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ANALYSIS OF WATERSHED AND STREAM ORDER IN NGASKI LOCAL GOVERNMENT AREA, KEBBI STATE

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ABSTRACT

Stream ordering is the quantitative analysis of a watershed. The goal of stream hydrology and ecology is to understand how the spatial structure of stream networks affects the movement of water, energy, and organisms. Understanding how stream networks exhibit a hierarchically branching structure, where conditions at one place in the network may be modified by conditions in related streams, is important for the geographic study of stream network topology (i.e., size and proximity of connected streams). ASTER DEM was downloaded from the NASA website. The software used in this study is ArcGIS 10.8.1 and Microsoft Excel 2021. ArcGIS is used to carry out the analysis and create the final map, while Excel 2021 is used to create some charts. Digital Elevation Model (Fill), Flow Direction, Flow Accumulation, Raster Calculation, Stream Order (Raster), and then Stream Order (Vector) were all generated from the ASTER DEM downloaded from the NASA website. The study shows that there are 838 total streams, of which 54.65% are of first order, 24.34% are of second order, 13.60% are of third order, and 0.84 of the streams are of fifth order. Also, the study further shows that the total length of streams in the Ngaski local government area of Kebbi State is 1506.343542 km, with order one coming first with 58.59% of the total length.

Keywords: *Stream order, GIS.*

INRTRODUCTION

A watershed is the area of land where all waterfalls and drains to a common outlet (Bose *et al.,* 2011). A watershed can be as small as a footprint or large enough to encompass all the land that drains water into rivers. Watershed has emerged as the basic planning unit for all hydrologic analyses and designs. Each watershed shows distinct characteristics, which are so variable that no two watersheds are identical. Stream ordering is the quantitative analysis of a watershed. The goal of stream hydrology and ecology is to understand how the spatial structure of stream networks affects the movement of water, energy, and organisms. For spatial analysis of stream network topology (i.e., size and proximity of connected streams), it is necessary to quantify the effects of stream networks and to compare these effects across large watersheds or regions (Betz *et al.,* 2010). Conditions in connected streams can have an impact on the state of a network point due to the hierarchically branched structure of stream networks. (Moussa, 2003).

Knowledge of basin hydrology is essential for proper management of water resources, and flood hazards in a basin depend upon the hydrological response of the upstream basin area. As an indivisible part of land, the drainage system is an important component of terrain analysis (Pawar*et al.,* 2014). DEM plays an important role in hydrologic and topographic character analysis. Up to the present, great progress has been achieved in river networks based on DEM, and it is an efficient way to extract river networks, which is considered an important factor for understanding watershed level hydrology. Some efforts are made to derive terrain features, including peak, pit, ridge, channel, plane, and pass, based on terrain analysis. Numerous studies have given a detailed analysis of the causes of floods and identified various factors such as heavy rainfall, topography, the effect of climate change, and the characteristics of the drainage networks of the city (Dawode et al., 2012; Youssef et al., 2016). In line with the management of flooding, Lindsay et al. (2019) opined that drainage and river directions characterize the structure of the stream network, which allows the identification of confluence points and an 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). The drainage network is the fundamental hydrologic and geomorphic area unit through which a detailed description of the geometry of landforms is collected, organized, and analyzed (Chorley, 1969). It is important to evaluate the drainage network's linear aspects, areal aspects, relief (gradient) aspects, and their impact on ground slopes in order to give an analytical account of the geometry of a drainage basin and its stream channel (Alfa et al., 2019; Salvi et al., 2017). Therefore, if a large enough sample is processed, the order number will often be directly proportional to the size of the contributing watershed, the dimensions of the channel, and the stream discharge at the specified point in the system (Shankar et al., 2014). This makes the stream-order system useful. But in any given order, there will be fewer stream segments than in the subsequent level down, but more in the next higher order. The purpose of this study was to determine the role of the tributaries that contribute to flooding in the study area by conducting a systematic examination of the various stream order segments that traverse the watershed in Ngaski Local Area, Kebbi State, as well as their actions and roles as they empty into the main river, the Niger River.

Study Area

Ngaski Local Government Area is one of the twenty-one (21) local government areas (LGA) of Kebbi State. It is situated in the southern part of Kebbi State on the shores of Kainji Lake, with its central district in Warrah town. It covers about two thousand six hundred and thirty-three (2,633 km2) square kilometers in area (National Population Commission (NPC), 2006). Ngaski LGA is surrounded in the east by Auna LGA, in the west by the river Niger, in the south by Nasko LGA, and in the north by Rijau LGA. It lies between latitude 10^{o} 05'N and longitude 4^{o} 10'E of the equator. The approximate population is about one hundred and twenty-four thousand seven hundred and sixty-six (124,766) people (National Population Commission (NPC), 2006). The climatic condition of the study area falls within the Guinea-Savannah zone. It usually receives rainfall ranging from 1200mm to 1500mm per year with a mean temperature of $35^{oC,}$ which favors the cultivation of crops ranging from cereals, pulses, and vegetables, as well as animal production and fisheries resources (Zakari, 1999).

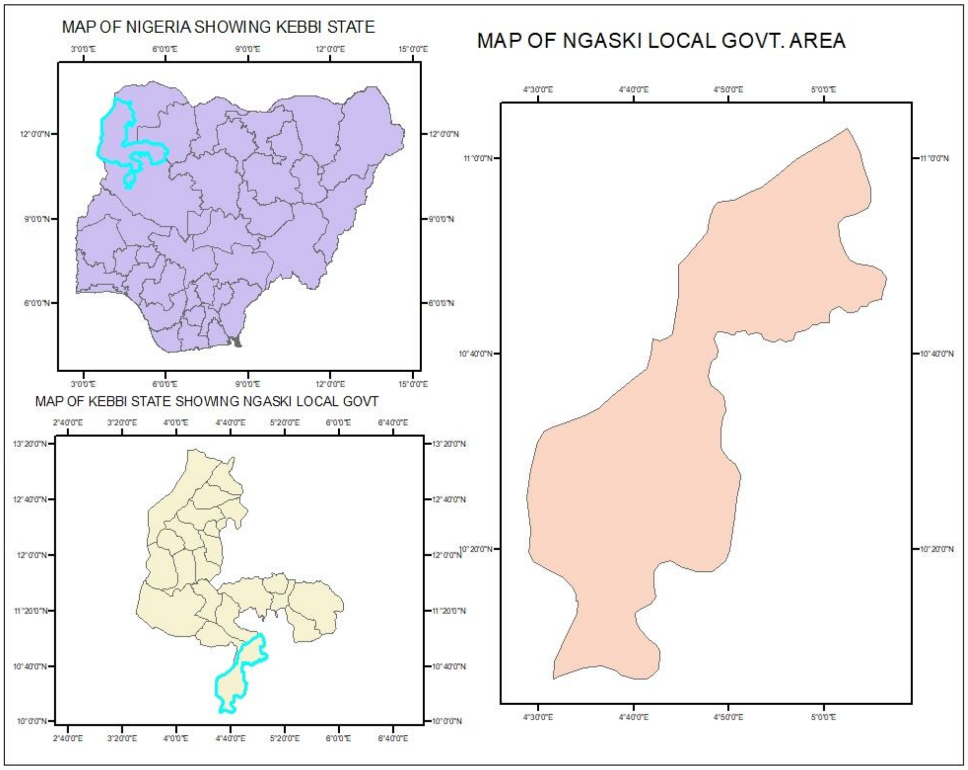

FIG 2.1: Map of the Study Area

Method

ASTER DEM data, with a resolution of 30 m, was downloaded as described.

1. Search for the NASA website on a browser: https://www.search.earthhdata.nasa.gov/search
2. Click on the instrument on the left side of the website page and select "ASTER."
3. Now click on the rectangle and zoom to the region of your choice, as seen below, then select the area, expand the panel, and click on ASTER Global Elevation V003.
4. It shows six granules available for download for the selected area; click on download all to download at the same time or download a single granule.

Six granules covering the area were exported to ArcGIS software for processing. The granules downloaded are then imported into ArcGIS software along with the shapefile of the study area. The raster images were merged (mosaic), followed by the extraction of a mask to clip out the study area, as shown in Fig. 2.1.

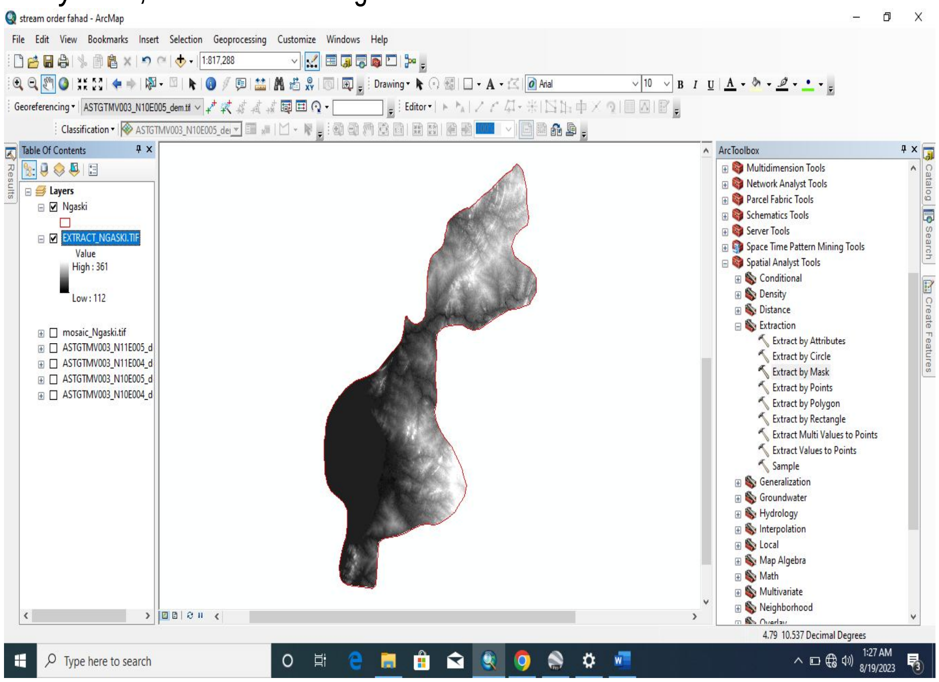

Fig 2.1: After Extraction by Mask showing the study Area

From the spatial analyst tool, fill data was used to generate flow direction. The flow direction was also used as an input to generate flow accumulation. Set the class value to 2 under the symbology and break the value to 1500. Raster calculation was done, which was used to generate the stream order in the raster method of stream ordering (STRAHLER), which was later converted to vector features. The feature created was classified with different grid codes, starting from 1 to 5. The higher code means the river line is going to be a stream with a higher order.

RESULT AND DISCUSSION

Generation of DEM, Flow Direction, and Accumulation

The digital elevation model and both flow direction and accumulation were all generated from the ASTER DEM downloaded, as shown in FIGS. 3.1, 3.2, and 3.3, respectively.

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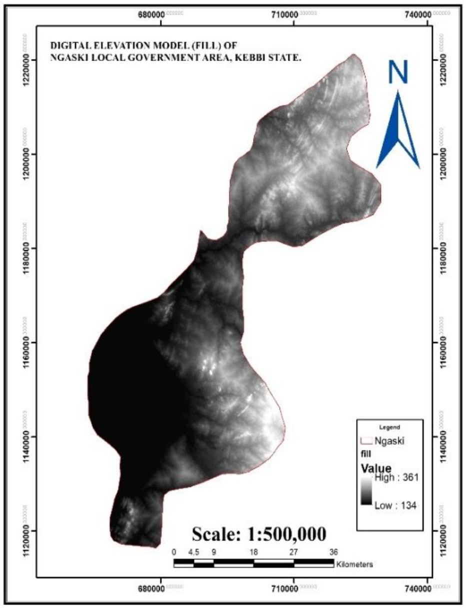


FIG 3.1: Digital Elevation Model

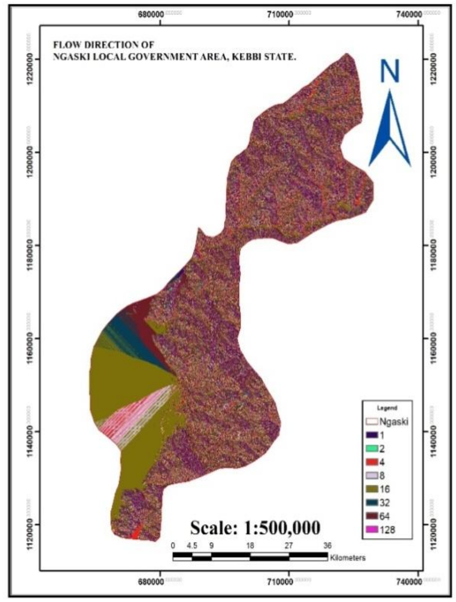


FIG 3.2: Flow Direction

The DEM generated represents the continuous topographic elevation surface through a series of cells. Each cell represents the elevation (Z) of a feature at its location (X and Y). The dark portion in Fig. 3.1 has the lowest elevation, and the lighter it gets, the higher the elevation. The flow direction (Fig. 3.2) means the direction in which a stream flows in each cell. This tool takes the DEM as input and outputs a raster showing the direction of flow out of each cell. There are eight valid output directions relating to the eight adjacent cells into which flow could travel. This approach is commonly referred to as an eight-direction (D8) flow. The output of the Flow Direction tool using the D8 flow direction type is an integer raster whose values range from 1 to 255. The direction of flow is determined by the direction of the steepest descent, or maximum drop, from each cell. For example, if the direction of the steepest drop is to the left of the current processing cell, its flow direction value is 16, which can be seen in Fig. 3.2, as most of the study is coded 16 (direction of the steepest drop to the left).

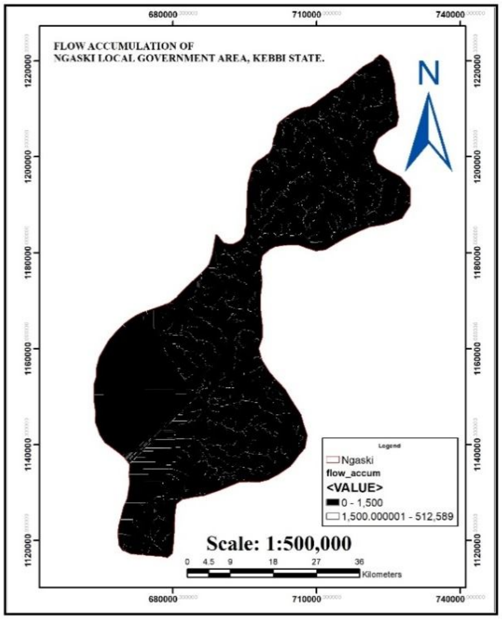
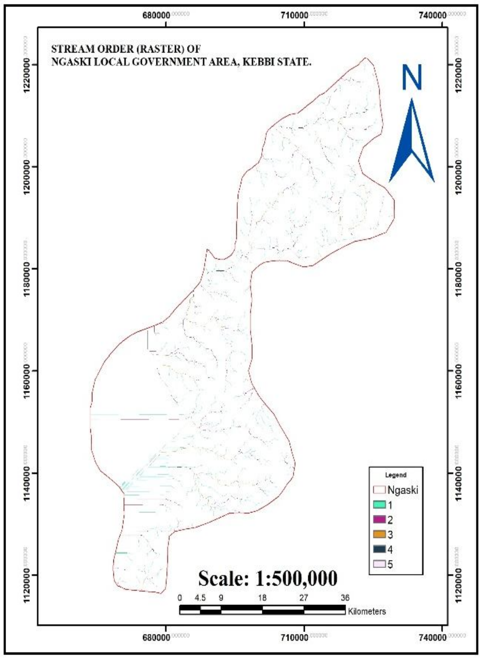


FIG 3.3: Flow Accumulation
Source: Author, 2023

Stream Order Generation

A raster stream order was generated to show the stream, and it was converted to a vector to enable the stream length and area to be calculated, as shown in both Figs. 3.4 and 3.5 below. In using the Strahler method, all links without any tributaries are assigned an order of 1 and are referred to as the first order. The Strahler method is the most common stream ordering method. However, because this method only increases in order at intersections of the same order, it does not account for all links and can be sensitive to the addition or removal of links.



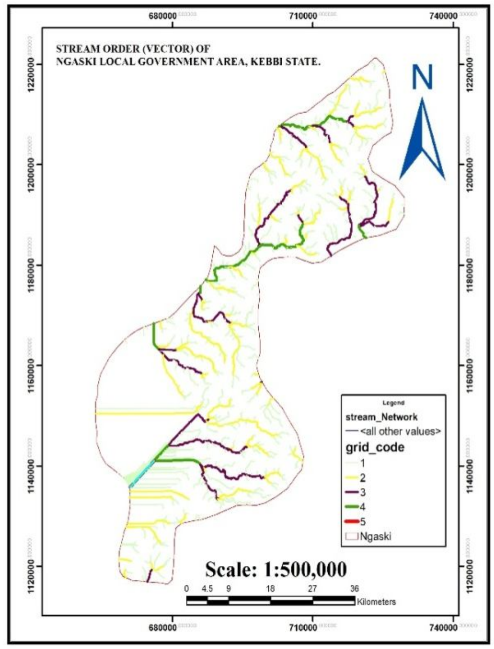


Fig 3.4: Stream Order (Raster) **Fig 3.5: Stream Order (Vector)**
Source: Author, 2023
Source: Author, 2023

The streams were classified into grid codes 1–5, as shown above. The stream order increases when streams of the same order intersect. Therefore, the intersection of two first-order links will create a second-order link, the intersection of two second-order links will create a third-order link, and so on. The intersection of two links of different orders, however, will not result in an increase in order. For example, the intersection of a first-order and second-order link will not create a third-order link but will retain the order of the highest-ordered link.
The total number of counts for each stream order is shown in Table 3.1 and Fig. 3.6 in percentages.

Table 3.1: Stream Order Count

Categories	**Total Number**	**Categories in %**
Stream order 1	458	54.654
Stream order 2	204	24.344
Stream order 3	114	13.604
Stream order 4	55	6.563
Stream order 5	7	0.835
Sum	**838**	**100%**

Source: Author, 2023 through ArcGIS 10.8.1

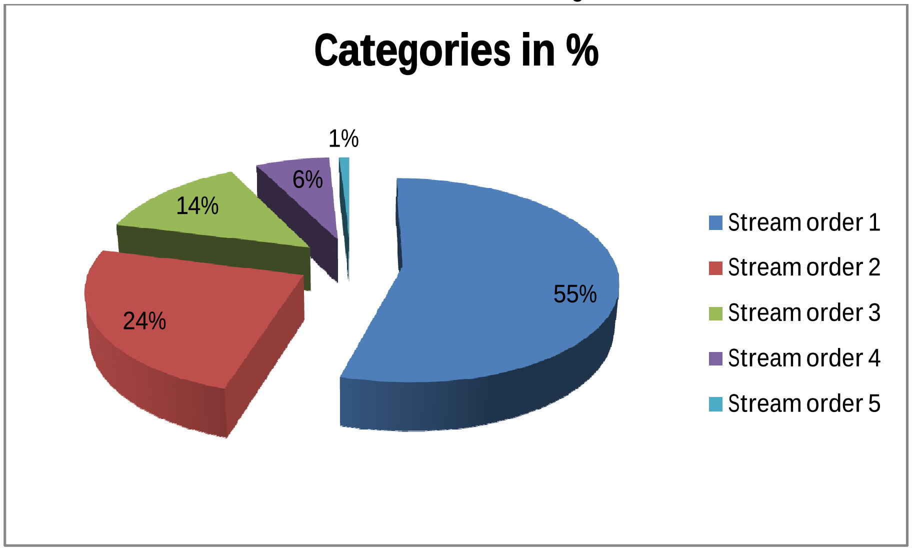


Fig 3.6: Stream Order Count in Percentage
Source: Author, 2023

Stream Order Length

The total length of each stream order type was computed from geometry field calculations, and the results are shown in Tables 3.2 and 3.7 in percentages.

Table 3.2

Categories	**Sum of length (km)**	**Categories**
Order five	7.329289047	0.486%
Order four	75.14512833	4.989%
Order one	882.6965445	58.599%
Order three	177.2284999	11.765%
Order two	363.9440798	24.161%
Grand Total	**1506.343542**	**100%**

Source: Author, 2023 through ArcGIS 10.8.1

From table 3.2, it shows that the total stream length is **1506.343542km**, and order one, which is the smallest in the order, has **882.6965445km**, being the highest, followed by order two with **363.9440798km**, order 3 with **177.2284999km**, order 4 and order 5 with **75.14512833km** and **7.329289047km** streams, respectively.

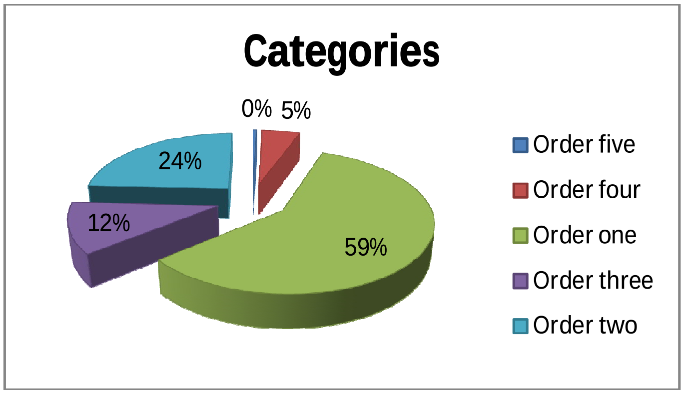


Fig 3.7: Stream Length in Percentage

CONCLUSION/RECOMMENDATION

The study shows that there are 838 total streams, of which 54.65% are of first order, 24.34% are of second order, 13.60% are of third order, and 0.84 of the streams are of fifth order. It further reveals that the total length of streams in Ngaski local government area of Kebbi State is 1506.343542 km, with order one coming first and having 58.59% of the total length. These streams can be harnessed for productive agricultural activities, especially rice and cereal farming; they could be extended to storing the water from the streams for fish farming. These will in turn increase the gross domestic product (GDP) and internally generated funds for the local government and state; they will also create a lot of job opportunities and alleviate poverty within the locality.

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