CHAPTER 4. MORPHOMETRIC ANALYSIS UTILIZING GEOINFORMATICS TECHNIQUES

4.1 Introduction

Morphometric analysis is the estimation also a numerical examination of the shape and design of the earth surface and the measurements of shape and its landforms. Morphometric analysis of the drainage system of the watershed gives the general perspective of the territory data like hydrological, lithological, slope, porosity and soil characteristics. It is also valuable for geographical, surface and groundwater prospects and ecological examinations (Harinath et al., 2013; Mokarram et al., 2017). In the late 1950s, Morphometric contemplates in the field of hydrology were started. It is entrenched that the impact of drainage morphometric is exceptionally critical in understanding the landform forms, physical properties of the soil and erosional qualities. In current times there has been an emphasis on various methods like Global Positioning System (GPS), Remote Sensing and Geographic Information System (RS&GIS), procedures in taking care of the issues of land use, making arrangements for water resource management, and during a morphometric analysis of watershed.(Abboud et al., 2017, Obireddy et al., 2004) GIS-based assessment utilizing SRTM and ASTER DEM data has given exact, quick and economical route of investigating hydrological frameworks.(Telfer et al., 2015, White et al., 2015, Start et al., 2009). Previously morphometric parameters of a watershed were extricated from geographical maps or field reviews. These parameter extractions from most recent two decades are more well-known from advanced geographical data which is called as Digital Elevation Models (DEM), which is all the more quick, exact and updated method for watershed analysis (Strahler 1964).

In nations like India, where the populace weight is persistently expanding, land and water assets are constrained, and their extensive use is primary. Basins and sub-basins are the main units for authoritative determinations to preserve natural resources. The catchment management idea perceives the interrelationships among the linkages between uplands, low land, geomorphology, slope, and soil. Soil and water preservation are critical issues in repository catchment management while outlining catchments. One of the upsides of the quantitative examination is that a significant number of the basin parameters determined are in ratios (dimensionless), accordingly giving a valid result and comparison independent of the scale (Chandrashekar et al., 2015).

The morphometric analysis comprises the estimation of the surface of earth, shape, and measurement of its landforms. This can be accomplished through the estimation of linear, aerial, and relief parameters of the watershed (Mosaad, 2017). Parameters such as drainage density, bifurcation ratio, drainage frequency, texture ratio, form factor, circulatory ratio are responsible for soil loss erosion and termed as erosion risk assessment parameters. All these parameters lead to a better understanding of the hydrological behavior of the sub-watersheds and thereby soil erosion in the respective sub-watersheds. Hence, analysis of these parameters helps to prioritize sub-watersheds for soil water conservation practices. Utilizing basin morphometry, the flood risk zones can be estimated (Kain et al., 2018, Taha et al., 2017). Additionally soil erosion-prone areas can be prioritized (Ameri et al., 2018), mapping of volcanic domes (Arya et al., 2014, White et al., 2015) can be done and prioritization for watershed management planning should be possible (Kar et al., 2009, Aher et al., 2014, Strahler 1964).

The present chapter plans to clarify the morphometric parameters and stream qualities of the study area by GIS & RS, which affect basin water circumstances and are seen as key for the eventual fate of water resources regarding groundwater supplies, water conservation methodologies, etc. Also, such investigations benefit in the acknowledgment of the geomorphological highlights, particularly the analysis of drainage systems and analyzing the morphometric situation of the study.

4.2 Methodology

4.2.1 Morphometric Analysis

The morphometric analysis is quantitative depiction and examination of the geology of earth surface, alleviation as is done in geomorphology, which can be connected to a particular kind of landform or important watersheds and areas all in all. Strahler, (1964) also expressed that morphometric analysis of any basin gives a quantitative depiction of drainage pattern and it is an essential part to comprehend the qualities of the watershed. In a morphometric examination, different data sources are required for the length of strength, stream number and so on. The initial step in the morphometric analysis of a basin is to identify the designation of the stream order. Streams can classify according to their position/order of magnitude within a drainage network.

Stream length (Lu) is the essential feature of any drainage system. In the watershed, it is the primary entity which contributes the flow to the basin and cause of various characteristics of the watershed. It shows the contributing area of the watershed of that stream order. Stream Length Ratio is the ratio of the mean stream length of a given order ($\bar{L}u$) to the mean length of the next stream of lower order ($\bar{L}u$-1) in the same watershed.

Basin Shape is the measure of the basin elongation. If there are reference points in the watershed, the difference in elevation of those points termed as Relief (H). It indicates undulation of the topography in the area Relief Ratio is a unitless measure of the gradient across the watershed boundary. It can be calculated by dividing the relief of the watershed by its length on which relief was measured. Ruggedness number (R) is combined with a measure of drainage density and relief. It will be increased as surface topography become complicated or say complex. It can be calculated by multiplying the drainage density and relief.

4.2.2 Procedure Followed

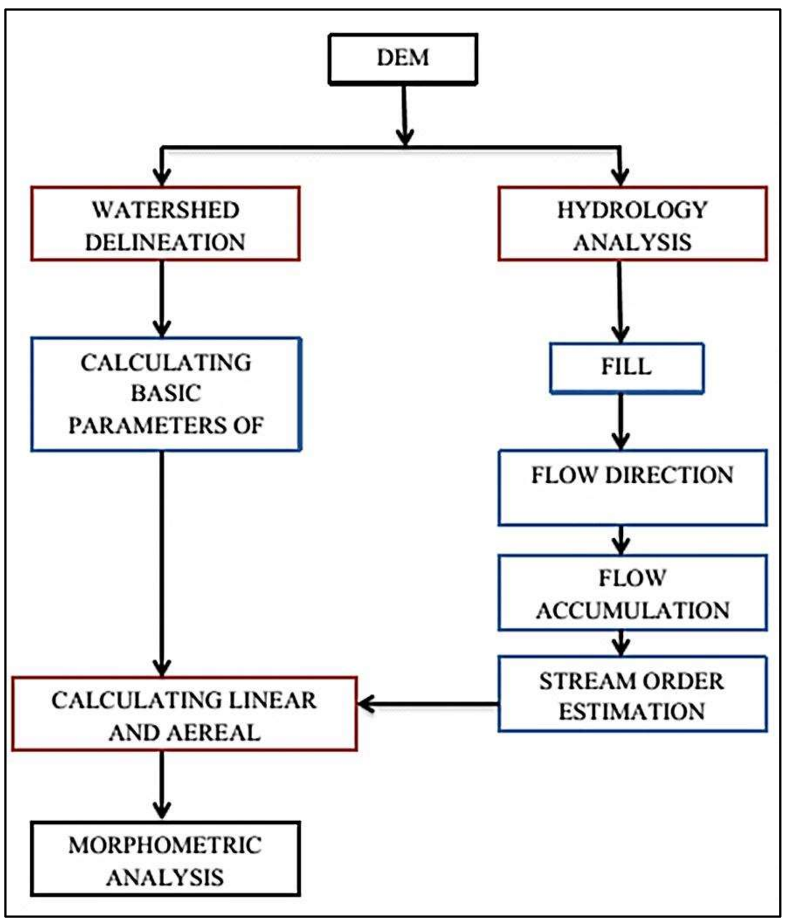

Figure 4.1 Flowchart for morphometric analysis

The flowchart in Figure 4.1 shows the complete procedure of analysis. SRTM DEM of 30 m resolution was procured from the website of USGS, which was utilized for delineating watershed shown in Figure 4.2 using ArcGIS 10 software. By using the Hydrology tool of ArcGIS, the Slope (shown in Figure 4.3), Flow direction, Aspect (Figure 4.4) and Flow accumulation map of the study area was prepared using DEM and ArcToolbox. Using these maps, the stream link was extracted for the watershed, and the stream order was calculated using Raster Calculator. The basic parameters of all the sub-watershed were calculated using the Calculate geometry tool of ArcGIS software.

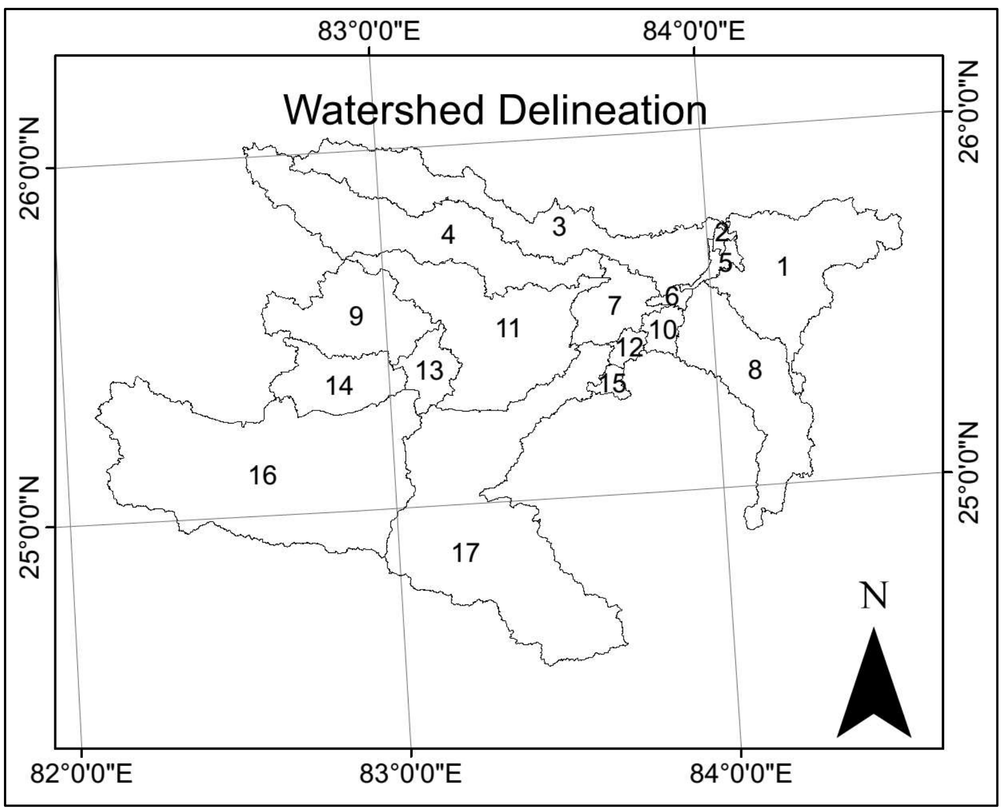

Figure 4.2 Watershed Delineation

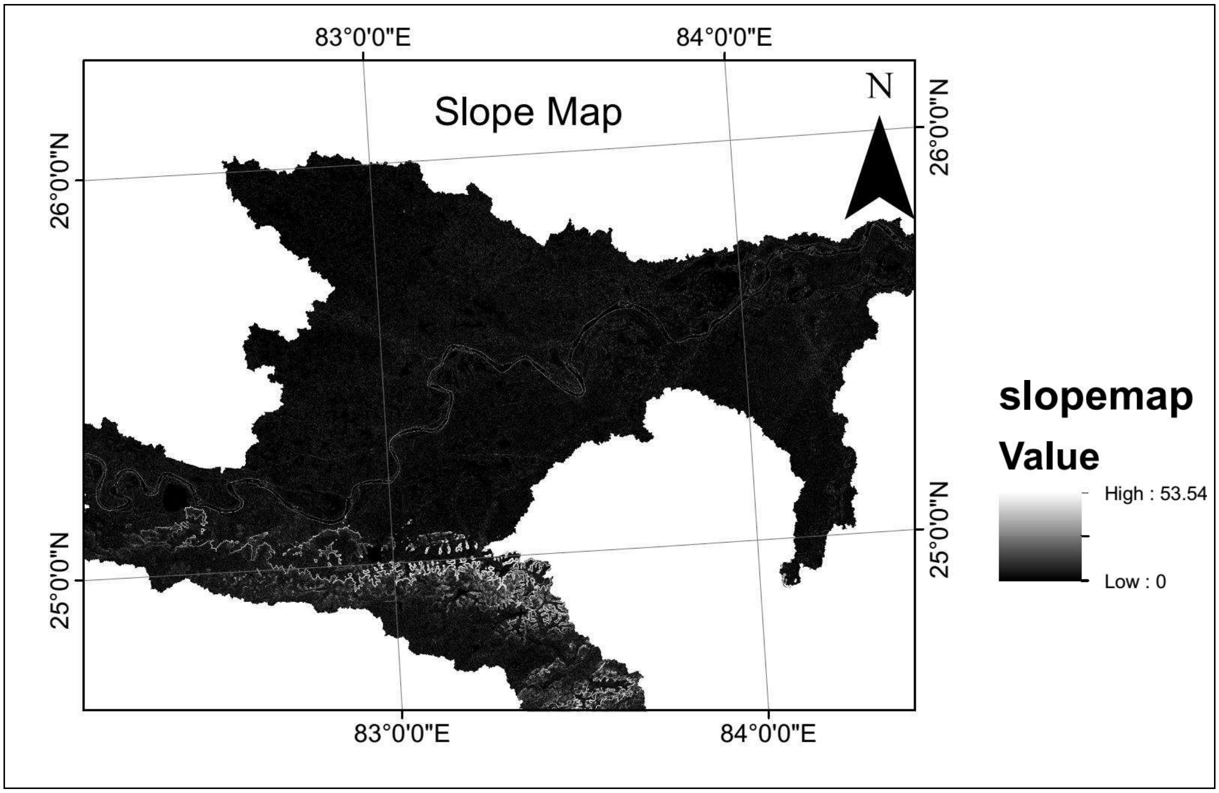

Figure 4.3 Slope map

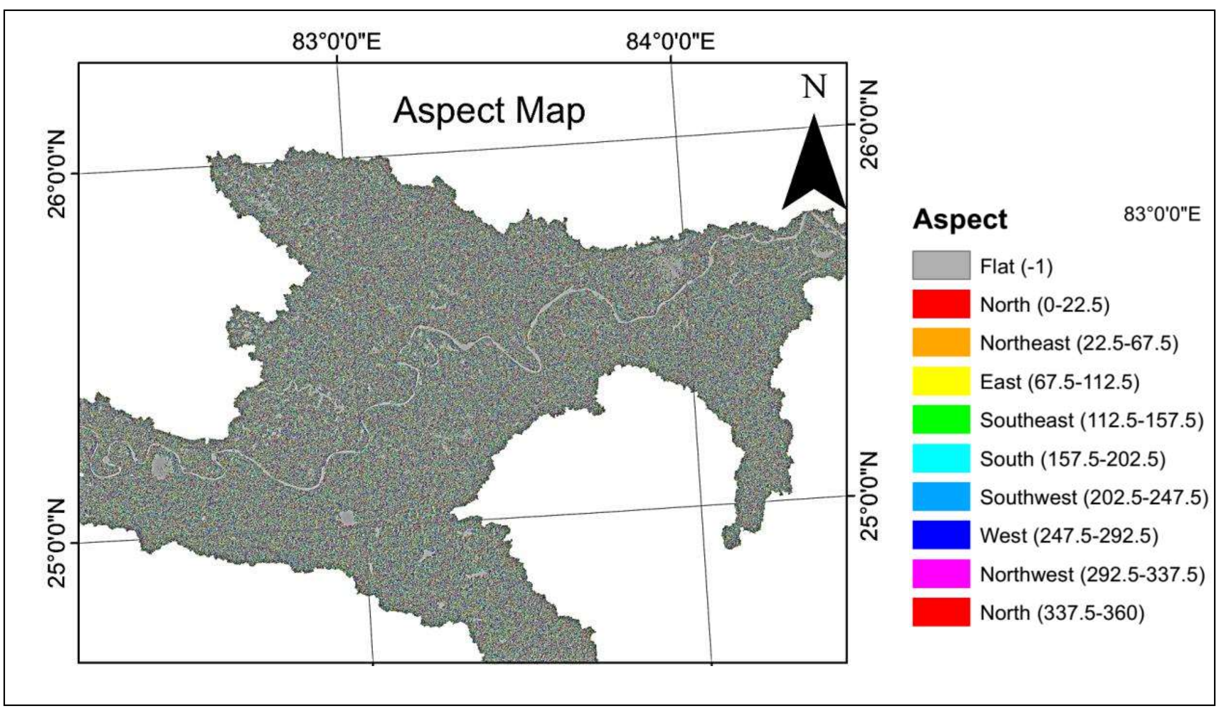

Figure 4.4 Aspect map

All parameters (Areal and linear) were calculated using formulas of Table 4.1

Where,

Nu = Total number of stream segment of order u.

N(u+1) = Number of stream segment of next higher order,

A = Area of Basin (km2),

Lu = Total stream length of all order,

P = Perimeter (km),

Lb = basin length and at last the morphometric analysis were done.

Table 4.1 Linear and Shape Morphometric Parameters

Parameters	**Formulae**
Stream Order (u)	Hierarchical rank
Stream Length (Lu)	Length of the stream
Mean Stream Length (Lsm)	Lsm = Lu/Nu
Stream Length Ratio	RL = Lu/(Lu -1)
Bifurcation Ratio (Rb)	Rb = Nu/Nu+1
Mean Bifurcation Ratio (Rbm)	Rbm = average of bifurcation ratios of all orders
Basin Length (Lb)	$Lb = 1.312*A^{0.568}$
Drainage Density (Dd)	Dd = Lu/A
Stream Frequency (Fs)	Fs = Nu/A
Circulatory Ratio (Rc)	Rc = 4πA/P2
Compactness Coeff.	0.2821 P/√A
Form Factor (Ff)	$Ff = A/Lb^2$
Length of Overland flow	Lo = 1/D * 2

Relief	R = H-h
Relief Ratio	Rr = R/L

Table 4.2 Calculated Values of Linear Morphometric Parameters

Sub. Basin Name	**D Density**	**Bifurcation Ratio**	**Stream Frequency**	**Circulatory Ratio**
SW1	0.88	1.93	1.51	0.04
SW2	0.80	1.61	1.40	0.05
SW3	0.81	3.21	1.30	0.08
SW4	0.60	5.14	0.89	0.05
SW5	0.50	3.33	0.62	0.11
SW6	0.02	4.21	0.05	0.09
SW7	0.46	7.42	1.02	0.14
SW8	0.79	1.67	1.46	0.11
SW9	13.61	3.45	1.45	0.083
SW10	0.76	2.31	1.24	0.16
SW11	1.53	1.41	3.41	0.12
SW12	0.62	2.82	0.78	0.17
SW13	0.68	2.28	0.97	0.14
SW14	0.73	2.18	1.47	0.14
SW15	0.64	2.30	0.72	0.14
SW16	0.77	1.79	1.13	0.09
SW17	0.77	1.81	1.34	0.14
Mean Value	1.47	2.88	1.22	0.11

4.3 Results

Table 4.2 and 4.3 show the resultant values of the Linear and Areal morphometric parameters of all the sub-basins. Bifurcation ratio (Rb) mainly emphasis on the structural disturbances of a watershed. The value of Rb varies from 1.4 to 5.14, and the mean value of the basin is 2.87 which show that the watershed is stable and less distributed. If the value of the form factor (Ff) would be 0.785 means that the watershed is circular. A circular watershed is the most dangerous from the drainage standpoint because it will yield the shortest time of concentration before peak flow occurs in the watershed. The value of Ff for this watershed is 0.29 which shows that the watershed is elongated. The texture ration (T) of the watershed varies from 0.15 to 8.6. The sub-watershed having low T values suggest that the watershed is plain with a lower percentage of slopes. The Stream Frequency (Sf) of the watershed varies from 0.05 to 3.4. These values reveal that the sub-watershed is covered with moderate vegetation and soil has a functional capacity of infiltration. Relief ration is a sign of the intensity of soil erosion processes. The values vary from 0.2 to 3.8. Higher the value of Relief ratio higher would be the probability of soil erosion in that sub-watershed. The value of Circulatory Ratio (C) varies from 0.04 to 0.17 which signifies that the watershed is mostly having impermeable surface and low relief.

Table 4.3 Calculated values of Shape Morphometric Parameters

Sub. Basin Name	Form Factor	Texture Ratio	Compactness Coeff.	Relief Ratio
SW1	0.08	3.51	4.94	0.26
SW2	0.12	3.95	4.14	0.43
SW3	0.22	4.15	3.43	0.64

SW4	0.15	0.59	4.18	1.33
SW5	0.35	0.36	2.93	2.80
SW6	0.21	0.16	3.22	3.84
SW7	0.24	0.85	2.60	1.75
SW8	0.29	2.97	3.01	0.87
SW9	0.32	4.98	3.46	0.63
SW10	0.66	1.68	2.52	1.68
SW11	0.33	10.49	2.88	0.64
SW12	0.37	0.89	2.39	1.14
SW13	0.40	0.90	2.63	1.02
SW14	0.35	3.92	2.67	0.94
SW15	0.35	1.29	2.71	1.34
SW16	0.14	5.45	3.37	3.76
SW17	0.37	8.60	2.66	2.57
Mean Value	0.29	3.22	3.16	1.51

If the estimation of Compactness coefficient (Cc) is exactly equivalent to one, at that point, it suggests that the basin is entirely circular. Here the qualities shift from 2.3 to 4.89 which implies that the sub-watersheds are not circular and the sub-watershed having the value of Cc equal to 4.9 has the longest time of concentration before peak flow occurs in the watershed out of all the sub-watersheds. The movement time by the water inside a basin is controlled by Drainage density (Dd). Here the estimations of Dd shift from 0.88 to 13. The low and moderate values of Dd values uncover that they are made out of a porous sub-surface material, great vegetation cover, and low relief brings about more infiltration capacity and is a decent site for groundwater recharge when contrasted with high Dd esteemed sub-watersheds (Abdalla 2012).

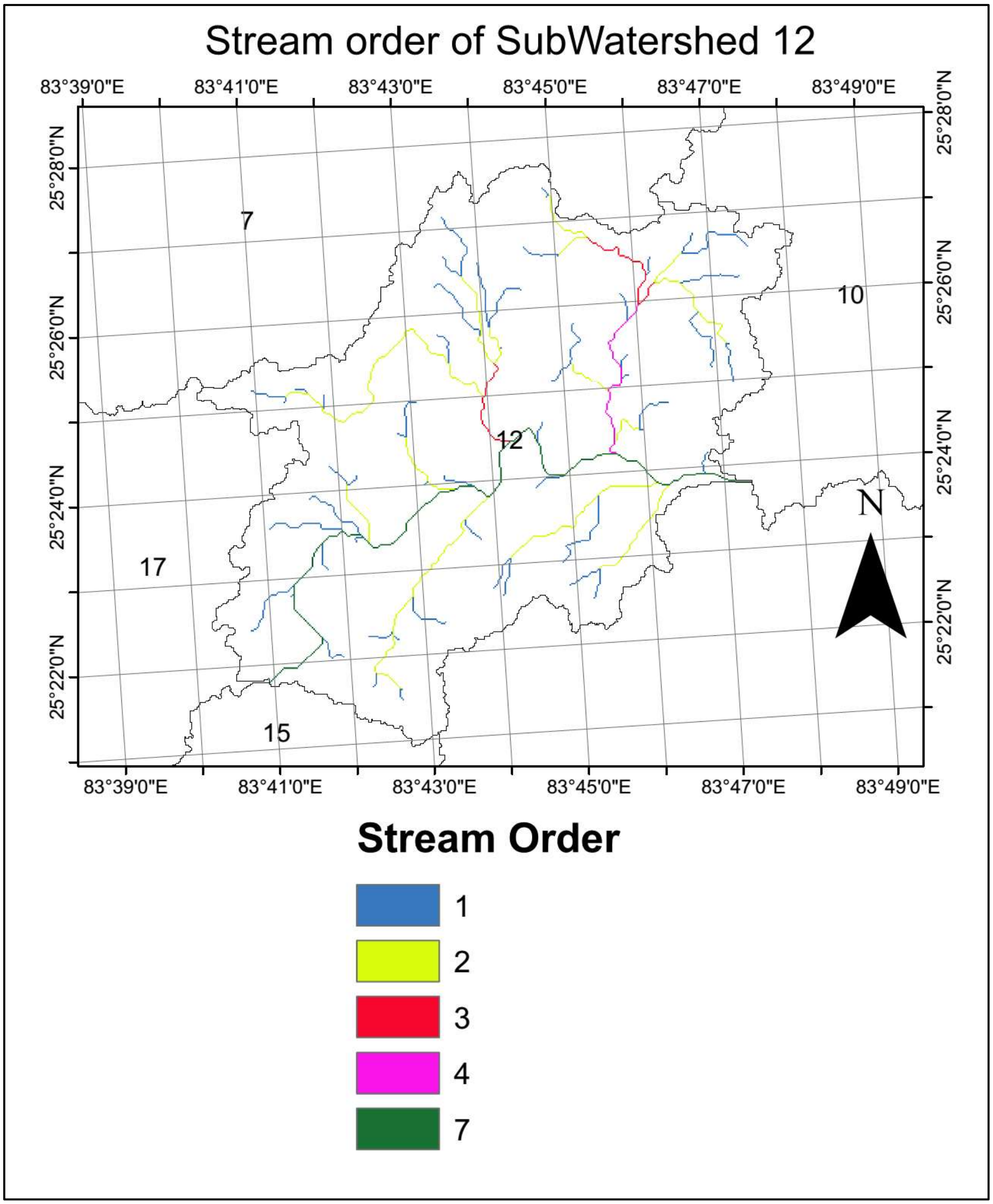

Figure 4.5 Stream Order map of SW 12