highest point is 162 m, and the lowest is 15 m above sea level. The climate is tropical according to the Koppen climate classification, with two seasons: the rainy season between April and October and the dry season between November and March. The temperature ranges between 21 °C to 29 °C, and relative humidity is high. Annual rainfall varies from 2,000 mm in the Southern to 1,150 mm in the Northern area. Harmattan is felt between December & January. Agriculture is the major occupation of the people. They produced crops such as rice, yam, cassava, plantain, banana, maize, cocoyam, groundnuts, palm produce, etc

Method

Nigeria satellite imageries (NIGSAT X), Topographic map, and SRTM (shuttle radar Topographic mission) of Ebonyi states were acquired from Advance Space Technology Application Laboratory (ASTAL) Ikwo LGA Ebonyi State, and National Space Research and Development Agency (NASRDA). The LANDSAT data were downloaded from USGS Earth Explorer, in 2019. The Thematic Mapper (TM) images were downloaded for 2009. The Enhanced Thematic Mapper Plus (ETM+) image was downloaded for 2012 and the Operational Land Imager (OLI) for 2018. The intervals of 3 years were deliberately chosen by the researcher to ensure uniformity between the datasets. The TM and ETM+ images have a spectral range of 0.45 - 2.35 micrometer (μm) with bands 1 to 7 and 8 respectively, while the Operational Land Imager (OLI) extends to band 12 were used for image classification and LST extraction. The administrative maps of Nigeria containing states and LGA's were gotten from the National Space Research and Development Agency (NASRDA). A projected vector shape file was used to specify the boundary of the study area. The LANDSAT 7 and LANDSAT 8 were used to pick images in the fieldwork conducted for map exploration utilized in analyzing data collected which was compared with the online imageries already in existence from 2009 to 2018. Also contained is the Shuttle Radar Topographic Mission (SRTM) and the Digital Elevation Model (DEM) an advanced technology implored to present the terrain of study using a structured map as raw data from the field. The SRTM was used to generate the river network of the Topographic Analysis of spatial Analysts on Hydrology, the classification of the river network, and spatial analytical modeling on stream flow direction, stream order, flow basin, catchment concentration, and river buffer zone.

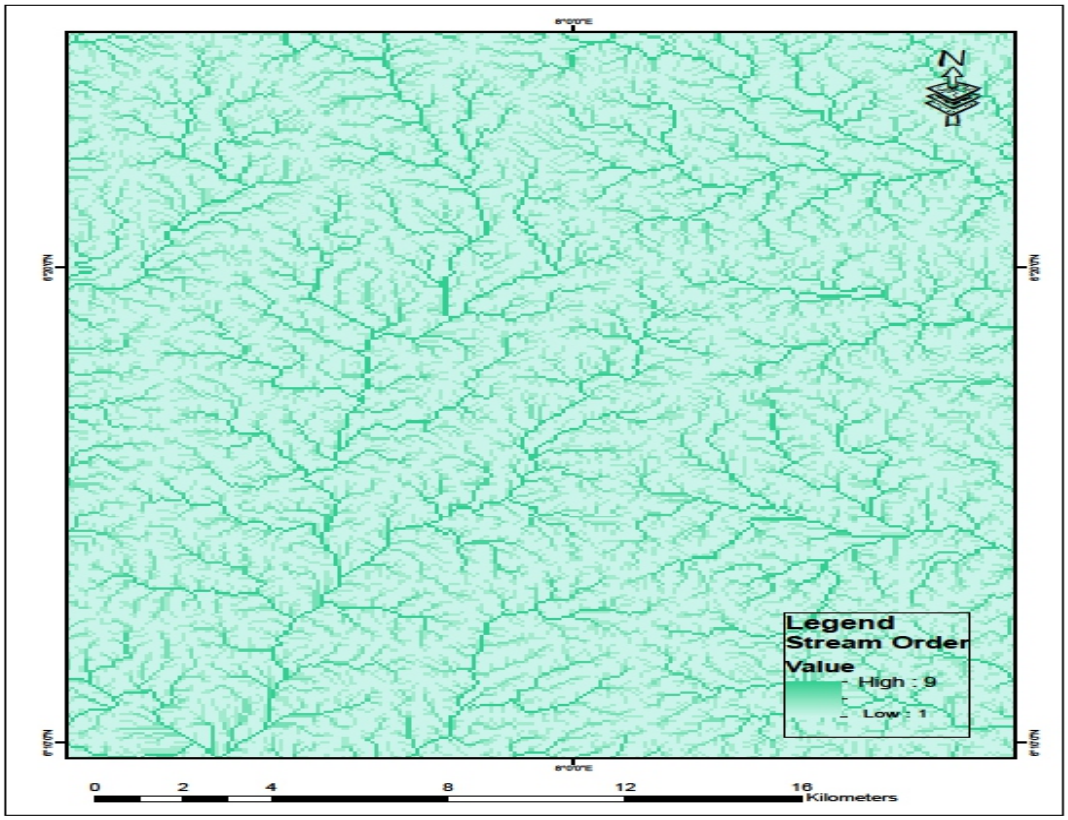

Figure 2: Stream order and drainage pattern of Ebonyi State.

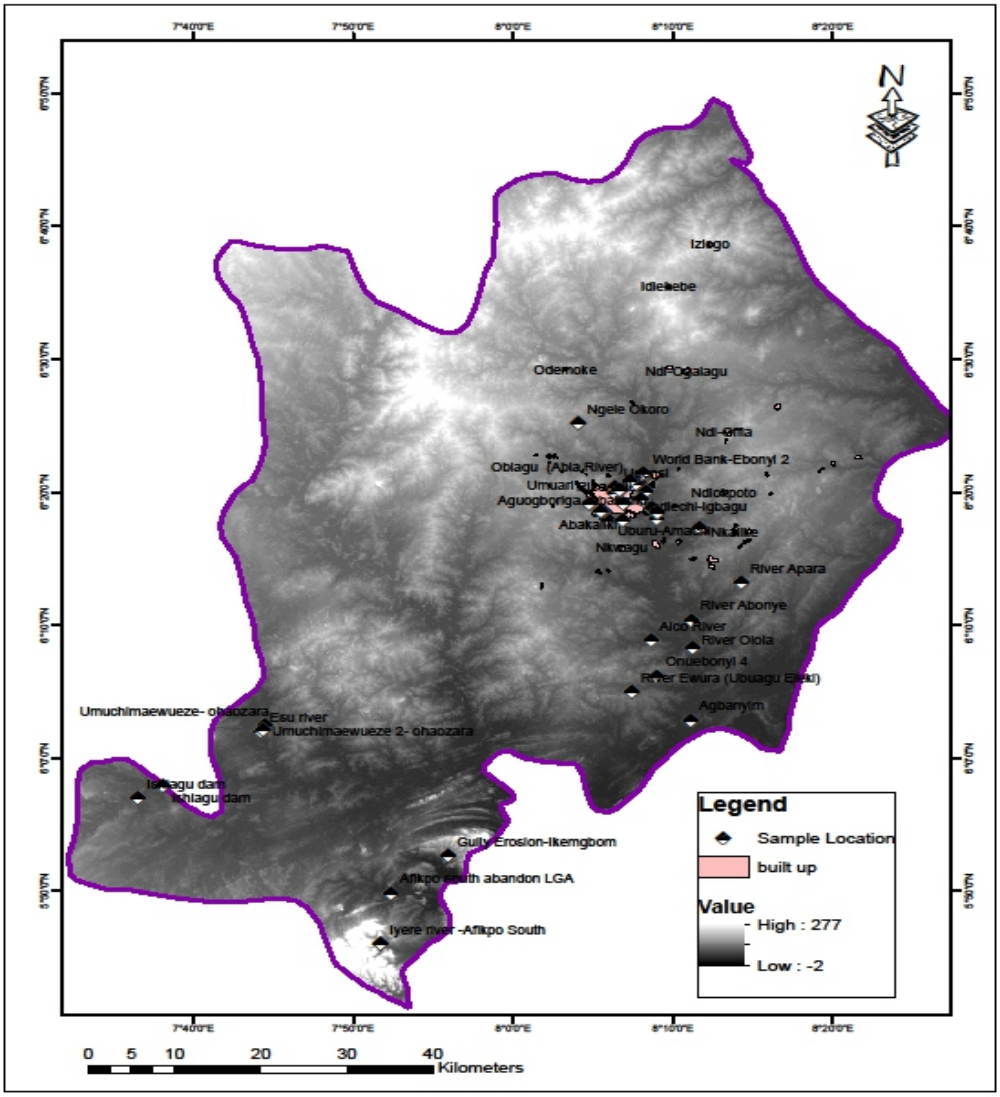

Figure 3: Ebonyi state DEM map showing stream order and drainage pattern (source: field work, 2021).

RESULTS AND DISCUSSION

Figures 2 and 3 above show the effects of stream order and drainage pattern on flood prone areas of Ebonyi River Lower Basin of Ebonyi State using the Digital Elevation Model (DEM). The drainage gets darker down the slope as more volumes of water are added into the traversing drainage channels in their corresponding orders down the slope. We observed that the map towards the Southeastern part of Ebonyi State that houses the Cross River basin is the major consequent river draining the area down to the Atlantic Ocean. As the stream order progresses down the slope, flood magnitude increases, and the velocity decreases because much more water from different river orders or tributaries has been added to the adjusting channels correspondingly.

Several rivers tributaries joined the slope and invariably affected the drainage pattern so much that the accumulation of water by the different drainage tributaries causes an upsurge of water within the basin as floods. These floods occur mainly within the lower river basins of Izzi, Ikwo, Abakaliki, Ohaozara, and Afikpo South LGAs because of the typography nature of the areas and the stream order pattern is not enough. These LGAs occupy the southeastern part of Ebonyi State. Most of these rivers with adjourning tributaries are purely dendritic in their drainage pattern because the rock structure is homogenous and permits uniform erosion within the rainy periods shaping the drainage pattern.

As earlier recorded in 2015, the unprecedented flood that chocked Abakaliki metropolis created a devastating impact as perceived by inhabitants and confirmed by authorized reports when compared to its effect as illustrated in the GIS map in Figure 2. Therefore, examining through the observed GIS map, stream order plays a role in the drainage pattern especially in the flood prone areas of Ebonyi State.

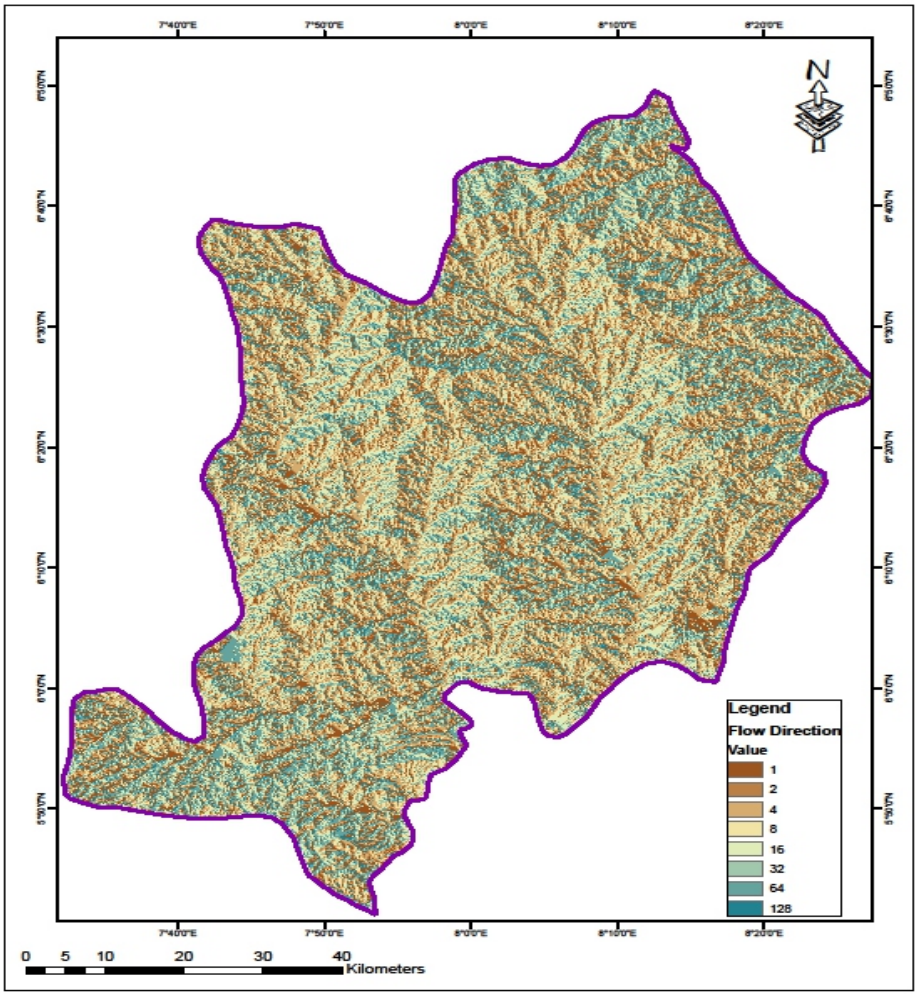

Figure 4: Ebonyi stream flow order.

Figure 4 illustrates the Ebonyi State River flow order. There are many tributaries that the river orders are joined severally and flow down the slope to accumulate the basin. These numerous tributaries that joined together have their implications. When more water is drained into a channel, its volume increase, and the river magnitude is invariably affected.

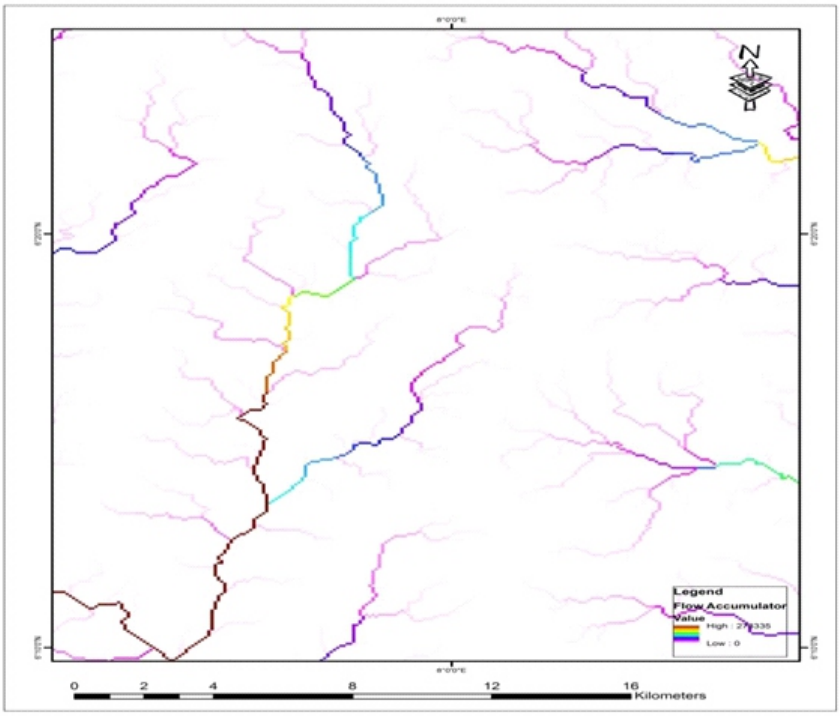

Figure 5: Ebonyi state flow accumulator drainage (source: field work, 2021).

Figure 5 shows the Ebonyi State flow accumulator drainage basin with her river channels and their tributaries. This truly exemplifies first and second stream orders in clearer terms.

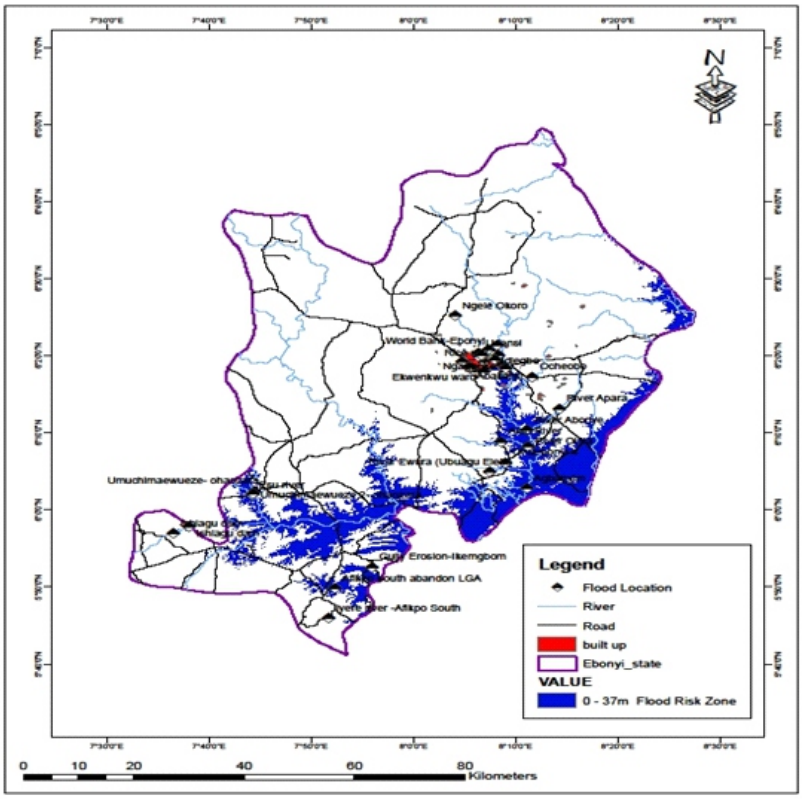

Figure 6: Ebonyi state river basin.

The basin is saturated when more water accumulates through the adjourning tributaries to most of their respective consequent rivers like the Enyim river of Izzi, Iyiokwu river of Abakaliki, Alcor river of Ikwo, Iyere River of Afikpo South, and Esu Umuchimaewuze River of Ohaozara Local Government areas down the slope. The relationship between stream order and flood magnitude in flood prone areas of Ebonyi State shows that stream order is the key behind the magnitude of flood often experienced in the area. In the above figure 6, the map legend with thick blue is the outcome of the flood originating from the Enyim River of Izzi, Iyiokwu River of Abakaliki, Alchor River of Ikwo, Iyere River of Afikpo South, and Esu Umuchimaewueze River of Ohaozara indicating the tributaries after they have emptied their water into the corresponding major river. This singular action transmits more water down the slope and increases incessant flooding. One of the most challenging aspects of flood hazard characteristics is assessing the spatial extent of flooding and its impending dangers in such areas. The spatial resolution of flood magnitudes is a reflection of the interaction between temporal and spatial rainfall variability, land surface characteristics that influence infiltration and runoff production, and the network architecture of the channel system (Lu *et al.,* 2017). Breinl, *et al.,* (2021), added that rainfall patterns and trends can change drastically depending on the time of year, which can lead to dramatic differences in the size of floods across the drainage network. The drainage basin in the study area is visibly treated and seen as a collection of hill slopes connected by channel links, which are compartmentalized and derived from a high-resolution digital elevation model (DEM). Therefore, the river network is represented by a binary tree defined by links and nodes. From DEM link, the information about the correct position, geometry and flow of each link in interpreting the hydrologic modeling and the magnitude of flood often experienced in the study area. So, one cannot remove stream order from the magnitude because these several orders transmit more volumes of water into the corresponding consequent river and increases the degree of magnitude content resulting in floods.

CONCLUSION

In examining the effect of stream order and drainage patterns of the study area, we found that the flood majorly occurs within the lower basins of Izzi, Ikwo, Ohaozara, and Afikpo South LGAs. The resultant effects of several river tributaries that joined the consequent river without adequate drainage channels resulted in the upsurge of more water volumes chocking up the entire area. The basin becomes saturated when additional water accumulates. The result demonstrates first and second stream orders and a consistent relationship between stream order and flood magnitude, such that stream order is the key behind the flood often experienced in the area because stream order transmits more water volume down the slope that subsequently increases incessant flood because the pattern of the streams are not wide enough. There is a need for urgent adjustments and construction of a drainage system in the study area to accommodate more water volumes into the major consequent river down the slope.

ACKNOWLEDGEMENTS

We thank Prof. Virginia Okwu-Delunzu, Prof Eze, B. U and the staff of Zonal Advance Space Technology & Application Laboratory (ZASTA), Federal University Ndufe-Alike Ikwuo for their contributions.

FUNDING

This project was supported by the authors.

CONFLICT OF INTEREST

The authors have no conflicts to declare.

AUTHORS' CONTRIBUTION

All authors contributed to the planning, conduct and reporting of the work described in the article.

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