MAPPING THE GROUND WATER PROSPECTIVE ZONES USING INTEGRATED APPROACH BY RS & GIS-A CASE STUDY FOR TUMAKUR TALUK.

UPDATION OF DRAINAGE NETWORK USING ASTER GDEM FOR GROUND WATER PROSPECT ZONE ANALYSIS FOR TUMAKURU TALUK

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Abstract : In present study, the digital elevation model from Advanced Spaceborne Thermal Emission and Reflection Radiometer - Global Digital Elevation Model (ASTER GDEM) of 30 m resolution is used to carry out the automatic extraction of stream network at the threshold of 0.05 km2. ASTER GDEM was processed using ArcGIS Hydrology tool by adopting Deterministic Eight-node (D8) method to derive the stream (drainage) network map of Tumakuru sub-basin in Karnataka State of India. The delineation and extraction of stream network has helped in calculating the length of streams under different stream orders as follows: 1st order has a total length of 782.96 km, 2nd order 391.31 km, 3rd order 174.55 km, 4th order 118.82 km and 5th order 40.69 km covering 51%, 25%, 12%, 9% and 3% of the study area respectively. The automatic drainage network extracted from ASTER GDEM after sinks filled with the threshold value >500 for the flow accumulation was subjected to ground truth analysis based on GPS survey. There is a good match between the random check points generated on the map and the ground truth measurements. The accuracy of the stream order map generated from ASTER GDEM is found to be 87%.

***IndexTerms* - Stream network, ASTER GDEM, Stream ordering, D8 method, flow direction, flow accumulation.**

I. INTRODUCTION

Accurate delineation of drainage network is a prerequisite for many natural resource management issues (Paik, 2008)11; Liu and Zhang, 2011)6 Digital Elevation Model (DEM) refers to a quantitative model of a part of the Earth's surface in a digital form (Burrough and McDonnell, 1998)2. Several radar satellite based DEMs like Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) with 30 m resolution and Shuttle Radar Topographic Mapping (SRTM) with 30 m resolution are available for the public use. The availability of satellite based new topographic datasets have opened new venues for hydrologic and geomorphologic studies including analysis of surface morphology (Staley et al., 2006; Frankel and Dolan, 2007; Patel et al., 2016)13 and channel network structure (Lashermes et al., 2007).7

A variety of methods have been developed to process raster DEMs automatically to extract drainage networks and measure their properties (O'Callaghan and Mark, 1984; Tarboton et al., 1991)9 Martz and Garbrecht, 1999; Al-Fugara et al., 2016).8 Studies have shown that the fast and easy way to determine flow direction of a river basin is using different procedure to extract the information from DEM automatically. Different algorithms are generally used. D8 method, the easiest and simplest method for specifying flow direction, was proposed by O' Callaghan and Mark (1984)9 and has been widely used at present. This method enables to assign flow from each pixel to one of its eight neighbours by identifying the direction with steepest downward slope.

The quantitative analysis of drainage pattern is one of the important aspects in characterization of watersheds (Strahler, 1964)14. GIS based methods are highly used to delineate channels automatically for the use in hydrologic models. Still, care needs to be exercised to ensure that networks are extracted from DEMs at an appropriate scale. Many authors have attempted to analyze the drainage characteristics of the basins using GIS techniques in determining the quantitative description of the basin geometry (Biswas et al., 1999; Reddy et al., 2002, 2004; Vijith and Satheesh, 2006; Kattimani and Prasad, 2016)3. In present study, the digital elevation model from ASTER GDEM of 30 m resolution is used to carry out the automatic extraction of stream network at the threshold of 0.05 km2. ASTER GDEM was processed using ArcGIS Hydrology tool by adopting Deterministic Eight-node (D8) method to derive the stream (drainage) network map of Tumakuru sub-basin in Karnataka State of India.

II. Study Area

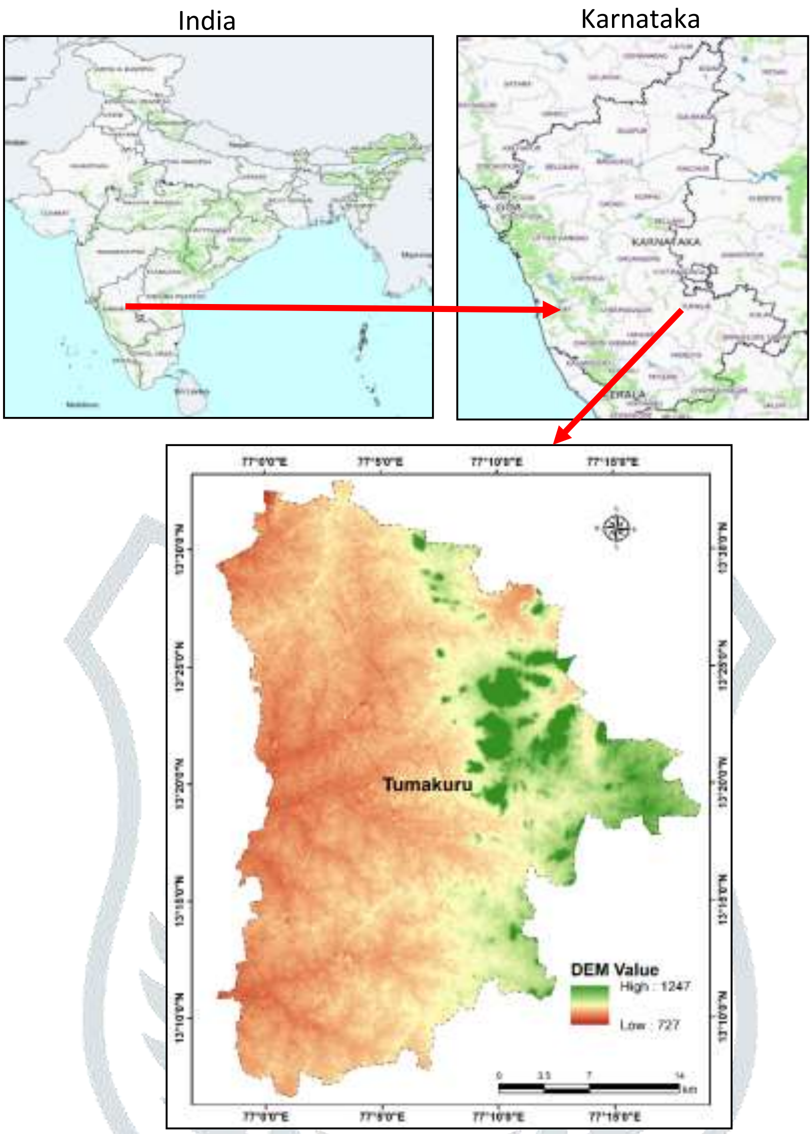


Fig. 1. Study area map

The study area, Tumakuru taluk, falls under Tumakuru district of Karnataka State, India which is shown in Fig. 1. Tumakuru is an industrial city situated at a distance of 70 km northeast of Bengaluru, the capital of Karnataka. The Tumakuru taluk lies between 13.11° & 13.55° N Latitudes and 76.96° & 77.32° E Longitudes. The altitude of the study area ranges from 727 to 1247 meters. The average annual rainfall of the study area is 540.7 mm and annual potential evapotranspiration is over 1800mm with monthly rates less than 100 mm during December and January months and over 250 mm during May month (Directorate of Economics & Statistics, Karnataka). As the area is under semi-arid climatic condition the temperature start rising from January and reaches its peak value in May with a maximum temperature of around 40°C.

III. MATERIALS AND METHODS

ASTER satellite image acquired on 15-10-2017 was used in the present study. The data details are given in Table 1.

Table. 1. Details of the data used

Data Type	ASTER GDEM
Entity ID	ASTERDEMV2
Acquisition Date	15-10-2017
Pixel Size	1 arc-second

Source	USGS Earth Explorer

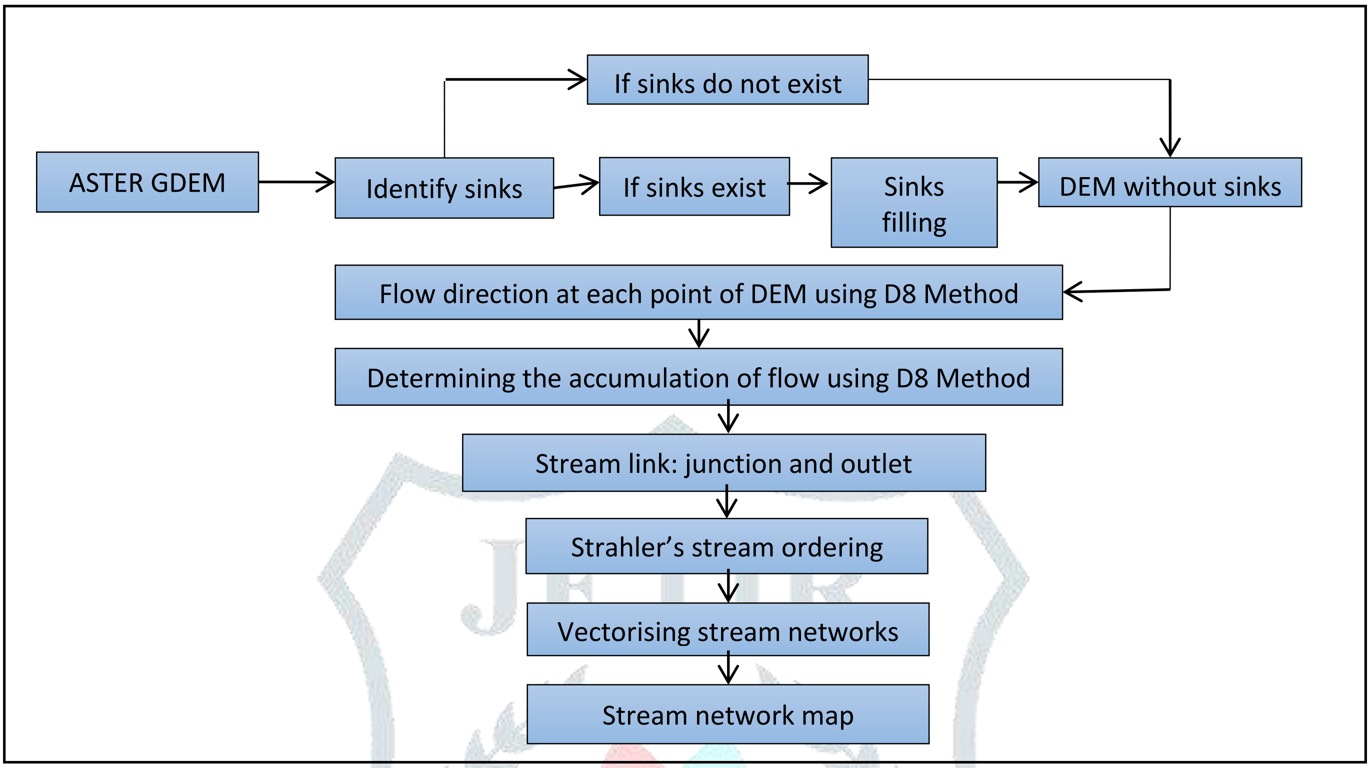


Fig. 2. Flow chart of stream network extraction and mapping

3.1 Data and Pre-Processing

The drainage extraction was carried out using Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM). The ASTER GDEM is available and downloadable free of charge in seamless 1° x 1° tiles via the United States Geological Survey`s Earth Explorer (http://earthexplorer.usgs.gov).

3.2 Fill Sinks

The ArcGIS Hydrology tools were used to extract the stream network of the study area. The first step in the GIS Hydrology analysis was to remove the sinks from the DEM by implementing the fill-sink algorithm in the Hydrology tool. For each fill/cut operation the volume was calculated by the formula:

$$\text{Vol} = (\text{cell area} * \Delta Z)$$

For each of the cut/fill operation, the area was calculated as the number of cells in the region multiplied by the cell size of the raster. According to the formula, in the region where material has been cut, the volume will be positive (larger value - smaller value> 0). When the material was added, the volume will be negative (smaller value - larger value < 0).

3.3 Flow Direction

Flow direction is a measurement based on Digital Elevation Model (DEMs) which determines the paths of water, sediment and contaminant movement and shows the direction of the steepest down slope neighbour for each cell by colour coded direction. The direction of flow is determined by the following equation:

$$\text{Maximum drop} = \frac{\text{change in z-value}}{\text{distance} * 100}$$

Where:

The denominator is the height difference between two locations and the denominator is the horizontal difference. Two adjacent cells have a horizontal distance of 1; two diagonal cells have a horizontal distance of √ 2.

0	0	0	0	0	0	0	[2^0]	=	1	(E)
0	0	0	0	0	0	[2^1]	0	=	2	(SE)
0	0	0	0	0	[2^2]	0	0	=	4	(S)
0	0	0	0	[2^3]	0	0	0	=	8	(SW)
0	0	0	[2^4]	0	0	0	0	=	16	(W)
0	0	[2^5]	0	0	0	0	0	=	32	(NW)
0	[2^6]	0	0	0	0	0	0	=	64	(N)
[2^7]	0	0	0	0	0	0	0	=	128	(NE)

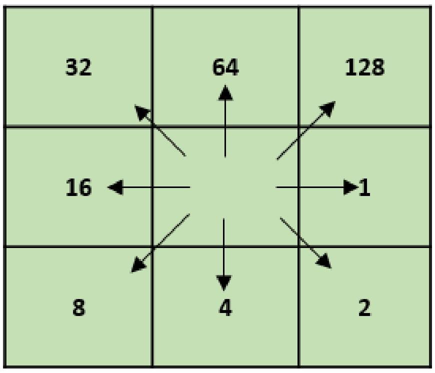


Fig. 3. Direction coding: the eight possible flow directions

3.4 Flow Accumulation

This approach of deriving accumulated flow from a DEM is presented in Jenson and Domingue (1988). Stream raster which represents a linear stream network and flow direction raster was used as input data for creating the stream link raster in the present study.

3.5 Stream Ordering

There are two methods for stream ordering proposed by Strahler (1957) and Shreve (1966). The Strahler method was used in the present study. With Strahler method, one can assign for all links without any tributaries an order of 1 and are referred to as the first order. The intersection of two first-order links creates a second-order link, the intersection of two second-order links create a third-order link, and so on.

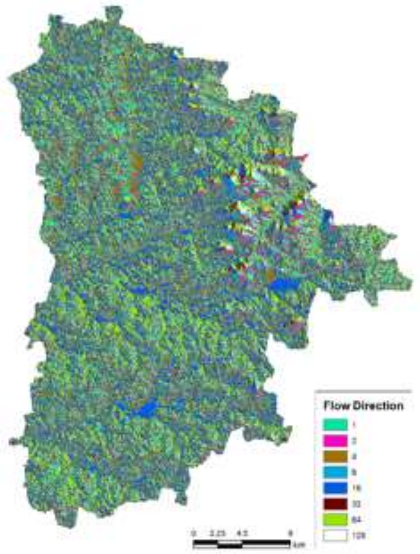
3.6 Vectorisation of stream network

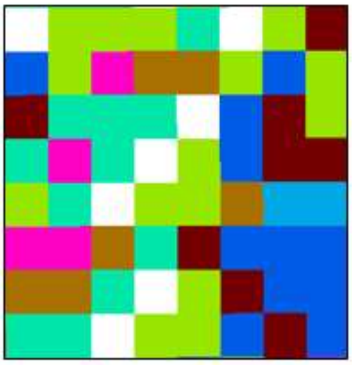
This step converts a raster map that represents a linear stream network into vector format. Vectorisation helps in analysis and quantification of map features.

IV. RESULTS AND DISCUSSION

The results show that the land surface modified by the removal or addition of surface material i.e., sinks filled area represents 25.31% of the total area. The first important step in deriving hydrologic characteristics of a surface is to determine the direction of flow from every cell in the raster ASTER GDEM. This is done with the ArcGIS Flow Direction tool. The DEM shows the water flow direction for each cell. Eight possibilities identified in the present study are E, SE, S, SW, W, NW, N and NE which are shown in the Fig.3.

The threshold value represents the minimum upstream area required to form a channel segment in which water starts to flow as channel runoff (Rieger, 1993). The stream network is normally displayed as inter-connected linear features and these features begin where the threshold value is exceeded. In the present study, the drainage streams are delineated using stream threshold of 0.05 km2 from the input ASTER GDEM. The order-wise streams generated for the study area is shown in Fig. 6. It is identified that the cumulative stream length is higher in first-order streams and decreases as the stream order increases. In almost all the cases, the basin length decreases as the order increases. This is due to the variation in relief over which the segments occur. The highest stream order i.e., 5th order has a total length of 40.69 km covering 3% of the total study area. The 1st order has a length of 782.96 km, 2nd order has a length of 391.31 km, 3rd order 174.55 km and 4th order 118.82 km covering 51%, 25%, 12% and 9% of the study area respectively.





128	64	64	64	1	128	64	32
16	64	2	4	4	64	16	64
32	1	1	1	128	16	32	64
1	2	1	128	64	16	32	32
64	1	128	64	64	4	8	8
2	2	4	1	32	16	16	16
4	4	1	128	64	32	16	16
1	1	128	64	64	16	32	16

Fig. 4. Flow direction matrix with numerical value for each direction

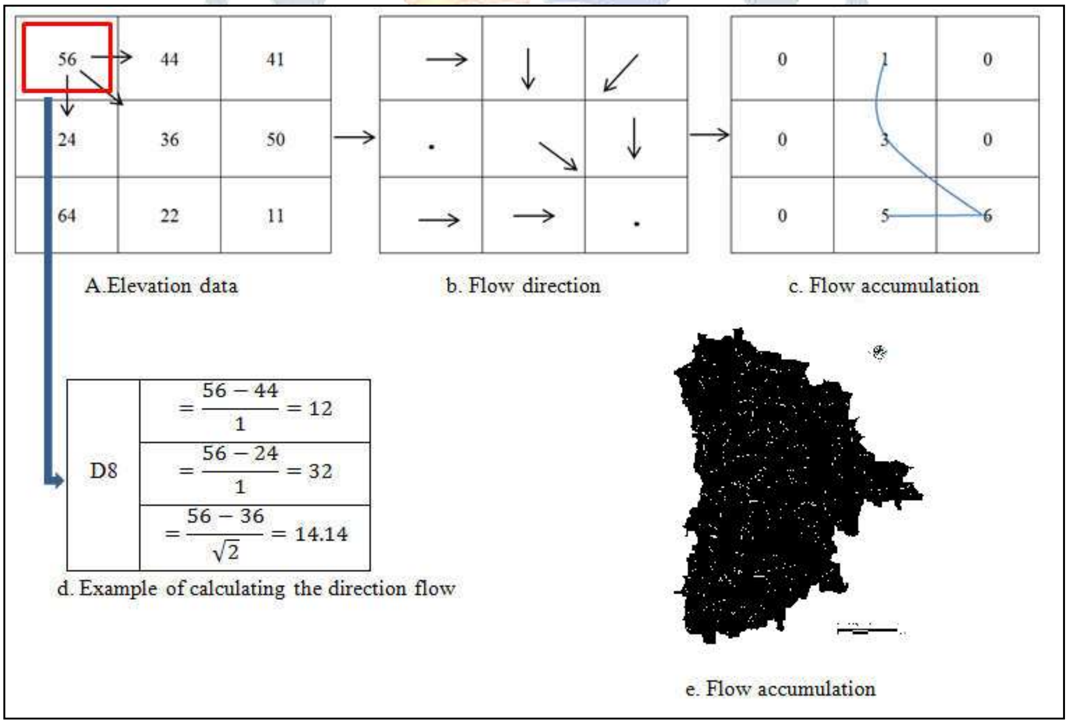


Fig. 5. Flow accumulation of Tumakuru taluk result with threshold value >500

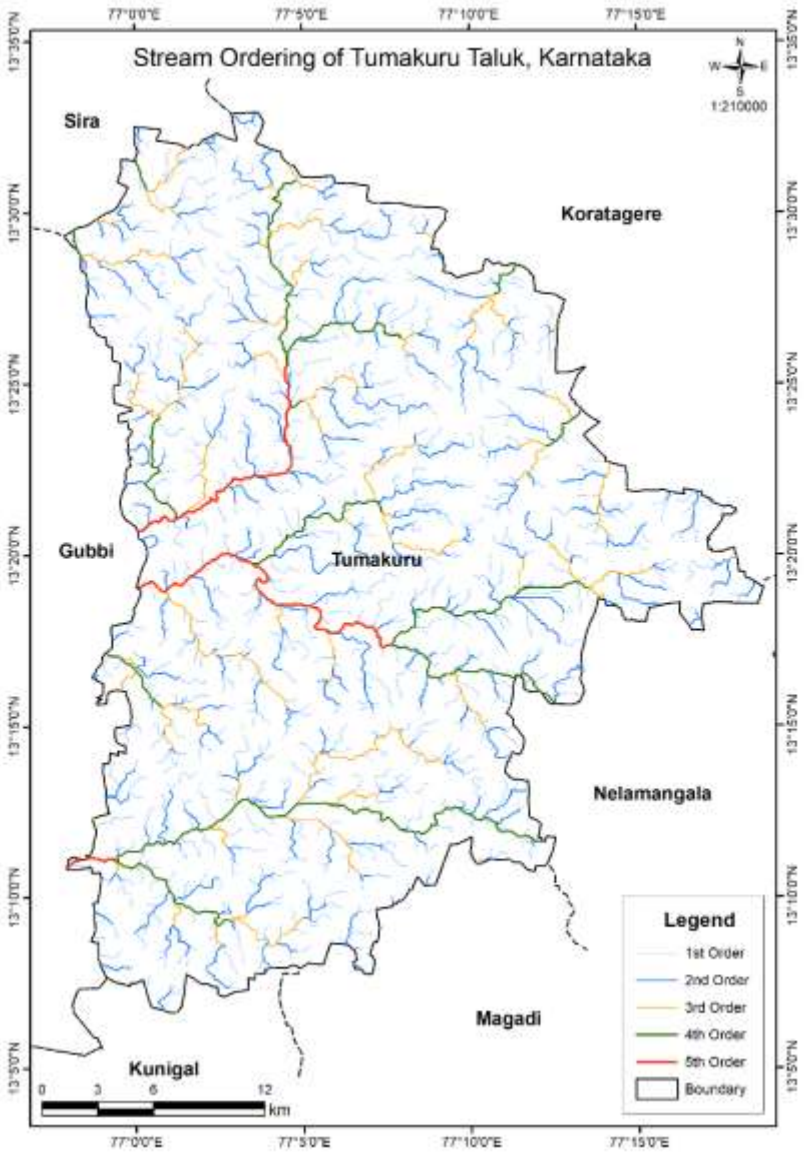


Fig. 6. Stream ordering for Tumakuru taluk using Strahler`s method

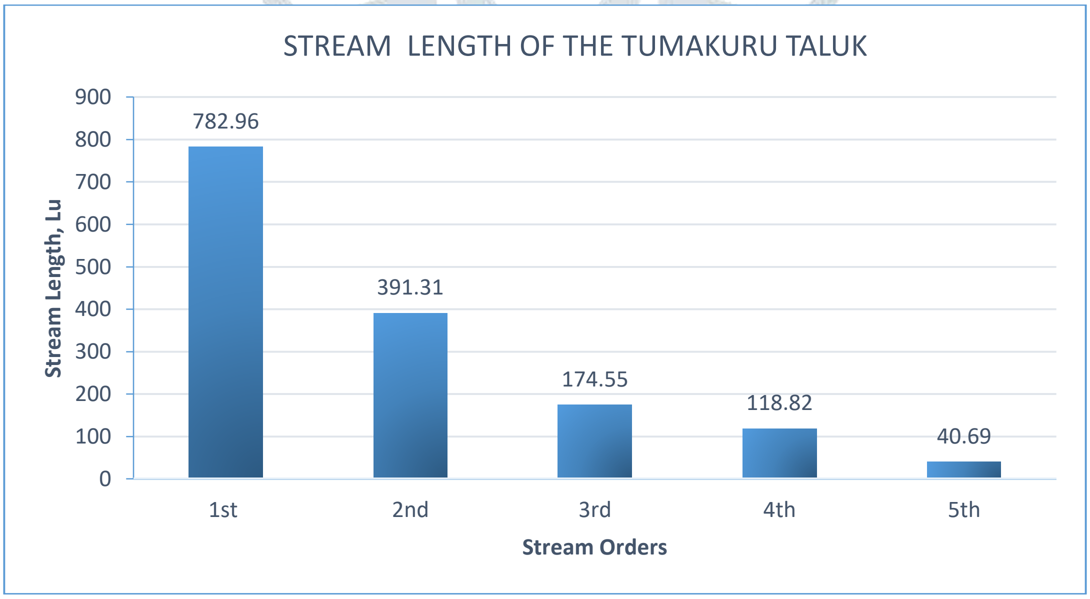


Fig. 7. Stream Length of the Study Area

Table 2. Ground truth data analysis based on GPS survey

Sl. No.	Ground Truth GPS Points (Lat/Long)		Stream Order	Match with Field Input
	Lat	Long		
1	13.13	77.03	2	✓
2	13.13	76.99	2	✓
3	13.15	77.01	1	✓
4	13.15	77.08	1	✓
5	13.18	77.13	1	✓
6	13.19	77.07	1	X
7	13.19	77.12	2	✓
8	13.21	77.11	4	✓
9	13.21	77.01	1	✓
10	13.23	77.12	1	✓
11	13.23	77.17	1	✓
12	13.24	77.03	1	X
13	13.28	77.03	1	✓
14	13.30	77.21	1	✓
15	13.32	77.08	1	X
16	13.33	77.16	1	✓
17	13.35	77.01	5	✓
18	13.35	77.22	1	✓
19	13.37	77.12	3	✓
20	13.39	77.10	2	✓
21	13.39	77.04	1	X
22	13.40	77.21	4	✓
23	13.40	77.15	1	✓
24	13.45	77.18	3	✓
25	13.45	77.19	1	✓
26	13.45	77.02	1	✓
27	13.48	76.99	3	✓
28	13.48	77.06	1	✓
29	13.50	77.12	1	✓
30	13.51	77.03	1	✓

The stream order extracted from ASTER GDEM was subjected to ground truth analysis based on GPS survey. There were about 30 random points generated from the stream network map and the geographical coordinates were verified in the field using GPS measurements encompassing all the stream orders. Results show that there is a good match between the random check points generated on the map and ground truth measurements. The accuracy of the stream order map generated from ASTER GDEM is found to be 87%.

IV. Conclusion

Morphology of surface drainage or streams changes from time to time due to environmental processes and anthropogenic factors. Hence, there is a need to update the existing drainage/stream network maps generated from the Topographical Maps regularly. Remote sensing measurements are quick, economical and reliable and they provide alternative sources for generating updated stream network maps. The present study shows that the ASTER GDEM product can effectively be used for steam network mapping using Deterministic Eight-node (D8) method of processing under GIS domain.

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