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Research Article **Open Access**

Morphometric Analysis of Singki River Catchment using Remote Sensing & GIS: Papumpare, Arunachal Pradesh

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Abstract River is playing an important role in landform development, its shapes the structure of area. River process is a natural phenomenon supported by many agents such as precipitation. It has participated role in changing river behaviour, rainfall contributes in the volume of water and work as an agent in erosional process. Carrying scientific study to understand the characteristics of the area, river is one of the assets which describe the aspects and phenomenon related to Landforms. With the help of remote sensing & GIS, we can extract all the physical information of river, called morphometric parameters. The Singki river catchment accumulated an area of 79.8 Km^2 and has elevation 2353 metre; the rugged and irregular terrain surface shapes Dendritic drainage pattern.
Keywords *Geology; Morphometry; River Catchment; Remote Sensing & GIS*

1. Introduction

Himalaya known as water tower of Asia because all the major rivers of India originate from Himalayan regions and all are perennial, the huge amount of Area is under Cryosphere. Arunachal Pradesh has five major rivers and its tributary including nine all are originates from Himalaya such as Siang is known as Yarlung-Tsangpo in Tibet originates from Angsi Glacier in Tibet and also known as Brahmaputra in Assam, Siang is the main tributary of River Brahmaputra, there are many small tributary joins Siang is Siyum, Yamne, Yameng etc. The River Subansiri is largest tributary of River Brahmaputra joins in the North Lakhimpur district of Assam, the river originates from China and has total length of 442 km. River Kameng is originated from Glacial Lake situated in Gori Chen Mountain district Tawang and also known as Jia-Bharali in Assam and a Tributary of Brahmaputra. From Eastern part of state a river flow towards South direction and later joined Brahmaputra called Dibang; it originates from Keya Pass on the Indo-China border. Before joining Brahmaputra River Lohit discharge water to River Dibang.

Singki River flows in the foothills of Himalayan state, Arunachal Pradesh. The state is situated in the far-eastern region of India and also receives first dawn of Sunlight. The Singki River has 5^{th}order of streams and has characteristics of dendritic pattern (Figure 1). The river has a minimum discharge of 8857 MLD which is sufficient for Itanagar Town and it is controlled & managed by PHED department (Paron Omem et al., 2014). Singki is a perennial river flows with high velocity all year round and transported high boulders. River channel erosion is common in Singki basin because of deforestation near the banks of river and high velocity streams supported by many non-perennial streams helps in increase in the volume of the river which is also an important factor contributing in erosional and carrying process. On the other hand, the micro-climate playing its role literally, it influences on both the discharge of water and sediment to and along the channel and the channel boundary characteristics.

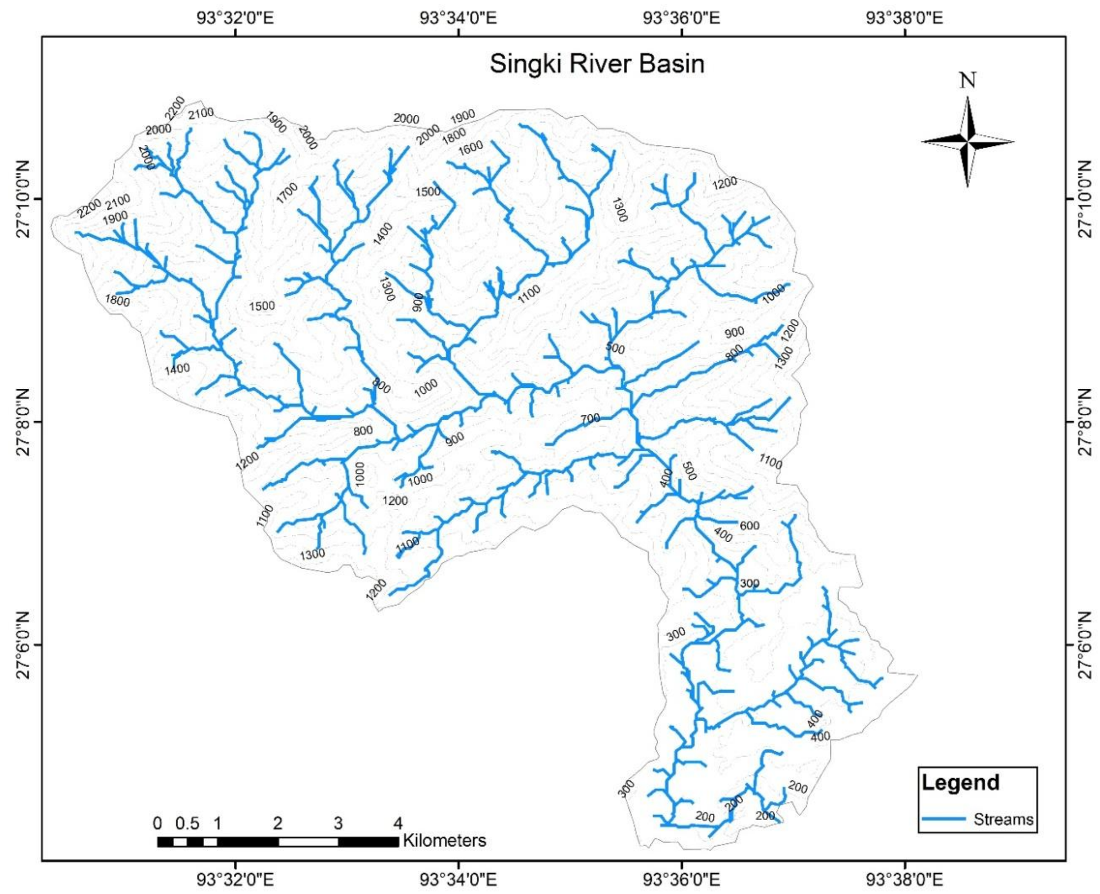


Figure 1: *Showing the Drainage Pattern of Singki River Basin with Elevation in metre*

2. Study Area

Singki River basin falls in Papumpare district of Arunachal Pradesh (Figure 2). The total area of the Singki river basin is 79.8 Sq.km. The study area is located lies between longitude 93°30'- 93°38''E and latitude 27°4'- 27°12'N. The study area falls under tropical climate. It has moderate temperatures in summer and is very cold in winters. The warmest month of the year is August, with an average temperature of 27.5 °C. January has the lowest average temperature of the year. It is 15.2 °C. Itanagar features an oceanic climate (Köppen climate classification Cwa), with dry, mild (however, cold by Indian standards) winters and cool, wet summers (en.climate-data.org).

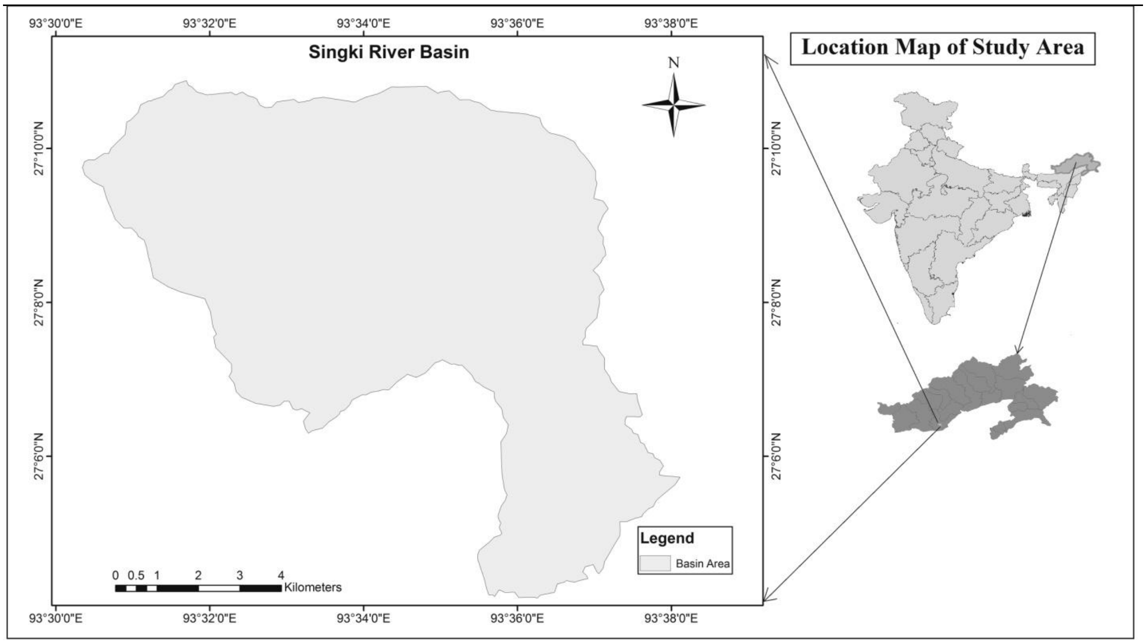


__Figure 2:__ Location Map of the Study Area

2.1. Geology

The lithosphere of Singki river catchment has characterized by numbers of formations consist of four types such as a) Lower Permian-lower Gondwana group-Bichom formation: constituted of dark grey Quartzite rocks, Shale/slate, sandstone and siltstone with coaly material and is thrusted over Siwaliks group and lie under Bomdila group. b) Lower Miocene-lower Pleistocene-Siwalik group-Dafla formation: consist of indurated sandstone and shale at bottommost, massive sandstone along with siltstone, clay and gravel. C) Paleoproterozoic-Biotite Granite Gneiss-Tourmaline. d) Paleoproterozoic-Bomdila Group-Tenga Formation consists of Gneissic rock types belong to Precambrian age, shale and Intrusive Granite etc. (Chakrabarti, 2016)

2.2. Climate

The climate is warm and temperate in Itanagar. In winter, there is much less rainfall in Itanagar than in summer. The climate here is classified as Cwa by the Köppen-Geiger system. The average temperature is 27.5 °C. The average annual rainfall is 2694 mm. The driest month is December, with 13 mm of rainfall. With an average of 489 mm, the most precipitation falls in July. The warmest month of the year is August, with an average temperature of 27.5 °C. January has the lowest average temperature of the year. It is 15.2 °C. The difference in precipitation between the driest month and the wettest month is 476 mm. During the year, the average temperatures vary by 12.3 °C (en.climate-data.org).

3. Methodology

3.1. GIS Based Data Collection

In the present study, extracting physical information of Singki River and prioritization of streams has been done using Remote Sensing and GIS techniques. Survey of India toposheets were also referred for the delineation of watershed boundary and draining network. The study was carried out on watershed level using Digital Elevation Model and using GIS software ArcGIS 9.3 for digitization and Arc Hydro tools using Aster Digital Elevation Model for delineating streams and watershed boundary. The following data/Software was used for the study:

- Aster - DEM data (30×30m)
- ArcGIS 9.3
- Erdas 9.1

3.2. Morphometric Analysis

The basin morphometry includes the analysis of the characteristics of linear, areal and relief aspects of drainage basins. It is a method of extracting physical information of the river and its basin. The formulas adopted for computation of morphometric analysis are given by many geomorphologist and experts (Table 1).

Table 1: *Formula used to quantify the Morphometric parameters*

Sl. No.	Morphometric Parameters	Formula	Reference
1.	Stream order	Hierarchical Rank	Strahler (1964)
2.	Stream Length	Lsm	Horton (1945)
3.	Mean stream length	Lū= Lu/Nu	Strahler(1964)
4.	Stream length ratio	$Rl=Lu/Lu^{-1}$	Horton (1945)
5.	Bifurcation Ratio	$Rb= Nu/Nu^{+1}$	Schumn(1956)
6.	Mean Bifurcation Ratio	Rbm	Strahler (1957)
7.	Relief Ratio	Rh=H/lb	Strahler (1957)
8.	Drainage Density	D=∑Lu/A	Horton(1932)
9.	Stream Frequency	Fs=∑Nu/A	Horton (1932)
10.	Drainage Texture	Rt=∑Nu/P	Horton(1945)
11.	Form Factor	$Rf=A/Lb^2$	Horton (1932)
12.	Circulatory Ratio	$RC=4\pi \times A/P^2$	Miller (1954)
13.	Elongation Ratio	$Rc = \frac{2\sqrt{A}}{\pi} / Lb$	Schuman(1956)
14.	Length of overland flow	Lg=1/D ×2	Horton (1945)

4. Results

1) **Linear Aspect** It is related to the channel patterns of the stream network and the topological characteristics of the stream segment (Savindra Singh, 2011).

a) Stream Order: The method of stream ordering proposed by Strahler in 1952. Stream order only increases when streams of the same order intersect. Therefore, the intersection of a first order and second order link will remain a second order link, rather than create a third order link. Singki river basin has 5^{th} order of stream (Figure 3) and has total length of all order of streams is 166.2 Km.
b) Stream Number (Nu): The total number of streams of all orders is 446. In 1^{st} order has 253, 2^{nd} order has 96, 3^{rd} order has 69, 4^{th} order has 27 and 5^{th} order has 1 streams (Table 3).
c) Stream Length (Lu): The length of the stream of all order calculated through GIS software, the total length is 166.2 Km. The order wise length is 1^{st} order has 83.1 km, 2^{nd} order has 35.2, 3^{rd} has 21 km, 4^{th} has 9.8 km and 5^{th} order has 17 Km (Table 2).
d) Bifurcation Ratio (Rb): The ratio between the two orders of stream segments; lower to the next higher order, called Bifurcation ratio. If the bifurcation ratio of any drainage is low, chances of flooding increases, the flow of water will accumulate in particular streams rather than spreading. Comparatively by analysing the bifurcation ratio of sub basins we can easily analyse which portion of drainage basin is having higher risk of flooding (Waugh, 2002).
e) Stream Length Ratio (Rl): The ratio between the number of stream length of particular stream order and the lower order (Table 3).

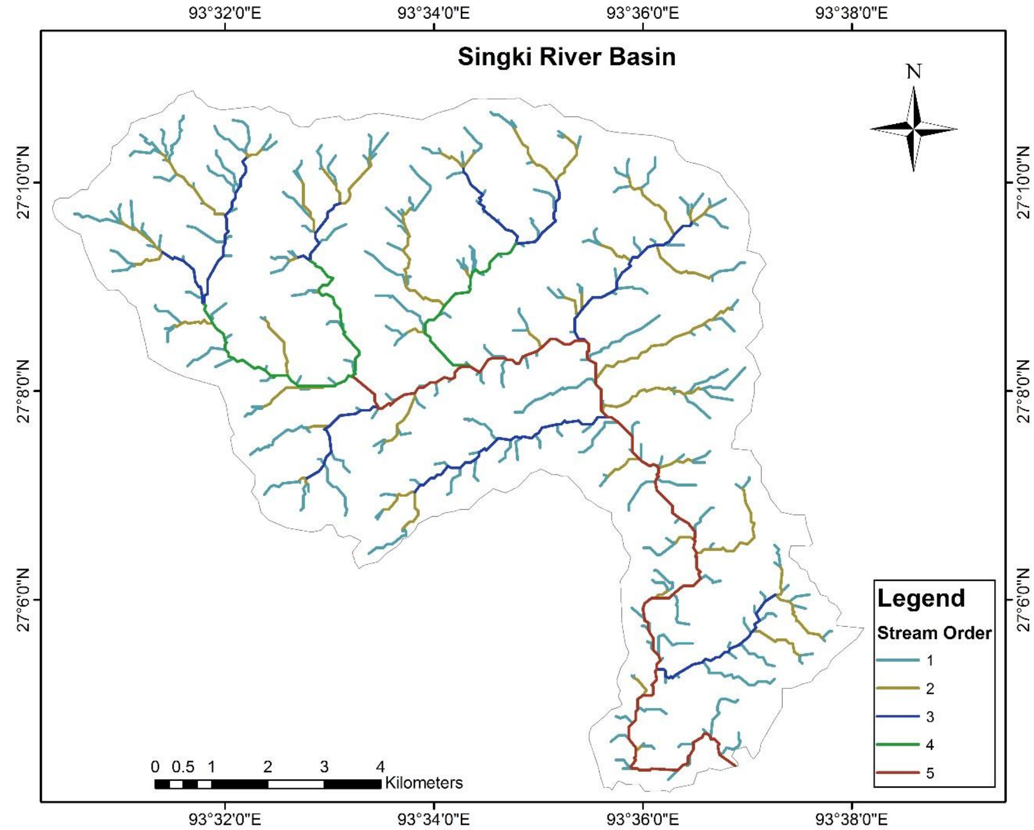
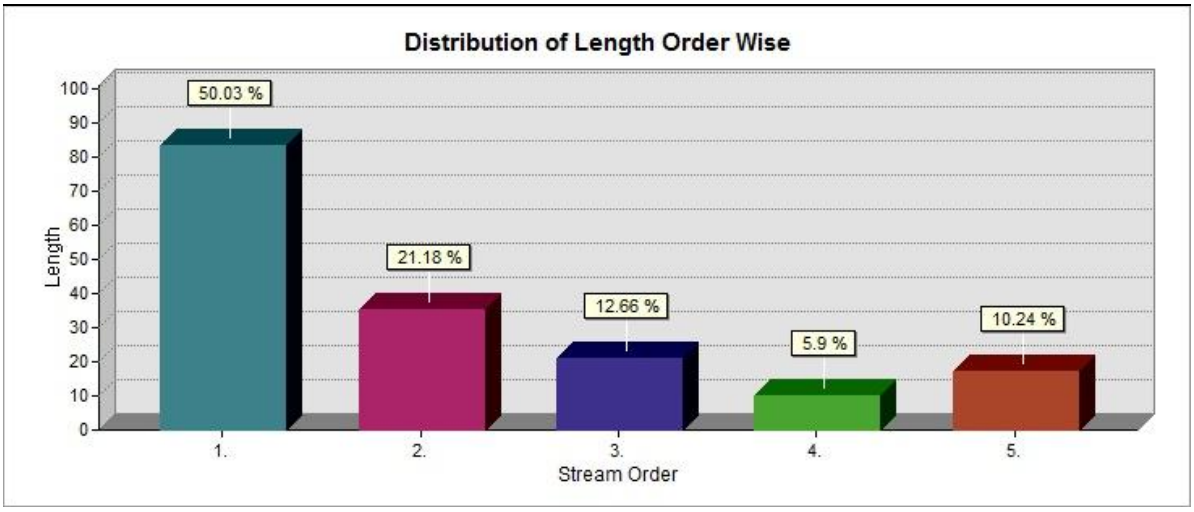


Figure 3: *Showing the Stream Ordering of Singki River*

Table 2: *Showing the distribution of Length (in km) Order Wise*



2) Areal Aspect

a) Basin Area: The basin boundary demarcated from Digital Elevation Model with the help of ArcGIS software. The area of Singki Basin is 79.8 Km^2. The area has undulating terrain surface and forms dendritic drainage pattern (Figure 1). Because of Altitude ranges from 167m to 2353 m the river velocity is high and terrain is sloppy too (Table 3).

b) Stream Frequency: Stream frequency is the measure of segments of streams per unit area of a basin. The stream frequency of Singki river is 5.6 Km (Table 3).
c) Drainage Density: It is the ratio of total stream length of the basin to basin area. The drainage density of Singki is 2.08 Km^2. higher drainage density reflects the weak subsurface materials, scattered vegetation and mountain relief (Zavoianul, 1985).
d) Drainage Texture: It defines the total number of streams in the basin of all orders over length of the Perimeter. The drainage texture of Singki basin is 2.08 km^2 (Table 3).The low density with highly spaced channels forms in hard and erosion resistant layer and high drainage density with low spaced channels appears on erosion landforms.
e) Form Factor: It is defined as the ratio of the basin area to the square of the basin length. This factor indicates the flow intensity of a basin of a defined area (Horton, 1945). The form factor is should always less than 0.13 it indicates the basin has elongated and lower peak flows of longer duration.
f) Elongation Ratio (Re): is defined by Schumm (1956) as the ratio of the diameter of a circle with the same area as that of the basin to the maximum basin length. Strahler states that this ratio runs between 0.6 and 1.0 over a wide variety of climatic and geologic types. The varying slopes of watershed can be classified with the help of the index of elongation ratio, i.e. circular (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (less than 0.5).The elongation ratio of Singki River is 0.23 (Table 3).
g) Circularity Ratio: Miller (1953) Introduced basin circulatory ratio and defined it as the ratio the basin area to the area of a circle having a circumference equal to the perimeter of the basin. The circulatory ratio of study area is 0.4 (Table 3). He described the basin's circulatory ratio ranges from 0.4-0.5 indicates strongly elongated and highly permeable homogeneous layers.
h) Length of Overland Flow: It is all about the soil infiltration capacity when it's exhausted due to heavy precipitation, the excess water flow towards channel and steep slope. It is important parameters to analyse runoff and flood process. According to Horton (1945), this parameter is in most cases half the average distance between the stream channels and hence it approximately equals to half the reciprocal of drainage density. The length of overland flow of Singki basin is 0.24 (Table 3).

3) Relief Aspect

a) Basin Relief: It is the vertical distance between the highest elevation point and lowest point of the basin. Basin relief of Singki is 2186m (Figure 4).
b) Relief Ratio: It is the ratio between the basin relief and basin length. It analyse the terrain steepness of a drainage basin and it also indicates the intensity of erosional processes operating on slopes. Possibility of a close correlation between relief ratio and hydrology characteristics of a basin is suggested by Schumm (1956), who found that sediment loss per unit area is closely correlated with relief ratio. The relief ratio is 89.6 m/km (Table 3).

Table 3: *Results*

Sl. No.	Morphometric Parameters	Formula	Result	Reference
1.	Stream order	Hierarchical Rank(u)	1^{st}, 2^{nd}, 3^{rd} ,4^{th},& 5^{th} (orders)	Strahler (1964)
2.	Stream Length	Lsm	Total stream length=166.2 km	Horton (1945)
3.	Mean stream length	Lsm=Lu/Nu	Orders 1^{st} =0.32km 2^{nd} =0.36km 3^{rd}=0.30km 4^{th} = 0.36km 5^{th} = 17 km	Strahler(1964)
4.	Stream length ratio	$Rl=Lu/Lu^{-1}$	$2^{nd}/1^{st}$ =0.42	Horton (1945)

			$3^{rd}/2^{nd}=0.6$ $4^{th}/3^{rd}=0.46$ $5^{th}/4^{th}=1.7$	
5.	Bifurcation Ratio	$Rb= Nu/Nu^{+1}$	$1^{st}/2^{nd}=2.63$ $2^{nd}/3^{rd}=1.39$ $3^{rd}/4^{th}=2.55$ $4^{th}/5^{th}=27$	Schumn(1956)
6.	Mean Bifurcation Ratio	Rbm	Rb= 8.39	Strahler (1957)
7.	Relief Ratio	Rh=H/lb	89.62 m/km	Strahler (1957)
8.	Drainage Density	D=∑Lu/A	2.08 km^2	Horton(1932)
9.	Stream Frequency	Fs=∑Nu/A	5.6 km	Horton (1932)
10.	Drainage Texture	Rt=∑Nu/P	9	Horton(1945)
11.	Form Factor	$Rf=A/Lb^2$	0.13	Horton (1932)
12.	Circulatory Ratio	$RC=4\pi \times A/P^2$	0.4	Miller (1953)
13.	Elongation Ratio	$R_c = \frac{2\sqrt{A}}{\pi}/Lb$	0.23	Schuman(1956)
14.	Length of overland flow	Lg=1/D ×2	0.24	Horton (1945)

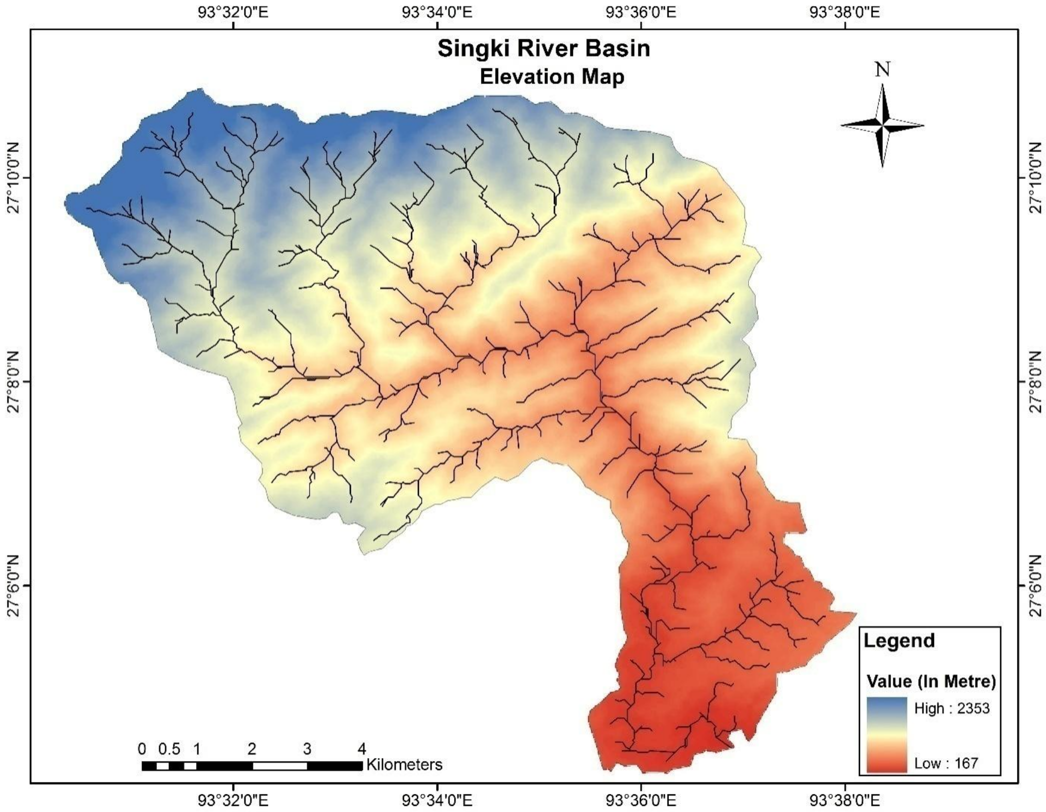


Figure 4: *Showing the Basin Relief Using ASTER Digital Elevation Model (30×30) m*

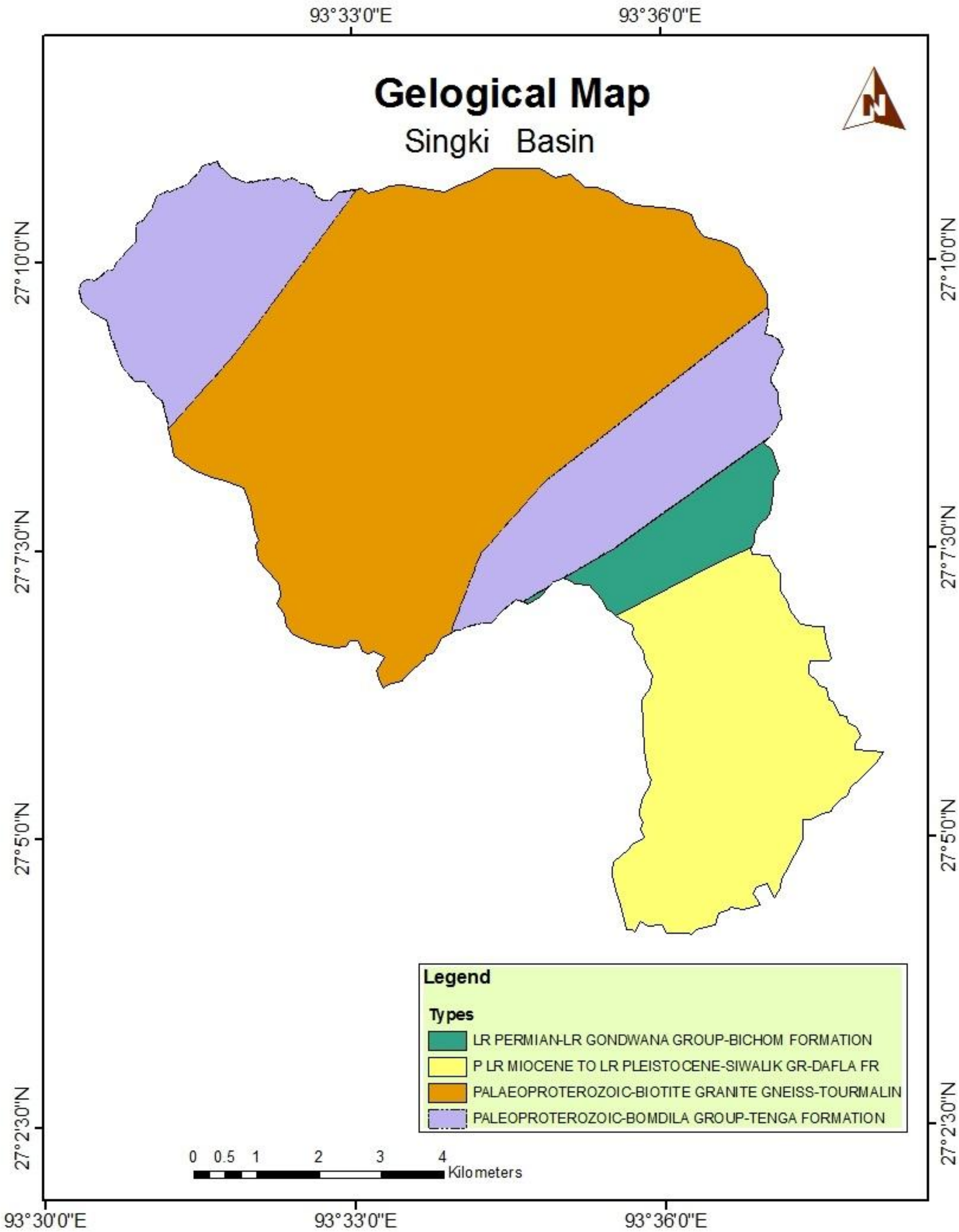


Figure 5: *Geological Map of Singki Basin*

4. Discussion

Singki River is the lifeline of Itanagar, and it plays very important role in the fulfillment of drinking water supply in the capital city of Arunachal Pradesh. The river is very important because it is the only source of pure water in Itanagar area and has minimum discharge of 8857 MLD which is sufficient for Itanagar Town. Hence the government built many small reservoirs near river to maintain the stability of drinking water supply.

The Singki River has dendritic drainage pattern which reveals the surface characteristics, the area has very irregular and hard rock surface. Generally this type of area has horizontal sedimentary or intrusive igneous rock where reasonably the rock mass is homogeneous (Press, F., and Sevier, R., 1982).

The remote sensing and GIS is advanced technology to study earth surface with high accuracy, in this study Aster DEM has been used to extract the information of the Singki River with the help of GIS software. The hydrology toolset of GIS is very flexible to use and helps to accumulate all the physical information. The use of digital elevation model (DEM) make so easy to delineate watershed and sub-watershed boundary and also helps in carrying out sub-watershed study separately. With the use of GIS software we can calculate all the geometrical information quickly using UTM projection in an accurate manner and it is time saving process.

Acknowledgement

The non-imagery satellite data (Digital Elevation Model) has been downloaded from the USGS website. And it is freely available, which helps to undertake this research. I acknowledge the USGS to provide useful data.

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