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Evaluation of Morphometric Parameters Derived from ASTER and SRTM DEM –A study on Sukhna Choe Watershed Shiwalik Hills India.

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Abstract

The analysis of drainage morphometry performs manual and computerized delineation, which enables detailed morphometrical measures. Morphometric parameters derived from three different sources viz., Survey of India topographic map (1:50,000), SRTM (Shuttle Radar Topographic Mission-90 m) and DEM derived from ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer-30 m) are evaluated to examine any difference within the results for the proper planning and management of the watersheds. Extracting drainage network from DEMs is mainly based on the flow of water from higher to lower elevation and steepest descent in a pixel. Common morphometric parameters are considered for analysis. The results show that the morphometric parameters derived from the SRTM and ASTER data provide good and satisfying results. The results will be more efficient when the DEM cell size is smaller or the resolution of the image is higher. The river is 5th order drainage basin and drainage pattern in dendritic type. It is observed that drainage density value is low which indicates the basin is highly permeable. The circularity ratio value reveals that the basin is nearly elongated and highly permeable homogenous geological materials.

Keywords: Morphometry. ASTER . SRTM . DEM Sukhna Choe Watershed Shiwalik Hills India.

Introduction

Remote Sensing (RS), Geographical Information System (GIS) and Global Positioning System (GPS) have proved to be an efficient tool in delineation of drainage pattern and water resources management and its planning. The analysis of drainage morphometry have been performs manual and computerized delineation, which enables detailed morphometrical measures. The analysis of Sukhna Choe Watershed catchment of Siwalik Hills India has been selected for drainage morphometric analysis. It can be thought of as an open system that receives energy or input from the atmosphere and sun over the watershed and loses energy or out put through the water and sediment mainly through the watershed mouth or outlet (Strahler 1964). The present form of any drainage watershed is the result of the processes that have operated in the past on the material available locally. The importance of studying the drainage watershed characteristics derives from the need of studying forms of channels and channel networks as they are related to physical characteristics of the drainage watershed.

Study Area

The study area is nearly located between latitudes 76°49’30” to 76°52’30”E and longitude 30°48’0’’ to 30°45’0’’N and area covering approximate 43.53 Sq Kms. Climate of the area is semi–arid with mean maximum

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temperature of 41.80 C during JUNE to minimum temperature 5.10.C during January. Average rain fall of the area is 1120 mm with a maximum of 2200 mm and minimum 713 mm. Out of the total rain fall received during year, 88% is receiver during monsoon season. Average daily pan evaporation ranges between 0.9 and 9.5 mm day during December and May respectively. Soils of the catchment area are highly variable with in short distances. Murthy and Shankaranaryana (1977) mapped the soil and Grewal and Juneja (1984) characterized the soil of Sukhna lake catchment with respect to their erosion behavior. There reported that the texture of the soil vary from Loamy sand, fine loamy to salty clay depending on their location in the catchment. The texture variation is so great that the small area, the Sand varies from 4.5% to 65%, Silt from 6.6% to 46.7% and Clay from 3.1% to 56%. Different parent material namely Sand Stone and Shale accrue side by side and there differential hydro – thermal properties and erosion behavior leads to lack of cohesion. The sealing of soil pores with high Clay and Silt laden run off their conductivity. This leads to heavy runoff from bare hill slopes. Natural vegetation consists of Trees, Shrubs, Climber and Grasses. Apart from the natural vegetation, plantation of Eucalyptus, D.Sisoo, Kardu, Acacia sp. Have also been done in the catchment area which have established well. Khair (Acacia catechu) ank Kikar (Acacia nilotica), Shisham (Dalbergia sisoo) are the dominant tree species, Lantana, Karonda, Beri, Mehnder, Adatoda and Karripatta are dominant bush species with rising presence of Lantana. The local grasses like Bhabar, Kana, Kahi, Bansa, Dub, Dholu and Aristida are common in the area. Location map of the study area is displayed in Figure 1.

Materials and Methodology

Topographical Map: Survey of India (1:50,000) 43K/13 or 53B/13 scale was registered to UTM projection (WGS 84North, Zone 43) and the drainage network was created manually by digitizing drainage lines in GIS. SRTM and ASTER images were downloaded from GLCF website (http:// glcf.umiacs.umd.edu). The drainage network from SRTM and ASTER DEM was extracted, using the Arc Hydro toolset in Arc GIS (Fig 2). Land Use/Land Cover map has been prepared by using knowledge classification method in GIS and IRS-P6 LISS-III satellite imagery and it has been verified through limited field Verification. Digital methods were applied for stream delineation. A number of digital applications were undertaken with the help of relating tools and all tributaries of different extent and patterns have been digitized. The watershed of Sukhna Choe also delineates digitally to create a outlet point. Flow direction of water in a river channel is delineated through Arc Hydrology tools. In order to have a better understanding some of the important morphological parameters have been calculated manually. Detailed methodology is displayed in Figure 2.

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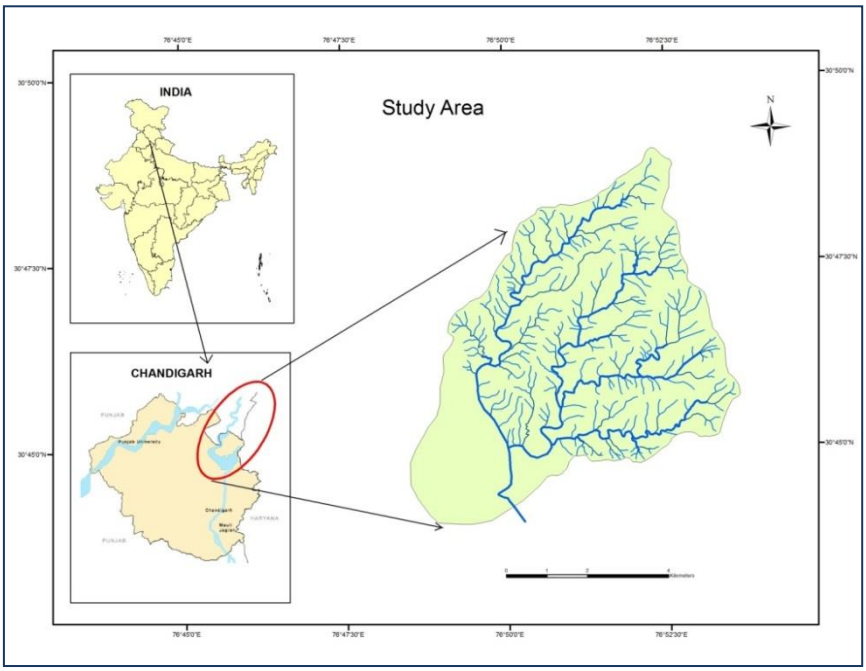

Figure 1: Location map of the study area

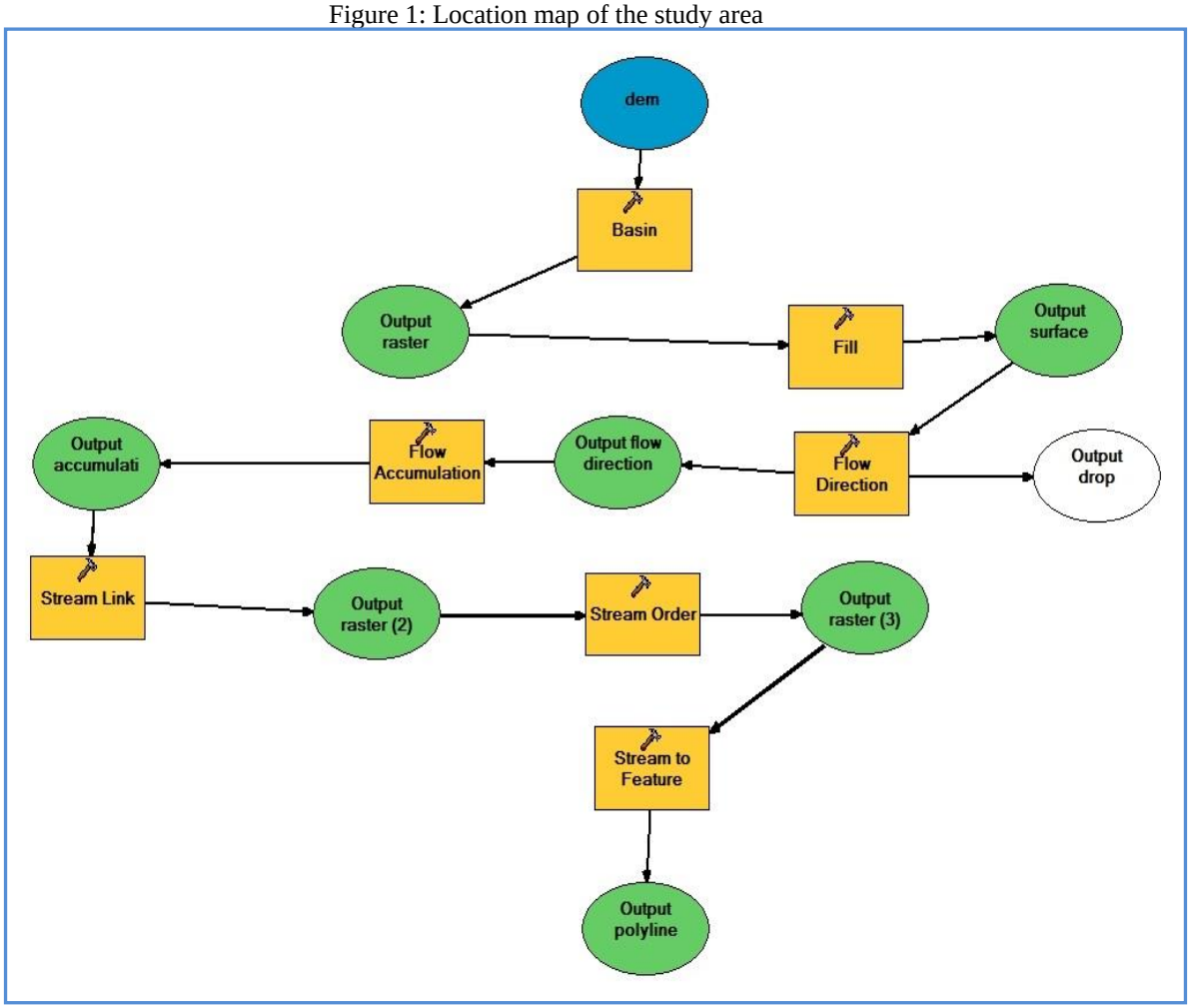

Figure 2: Methodology Flow Chart

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Results and Discussion

The morphometric analysis of Sukhna Choe Watershed Shiwalik Hills India was done using the parameters shown in Table 1.

Basic Parameters

The perimeter (P) is the total length of the drainage basin boundary. The perimeter of the Sukhna Choe Watershed 29 km for toposheet, whereas, the watersheds derived from the satellite data have 28.4 and 29.07 km, for SRTM and ASTER respectively. It is clearly noticed that the accurate delineation is possible when a higher resolution image is used. The total drainage area (A) of Sukhna Choe Watershed has remained the same for all three sources of the data approximately 43.08, 43.22 and 43.53 km² for toposheet, SRTM and ASTER respectively. The values are shown in Table 2.

Table 1: Morphometric Parameters

Morphometric Parameters	Formula	Description	References
Basic Parameters			
Total Stream Order	(ΣNu)	Total order number in the basin	Strahler (1964)
Total Stream Length	(ΣLu)	Total length of each order was computed at Sub-basin level	Horton (1945)
Derived Parameters			
Bifurcation Ratio (Rb)	$Rb=Nu/Nu+1$	The ratio between the number of streams of any given order to the number of streams in ratio (Rb)	Horton (1932)
Stream Length Ratio (Rl)	$Rl=Lu/Lu-1$	The ratio of mean stream length of any given segment to the mean stream length of the next lower order	Sreedeviet *et al.* (2005)
Stream Frequency (FS)	Fs= ΣNu/A	The ratio between total number of streams and area of the basin	Horton (1945)
Drainage Density (Dd)	Dd=ΣLu/A	The ratio between the total stream length of all (Dd) orders to the area of the basin	Horton (1945)
Texture Ratio (T)	T= ΣNu/P	The ratio between the total number of strams of all orders and perimeter of the basin	Smith (1950)
Basin Relief (Bh)	$Bh=H_{max}-H_{min}$	The maximum vertical distance between the lowest and the highest points of a sub basin	Hadley and Schumm (1961)

Stream order (Nu)

The designation of stream orders is the first step in drainage basin analysis and is based on a hierarchic ranking of streams. Stream order or classification of streams is a useful indicator of stream size, discharge and drainage area (Strahler, 1957). The number of streams (N) of each order (u) is presented in Table 2. Sukhna Choe Watershed is

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a fifth order basin; it is observed that decrease in stream frequency as the stream order increases in all the three sources of the data. Sukhna Choe Watershed is a hilly terrain with moderate to steep slope. Which is clearly depicted by ASTER and SRTM? Therefore, the satellite data show a very high variation in I, II and III order streams.

Table 2: Basic Parameters of Sukhna Choe Watershed in Shiwalik Hills India

Name	Source	Basin Area (A) in km²	Perimeter (P) in km	Stream Order(Nu)	Total No of Streams Σ(Nu) in km	Stream Length in km	Total Stream Length Σ(Lu) in km
				I II III IV V		I II III IV V	
Sukhna Watershed	SOI Toposheet	43.08	29	225 56 10 3 1	295	81.4 30.21 20.4 10.86 5.15	147.69
	Aster Dem (30)	43.53	29.7	275 76 14 6 1	327	55.88 29.75 12.35 18.55 3.4	119.88
	Srtm Dem (90)	43.22	28.4	196 50 6 2 1	225	59.57 21.86 20.54 8.87 1.48	122.31

Table 3: Derived Parameters of Sukhna Choe Watershed in Shiwalik Hills India

Name	Source	Bifurcation Ratio (Rb)				Stream Length Ratio (RL)				Stream Frequency (Fs)	Drainage Density (Dd) km/km²	Drainage Texture (T) km/km²	Basin Relief(R)
		I/II	II/III	III/IV	IV/V	I/II	II/III	III/IV	IV/V				
Sukhna Watershed	SOI Toposheet	4.01	5.6	0.3	3	0.37	0.17	0.3	0.3	6.68	3.42	10.17	140
	Aster Dem (30)	3.61	5.42	2.33	6	0.53	0.41	1.5	0.18	7.51	2.75	11.01	160
	Srtm Dem (90)	3.92	8.33	3	2	0.36	0.93	0.43	0.16	11.01	2.82	8.97	160

Stream length (Lu)

The number of streams of various orders in a watershed was counted and their lengths were measured. The stream length characteristics of the sub-basins confirm Horton's second law (1945) "laws of stream length" which states that the average length of streams of each of the different orders in a drainage basin tends closely to approximate a direct geometric ratio. Generally, the total length of stream segments is high in first order streams and decreases as the stream order increases. In case of Sukhna Choe Watershed the stream segments of various orders show variation from general observation. When stream length was calculated for Sukhna Choe Watershed

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from toposheet, it was found that it follows a general pattern i.e. stream length is maximum in the first order and decreases with the least at fifth order (Table 2). However, stream length calculated from ASTER and SRTM DEMs shows variation from the general observation. The length of the fourth order stream was greater than third order in both of the satellite data.

Derived parameters

Bifurcation ratio (Rb)

It is observed from Table 2, that the Rb is not the same from one order to its next order. These irregularities are dependent upon the geology and lithology development of the basin (Strahler, 1964). The Rb ranges between 3.0 and 5.0 when the influence of geological structures is negligible (Ozdemir and Bird, 2009). The Rb for all the three data is given in Table 2. The Rb values for I and II order streams are higher than the Rb of higher order stream indicate the hilly terrain and active gullies and ravines. The mean Rb (Rbm) may be defined as the average of bifurcation ratios of all orders (Table 3). In the present case, Rbm varies from 3 to 6 and Sukhna Choe Watershed fall under normal basin category (Strahler, 1957). The lower values of Rb are characteristics of the subwatersheds which have suffered less structural disturbances (Strahler, 1964; Nag, 1998).

Stream length ratio (Rl)

Horton's law (1945) of stream length states that mean stream length segments of each of the successive orders of a basin tends to approximate a direct geometric series with streams length increasing towards higher order of streams. The Rl between streams of different order in the Sukhna Choe Watershed area reveals that there is a variation in RL (Table 3). Toposheet values show an increasing trend in the length ratio from lower to higher order, whereas, in ASTER and SRTM DEM the values change from one order to another order. Rl between successive streams order varies due to differences in slope and topographic conditions, and has an important relationship with the surface flow discharge an erosional stage of the basin (Sreedevi *et al*., 2004).

Stream frequency (Fs)

Hypothetically, it is possible to have the basin of same drainage density differing in Fs and basins of same Fs differing in drainage density. For Sukhna Choe Watershed Fs ranges from 6.68 for toposheet, whereas, the watersheds derived from the satellite data have 11.01 and 7.51, for SRTM and ASTER respectively. The values are shown in (Table 3). The SRTM data show a high Fs for the basin indicating the basin has moderate relief, high vegetation conditions and high infiltration capacity (Reddy *et al*., 2004).

Drainage density (Dd)

Drainage density is a measure of the degree of fluvial dissection and is influenced by numerous factors, among which resistance to erosion, infiltration capacity, vegetation cover, surface roughness and run-off intensity index and climatic conditions rank high (Langbein, 1947; Verstappen, 1983; Reddy *et al*., 2004). Dd indicates the closeness of spacing of channels. The amount and type of precipitation influences directly the quantity and character of surface runoff. An area with high precipitation such as thundershowers loses greater percentage of rainfall as run-off resulting in more surface drainage lines Amount of vegetation and rainfall absorption capacity of soils, influences the rate of surface runoff and affects the drainage texture of an area. The similar condition of lithology and geologic structures, semi-arid regions have finer Dd texture than humid regions. According to Nag

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(1998), low Dd generally results in the areas of highly resistant or permeable subsoil material, dense vegetation and low relief. High Dd is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low Dd leads to coarse drainage texture while high Dd leads to fine drainage texture. In the present study the Dd varies between 2.82, 2.75 (for ASTER and SRTM) and 3.42 (toposheet) km/km$_2$ indicating low Dd (Table 3), therefore the Sukhna Choe Watershed has low Dd indicating the region having highly permeable subsoil and dense vegetative cover.

Drainage texture (T)

The drainage texture (T) is an expression of the relative channel spacing in a fluvial dissected terrain. It depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development of a basin (Smith, 1950). The value of T for the sub basins are shown in Table 3. According to Horton (1945), T is the total number of stream segments of all orders per perimeter of that area. The drainage density < 2 indicates very coarse, between 2 and 4 is related to coarse, between 4 and 6 is moderate, between 6 and 8 is fine and >8 is very fine drainage texture. In the present study, a value of above 8 was noticed in satellite data indicating fine texture and above 10 for toposheets indicating moderate texture.

Slope

Slope defined as angular inclinations of terrain between hill top and valley bottom, resulting from the combination of many causative factors like geological structures absolute and relative reliefs, climate, vegetation cover, drainage texture and frequency are the significant morphometric attributes in the study of land forms of a drainage watershed. Absolute slope of watershed area ranging between 5 degree and 30 degree. Area 12.44 sq.kms of watershed that is 28.6 percent of the total area covering slope between 0 to 5 degree and area 0.44 sq.kms that is only one percent of the total area of watershed ranges between 25 to 30 degree slope. (Figure 4

Aspect

An aspect-slope map simultaneously shows the aspect (direction) and degree (steepness) of slope for a terrain (or other continuous surface). Aspect categories are symbolized using hues (e.g., red, orange, yellow, etc.) and degree of slope classes are mapped with saturation (or brilliance of color) so that the steeper slopes are brighter. This will result in a map that has the colors shown to the right. (Figure 4)

Relief

The incessant work of indogenetic and exogenetic forces, continuously fashion the surface configuration. The interaction between them gives rise to various land forms, the irregularities of the surface vary spatially as well as temporally depending upon the nature and relative strength of affecting factors. Watershed of Sukhna Choe having low to medium elevation ranging between 360 to 560 meters. On the relief map very dark patches showing The elevated areas more than 560 meters while light patch representing the lowest elevation of the area which is less than 360 meters (Figure 4).

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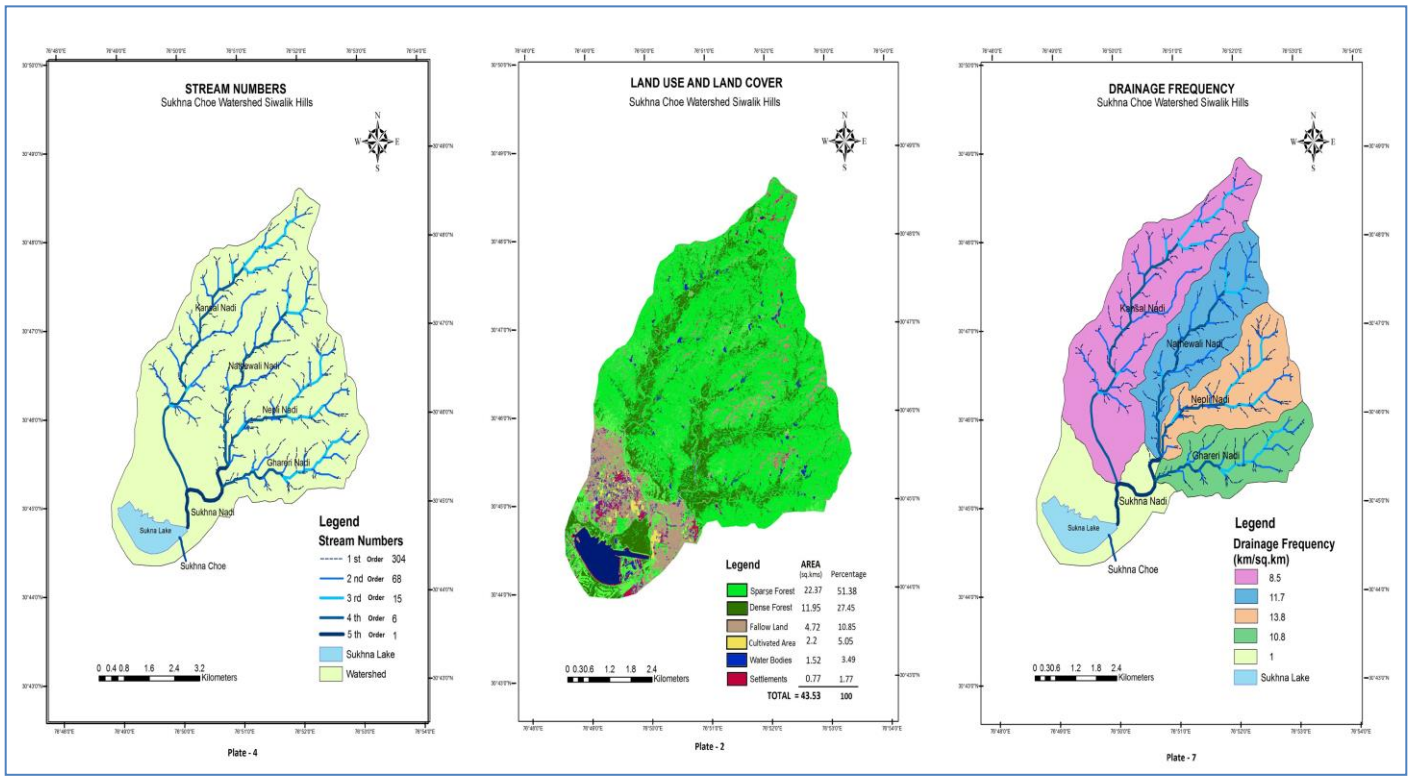

Figure 3: Stream numbers, land use/ land cover and drainage frequency maps of the Sukhna Cho Watershed

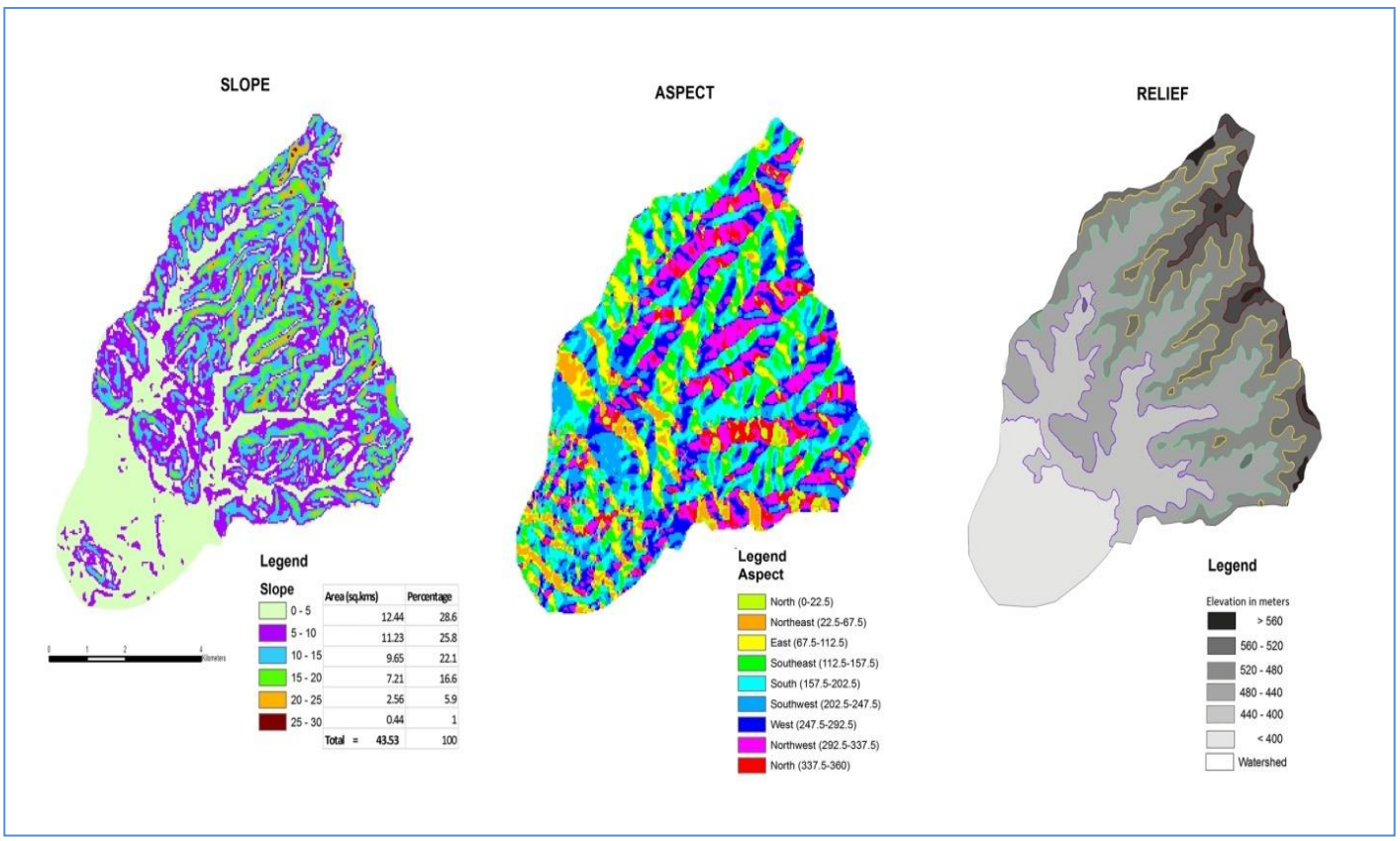

Figure 4: Slop, Aspect and Relief maps of the Sukhna Cho Watershed

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Summary and Conclusions

The analysis of drainage morphometry is usually a prerequisite to the assessment of hydrological characteristics of surface water watershed. In this study, the Sukhna Choe Watershed catchment of Shiwalik Hills was selected for drainage morphometric analysis. The morphometric analysis of the drainage networks of the watersheds of the study area show dendritic to sub-dendritic patterns with fine drainage texture. The variation in stream length ratio might be due to change in slope and topography. The bifurcation ratio in watersheds indicates normal watershed category and the presence of low drainage density suggesting that it has highly permeable sub-soil and fine drainage texture. The values of stream frequency indicate that all the watersheds show positive correlation with increasing stream numbers with respect to increasing drainage density. Stream ordering shows that first order streams are more than the other order streams the last and fifth order stream is high order main stream that carries the water of all order stream. Number of streams decreases with an increase in stream order. Absolute slope of watershed area ranging between 5\ degrees and 30 degrees. Area 12.44 sq.kms of watershed that is 28.6 percent of the total area covering slope between 0 to 5 degree and area 0.44 sq.kms that is only one percent of the total area of watershed ranges between 25 to 30 degree slopes. The elevation of the watershed area ranges between 360 m to 560 m which is low relief. This study would help local people to utilize the resources for sustainable development of the basin area.

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