Indian Journal of Spatial Science Vol - 4.0 No. 1 Summer Issue 2013 pp. 9 - 20

Indian Journal of Spatial Science

EISSN: 2249 - 4316 ISSN: 2249 - 3921

journal homepage: www.indiansss.org

Relief Analysis of the Tangri Watershed in the Lower Shivalik and Piedmont Zone of Haryana and Punjab

Tejpal
Research Scholar, Department of Geography, Kurukshetra University, Kurukshetra-136119, India

Article Info

Article History
Received on:
29 May 2012
Accepted in *Revised Form* on:
15 January 2013
Available *Online* on and from:
01 February 2013

Key Words
Watershed
Relief
Hypsometric Integral
Cycle of Erosion
DEM
Runoff
Longitudinal Profile

Abstract

Relief aspect of watersheds plays an important role in drainage development, surface and sub-surface water flow, permeability, landform development and associated features of the terrain. The study analyzes relief parameters, viz., absolute relief, relative relief, relief ratio, dissection index, ruggedness index, slope, hypsometric integral and landscape profiles for better understanding of hydrological processes operating in the watershed. The present study involves the applications of RS/ GIS techniques to evaluate and compare the relief aspects of the watershed. The experiment carried out in the Tangri watershed indicates that infiltration capacity and relief attributes vary from moderate to high with slope ranging between 0 and 56 degrees. The northern part of the basin, mostly occupied by the quartzite and basic intrusives has steeper slope. The hypsometric analysis reveals that the basin is passing through the old stage of the fluvial cycle. Thus, a modern integrated approach has great potential for exploring the relief parameters in order to facilitate planning and management of the watershed.

Introduction

Relief is an important attribute of terrain in general and a watershed in particular. According to Strahler (1964), relief measures are indicative of the potential energy of the drainage system because of its elevation above mean sea level. The relief aspects of a drainage basin are related to the study of three dimensional features of the basins involving area, volume and altitude of vertical dimension of landforms (Singh, 1997). Thus, it includes the analysis of the relationship between area and altitude (*hypsometric analysis*), slope, relative relief, relief ratios, dissection index *and* profiles of the terrain and rivers.

The pioneering investigations of Horton (1945), Thornbury (1954) and Strahler (1964) emphasized the advantages of morphometric analysis in characterizing geomorphic features and inferring the degree of structural and lithological controls in the evolution of fluvial landforms. Relief, geology and climate are the key determinants of running water ecosystems functioning at the basin scale (Lotspeich and Platts 1982; Frissel *et al.* 1986). The relief analysis helps to elaborate a primary hydrological diagnosis in order to predict approximate behavior of a watershed (Esper, 2008), thereby making such analysis an essential first step toward the basic understanding of the

Watershed dynamics.

In relief and terrain characterization studies, especially on the spatial variability of morphometric prperties, the contribution of Mather and Doornkamp (1970), Gardiner (1978), and Gregory (1978) are considered immensely important. In the Indian context, relief analysis has been employed for watersheds by a large number of geomorphologists, viz., Kharkwal (1971), Singh and Singh (1979), Singhal and Jhingran (1991), Singh and Sinha (1996), Thakur (2005), Patel and Sarkar (2010) to name a few. Locally, in the Siwaliks, examples of similar approaches have been applied in the Ghaggar and its adjacent tributary basins (Ali, 1966; Asthana, 1967; Kharkwal, 1968; Surajbhan, 1973; Bhardwaj, 1999). Recently, Thakur (2008) as well as ISPER (2010) and Saini and Gupta (2009) have analyzed the relief characteristics of Ghaggar and Kaushalaya rivers respectively using RS / GIS as a tool. The emerging trends in the applications of digital technology has enabled us to integrate a wide range of information about the physical system and to use these for research and solve practical problems. The advantages of this digital earth concept are its ability to create, manipulate, store, and use spatial data much faster and at a rapid rate. Moreover, it has made the quantitative approach for surface characterization and the mechanism for the interpretation and manipulation of the quantitative datasets much easier (Thomas et al. 2010).

Study Area

The Tangri watershed with an area of 656.24 km^2 sprawls across the Panchkula and Ambala districts of Haryana and Patiala district in Punjab (Fig. 1). It is bounded by latitudes 30°12'50"N and 30°43'24"N and 76°42'30"E and 77°7'5"E meridians. Tangri is one among the major tributaries of the Markanda river (with confluence near Naya Segti village in Ambala district) which is again a main tributary of Ghaggar river, the longest west flowing river in Haryana. The watershed lies in a subtropical climate characterized by hot summers and cold winters. Mean annual rainfall is about 1000 mm that mostly occurs in the months of July - September. Physiographically, the landscape is dotted with Siwalik hills - typified by moderately steep to steep slopes - in the northern part within Panchkula district. The piedmont zone is a broadly dissected tract with undulating topography underlain by a lithological matrix of sand, silt, clay and conglomerates. The Tangri river and its tributaries deposit rich alluvium in the middle and southern part of the watershed (Fig. 1).

Objectives

The present study primarily focuses on the description and nature of spatial variations of relief aspects of the Tangri watershed, in order to portray and evaluate the hydrological behaviour and denudational level of the watershed through creation of landscape profiles and hypsometric analysis.

Data Base and Methodology

Quantitative analysis of watershed requires various drainage and relief parameters to be measured. For this, the various maps of the watershed have been prepared through visual interpretation of Survey of India Toposheet (SOI) on 1:50,000 scale corroborated with the Landsat 7 ETM+ imagery (spatial resolution: 30 m; February 13, 2009; Path 147, Row 039) coupled with ground truthing.

ArcGIS 9.3, Erdas Imagine 9.1 and MS Office software packages have been used for creation of the digital database, data integration and analysis. The water divide (ridge line) of the sub basins and spot height has been used for demarcating and extracting the watershed boundary.

The digital elevation model (DEM) has been generated from SOI Toposheets with spot heights as the feature class. A geodatabase has then been prepared on GIS platform . The thematic maps have been also vectrozied in continuous mode and then the vectrozied values have been edited. Unique attributes are assigned for all the features of different thematic maps. The different vector layers in the thematic maps are labeled separately.

By using ArcGIS 9.3, the geometric dimensions of the relief aspects have been extracted (Table -1). The attributes of the relief properties have been analyzed by dividing the DEM into grids of 1km^2 dimension. The hypsometric integral has been computed and presented on the bases of sliced DEM at an interval of 50 m height and the landscape profiles have been drawn at an interval of 1 km^2 grid.

Slope analysis has been performed in degrees to prepare the slope data set using ArcGIS 3D analysis tool.

Result and Discussion

Absolute Relief

It refers to the maximum elevation of any area's morphology which also provides clues to estimate the type and intensity of denudational forces at work (Thakur, 2008). Analysis of absolute relief has been made by calculating the elevation above mean sea level for delineating the heights. Considering the range of elevations, five categories of absolute relief have been identified in the present study (Fig. 2). The range varies from a minimum value of 244 m in the south to a maximum of 1193 m in northeastern part of the watershed. About 47% of the Tangri watershed has an absolute relief less than 300 m. Likewise; about 43% of the watershed is characterized by the height category of 300-500m in moderately low absolute relief category and only a small portion (10%) of the area is at more than 500 m in lower Siwalik and piedmont zone of the watershed. Hence about 90% of the Tangri watershed has low absolute relief which is observed in the alluvium tract along the valley zone in the bottom, in the central and southern part of the watershed (Table and Fig. 2) which indicates the low runoff and high infiltration in this part of watershed.

Relative Relief

It means the difference between the highest and the lowest point in a spatial unit and plays an important role to understand the morphological characteristics of terrain, degree of dissection and denudational characteristics of the watershed, which together control the stream gradient, thereby influencing the flood pattern (Hadley and Schumm, 1961). Relative relief varies significantly in the watershed (Fig. 3). About 87% of the study area has extremely low to moderately low relative relief observed mostly in the whole southern part (Table-3). Moderate and moderately high relative relief together accounts about 8% of the total geographical area which is found in patches in the lower Siwalik ranges and its piedmont zone. The areas of high relative relief coincide with areas of high absolute relief, thereby corresponding to steeper slopes, paleo and neotectonic regimen of the Siwalik hills, and high gravity of water flow and erosion rates.

Relief Ratio

It is defined as the ratio between the total relief of a basin and the longest dimension of the basin parallel to the main drainage line (Schumm 1956). It measures the overall steepness of watershed and also an indicator of the intensity of erosional process operating on the slope of the watershed. There is a straight association between the relief, channel gradient and hydrological characteristics of a watershed. It is found that areas with high relief and steeper slopes are characterized by high value of relief ratios whereas the low value of relief ratio (0.02) in Tangri watershed (Table-1) indicates low potential energy available to move water and sediment down slope per unit length.

Dissection Index

It implies the degree of dissection or vertical erosion and expounds the stages of landscape development in any given physiographic region or watershed (Singh and Dubey 1994). It expresses the relationship between the vertical distance of the relief from the erosional base and relative relief, which is the dynamic potential of the area. Generally the values of dissection index vary between'0' (complete absence of vertical dissection or flat surface) and'1' (vertical cliffs on hill slope or at sea level). Higher the value of dissection index, larger is the undulation and instability of the terrain. The value of dissection index in the Tangri watershed varies from 0.01 to 0.52 (Fig. 4, Table 4). Maximum value of dissection index (0.52) occurs in about 7.14% area spread over Siwaliks and piedmont zone of the watershed. This high value indicates that this area of watershed is highly dissected and characterized by escarpments and steeply sloping divides. About 6% of the watershed comes under moderately dissected category. The remaining 75.56% of the watershed falls in the lower dissection index categories observed in the rich alluvial plain which is indicative of past peneplanation.

Ruggedness Index

It is defined as the product of relative relief and the drainage density and indicates the extent of

Instability of land surface (Strahler, 1957). The watersheds of high flood potentials will have a greater ruggedness index value (Patton and Baker, 1976). About 26% of the Tangri watershed has no ruggedness index value as there is no drainage line in the alluvial plain in southern part of the watershed (Table-5). The value of ruggedness index varies from 0 to 2.79 (Fig. 5). The watershed has 62% of its area below 0.50 category of ruggedness index which may be attributed to gentle slope where discharge rates are less. In the remaining 3% of the Tangri watershed, the higher values of ruggedness index correspond with the Siwaliks and its piedmont zone with inherent structural complexity, implying that these areas are more prone to soil erosion.

Hypsometric Analysis

Hypsometric integral (H_i) indicates the stages of cycle of erosion and is expressed as percentage. It is also an indicator of the remnant of the present volume of material as compared to the original volume of the watershed (Strahler, 1952). Differences in the shape of the curve and the integral value are related to the degree of disequilibria in the balance of erosive and tectonic forces. According to Strahler (1952) convex-up curves with high integrals are typical for youth, s-shaped curves crossing the center of the diagram characterize mature or equilibrium stage, and concave up with low integrals typify old geomorphic stage of landscapes (Fig. 6). For Tangri watershed, the hypsometric data has been derived from the DEM. The value of hypsometric integral for Tangri watershed has been evaluated to be 17%, thereby revealing the mature stage of fluvial cycle and moving towards the peneplanation or the old stage (Fig. 7). Hence, the hydrologic response in terms of runoff and sediment transport goes on at a slower rate, unless there are very high intense storms leading to high runoff peaks.

Slope

Slope is the most important and specific feature of the earth's surface form. Its understanding is fundamental for settlement planning, mechanization of agriculture, deforestation, planning of engineering structures, morpho-conservation practices, etc. (Sreedevi et al. 2005). The slope tool calculates the maximum rate of change in value from each cell to its neighbours (Burrough 1986). The lower slope value indicates the flatness of the terrain and vice-versa. It is evident from the Table 6 that more than three-fourth (78%) area of the Tangri watershed has very gentle slope whereas in counterpart about 5% falls under steep to very steep slope category. The spatial pattern reveals that in Tangri watershed, slope varies from 0□ to 56□ (Fig. 8). The very steep slope in watershed is mainly distributed over the Siwalik and piedmont zone sprawling the northern part of the watershed and characterized by steep escarpment and hills whereas the valley bottoms comprise the low degree of slope. Thus, in Siwalik and piedmont zone, the higher degree of slope facilitates rapid runoff and increased erosion rate with feeble recharge potential, whereas alluvial zone with very low slope reflects slight erosion.

Aspects

An aspect-slope map simultaneously shows the aspect (direction) and degree (steepness) of slope for a terrain. The aspect of slope has a very significant influence on the local climate and distribution of vegetation and bio-diversity of any area (Magesh *et al*, 2011). Fig. 9 shows the color-coded map of the Tangri watershed representing the compass direction of the aspect, 0 is true north; a 90 aspect is to the east, and so forth. Thus the southeast, south and southwest slopes are dominant in the Tangri watershed. As a result, these slopes have a high evaporation rate and are drier supporting poor vegetation cover.

Landscape Profiles

The drawing of a profile from a relief map (DEM) greatly assists in visualizing the relief, and in the description and explanation of the landforms (Monkhouse and Wilinskin, 1967). A planner in particular, seeking to analysis the nature of relief, is interested in surfaces with different slopes for better management of natural resources but contour maps often fail to bring out these significant surfaces. The landscape profiles at regular intervals of space are usefully drawn to understand the changes in topographic pattern of landscape and provide a panoramic view, indicating both the sharpness of relief features and flatness of the valley bottom in a more comprehensible and precise form (Wright, 1949). In the present study the profiles have been drawn across (E-W) and along (N-S) the Tangri watershed's surface at 1km interval (Fig. 10). It is evident from Fig.11 that both superimposed and composite profiles of the watershed, more or less conform to the results obtained by the analysis of relief and hypsometric curves. In southern part of the watershed, profiles barely rise above 400 m while the north-eastern portion has higher elevation i.e. more than 1000 m. The profiles also indicate that in the northern part, small area under the skyline is dominated by sharp hill tops. The surface then continuously grades down through a series of hills to the gentler plain toward south, implying more than one accordant level and existence of probable planation surface. The analysis thus corroborates well with the slope map of watershed, thereby corresponding to high gravity of water flow and high erosion rate in northern tract and vice-versa in remaining part of the watershed.

Longitudinal Profile

The longitudinal course of a river from its source to mouth is called longitudinal profile. It is an erosional curve, which can be used to interpret the surface history and different stages of valley development from source to mouth. The longitudinal profile of Tangri watershed reveals that about 85% length of Tangri river flows through alluvial plain having low to gentle slope (Fig. 12). The present morphology of the main stream is the result of different geomorphic processes with varying intensity indicating that this part of watershed has low relief and velocity of water and not susceptible to erosion.

Conclusion

The relief analysis, ut supra, of the Tangri watershed thus establishes well its significance in water and soil conservation at micro level. The preceding discussion reflects the relationships among the various attributes of the relief aspects of the watershed. The maximum area of watershed falls under 400 m elevation having low runoff and moderate to high infiltration capacity. The lower values of the relief ratio signifies low potential energy available to transport water and sediment down slope per unit length. The analysis of ruggedness and dissection index for the Tangri watershed has been found almost in harmony with each other. The hypsometric analysis of the study reveals that the basin is passing through the old stage of the fluvial geomorphic cycle. The degree of slope in the Tangri watershed is a sign of slight runoff and erosion rates with feeble recharge potential whereas the aspect map, dominated by south-facing slopes, is indicative of low moisture content. The landscape profile analysis corroborates well the slope conditions, thereby corresponding to high gravity of water flow and high erosion rate in northern tract and vice-versa in rest part of the watershed. Longitudinal profile shows that the southern part of the watershed has low relief and less velocity and is not susceptible to erosion. But the heavy precipitation events during monsoon months (July- September) causes a risk of seasonal flood in this part of the watershed which is attributed to the steep slope and fast discharge in mountainous areas of northern part where the intermittent tributaries also allow the surface runoff.

References

1. Ali S. M. (1966): The Problem of Dissection of Ghaggar plain, *The Ind. Geogrl. Journal*, 3: 166-178
2. Asthana V. K. (1967): Morphometric *E*valuation of Landforms in Almora and its environs, *The National Geographical Journal of India*, 13 (1): 37-54
3. Bhardwaj O. P. (1999): The Vedic Saraswati, *Memoir of the Geological Society of India,* 42: 15-24
4. Burrough P. A. (1986): Principles of Geographical Information Systems for Land Resources Assessment. OUP, NY.
5. Esper A. M. Y. (2008): Morphometric Analysis of Conalguil river basin and Flash flood Hazard, San Juan, Argentina, *Environmental Geology*, 55: 107-111
6. Gardiner V (1978): Redundancy and spatial organization of drainage basin form indices, *Transactions of the Institute of British Geographers,* New Series 3: 416-431

7. Gregory K. J. (1978): Fluvial Processes in British Basins, in: C. Embleton, D, Brunsden and D.K.C. Jones (ed) Geomorphology - present problems and future prospects. OUP, NY, pp 40-72
8. Hadley R. F. and Schumm S. A. (1961): Sediment Sources and Drainage Basin Characteristics in Upper Cheyenne River Basin, *USGS Water-Supply Paper*, 1531-B, p 198
9. Horton R. E. (1945): Erosional Development of Streams and their Drainage Basins: hydrophysical approach to quantitative morphology, *Geological Society of American Bulletin*, 56: 275 -370
10. ISPER (2010): Ghaggar: Studies to revive a Vedic river, Part 1, Chandika Press, Chandigarh
11. Kharkwal SC (1968): Classification of Kumaon Himalayas into Morphounits, *The National Geographical Journal of India*, 14 (4): 223-238
12. Lotspeich F. B. and Platts W. S. (1982): An Integrated Land-aquatic Classification System, *North American Journal of Fisheries Management*, 2: 138-149
13. Magesh N.S., Chandrasekar N and Soundranayagam J. P. (2011): Morphometric Evaluation of Papanasam and Manimuthar Watersheds: Parts of Western Ghats, Tirunelveli district, Tamil Nadu, India: a GIS approach, *Environ Earth Science*, 64: 373 - 381
14. Mather P and Doornkamp J. C. (1970): Multivariate Analysis inGgeography with particular reference to Drainage Basin Morphometry, *Transaction of the Institute of British Geographers*, 51: 163-187
15. Monkhouse F. J. and Wilkinson H. R. (1967): Maps and Diagram: their compilation and construction, 3rd Ed., Methuen and Co. Ltd., London
10. Patel P. P. and Sarkar A (2010): Terrain Characterization using SRTM Data, *Journal of the Indian Society of Remote Sensing*, 38 (1), March 2010, pp11- 24.
11. Patton P. C. and Baker V. R. (1976): Morphometry and Floods in Small Drainage Basins, *Water Resource Research*, 12: 941-952
12. Schumm S. A. (1956): Evolution of Drainage Systems and Slopes in Badlands at Perth Amboy, New Jersey, *Geological Society of American Bulletin*, 67: 597 - 646
13. Singh S and Dubey A (1994): Geo-environmental Planning of Watershed in India, Chugh Publications, Allahabad, India. pp 28-69
14. Singhal K. K. and Jhingran V (1991): Morpho-statistical Study of Drainage in Alaknanda River Basin, Kumaon Himmalaya, U. P., *The National Geographical Journal of India*, 37(3): 253-262
15. Singh S (2007): Geomorphology, 5TH revised edition, Prayag Pustak Bhawan, Allahabad, India
16. Singh S and Singh MB (1997): Morphometric Analysis of Kanhar River Basin, *National Geographical Journal of India*, 43(1): 31-43
17. Singh C. P. and Sinha N. P. K. (1996): Analysis of Relief of South Mirzapur Upland, U.P, India, *The National Geographical Journal of India*, 42(3, 4): 267-280
18. Sreedevi P. D, Subrahmanyam K and Shakeel A (2005): The Significance of Morphometric Analysis for obtaining Groundwater Potential Zones in a Structurally Controlled Terrain, *Journal of Environmental Geology*, 47(3): 412 - 420
19. Strahler A. N. (1952): Hypsometric (area-altitude) Analysis of Erosional Topography, *Geological Society of American Bulletin*, 63: 1117-1142
20. Strahler A. N. (1957): Quantitative Analysis of Watershed Geomorphology, *Transaction of American Geophysics Union*, 38: 913 - 920
21. Strahler A. N. (1964): Quantative Geomorphology of Drainage Basins and Channel Networks, in: Ven Te Chow (ed) Hand book of Applied Hydrology. McGraw Hill Book Company, New York
22. Surajbhan (1973): Changes in the Course of the Yamuna and their Bearing on the Prehistoric Cultures of Haryana, in: SB Deo (ed) Archaeological Congress and Seminar Papers, Nagpur, pp 125-128
23. Thakur B. R. (2005): Morphometric Analysis of Solani Watershed using Remote Sensing and GIS techniques, Unpublished Project Report for PG Diploma in RS and GIS. IIRS, Dehradun
24. Thakur B. R. (2008): Relief Analysis of Solani Watershed using Remote Sensing and GIS Technology, *Punjab Geographers*, 4: 26-36

25. Wright JW (1949): The White Nile Flood plain and the Effect of proposed Control Schemes, *Geographical Journal*, 114: 173 -190

Table – 1: Parameters used for the Computation of Relief Aspects of Tangri Watershed

Parameters	Formula/ Description	References	Computed Values
Absolute Relief (R_a)	Highest elevation in a Areal Unit	-	-
Relative Relief (R_h)	$R_h = (H\text{-}h)$ Where, R_h = Relative relief of the watershed H = Maximum elevation of the watershed h = Minimum elevation of the watershed	Hadley and Schumm (1961)	949 m
Relief Ratio (R_r)	$R_r = R_h/L_b$ Where, R_r = Relief ratio R_h = Relative relief of the watershed L_b = Watershed length	Schumm (1956)	0.02
Dissection Index (D_i)	$D_i = R_h/R_a$ Where, D_i = Dissection index R_h = Relative relief of the watershed R_a = Absolute relief	Pal *et al.* (2011)	0.79
Ruggedness Index (R_i)	$R_i = R_h{*}D_d/1000$ Where, R_n = Ruggedness index R_h = Relative relief of the watershed D_d = Drainage density	Schumm (1956)	1.40
Hypsometric Integral (H_i)	$H_i = (h/H)/(a/A)$ Where, H_i = Hypsometric integral (h/H) = Ratio of relative height (a/A) = Ratio of relative area	Strahler (1952)	17.0%
Superimposed Profile	Plot of Serial Profiles in single frame	Wright (1949)	-
Composite Profile	Highest parts of series of parallel profiles	Shaffer (1947)	-
Longitudinal Profile	Longitudinal Course of the river	Monkhouse and Wilkinson (1967)	-
Slope	Average Slope in degree	Wentworth (1930)	0°-56°
Aspect	Direction of Slope	Moellering and Kimerling (1990)	-

Source: Computed by the author

Table – 2: Distribution of Absolute Relief in Tangri Watershed

Range of Elevation (m)	Area (km^2)	Area (%)	Attribute
<300	308.50	47.01	Low
300-500	279.85	42.64	Moderately Low
500-700	37.39	5.70	Moderate
700-900	17.13	2.61	Moderately High
> 900	13.38	2.04	High
Total	656.24	100.00	

Source: Computed by the author

Table – 3: Distribution of Relative Relief in Tangri Watershed

Range of Relative Relief (m)	Area (km^2)	Area (%)	Attribute
< 100	536.19	81.71	Low
100-200	36.94	5.63	Moderately Low
200-300	28.74	4.38	Moderate
300-400	23.64	3.60	Moderately High
> 400	30.73	4.68	High

Source: Computed by the author

Table – 4: Distribution of Dissection Index in Tangri Watershed

Range of Dissection Index	Area (km^2)	Area (%)	Attribute
< 0.10	495.86	75.56	Low
0.11-0.20	36.74	5.60	Moderately Low
0.21-0.30	38.84	5.92	Moderate
0.31-0.40	37.98	5.79	Moderately High
> 0.40	46.82	7.14	High

Source: Computed by the author

Table – 5: Distribution of Ruggedness Index in Tangri Watershed

Range of Ruggedness Index	Area (km^2)	Area (%)	Attribute
NA	171.19	26.09	Low
< 0.50	405.32	61.76	Moderately Low
0.50 – 1.00	37.66	5.74	Moderate
1.00-1.50	22.57	3.44	Moderately High
> 1.50	19.50	2.97	High

Source: Computed by the author

Table – 6: Distribution of Average Slope in Tangri Watershed

Slope category (degree)	Area (km^2)	Area (%)	Attribute
< 10	511.74	77.98	Very Gentle
11-20	67.85	10.34	Gentle
21-30	45.35	6.91	Moderate
31-40	30.28	4.61	Steep
> 40	1.02	0.16	Very Steep

Source: Computed by the author

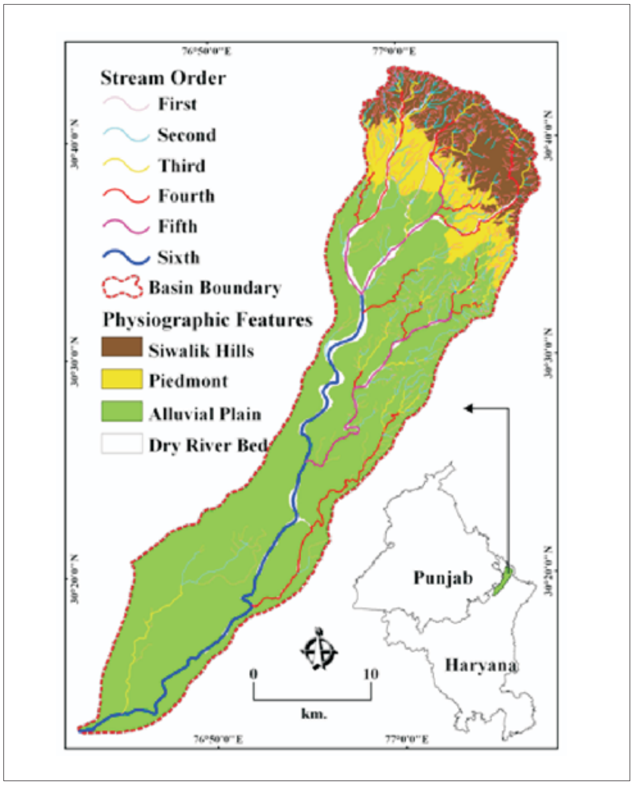

Fig. 1: Location of Tangri Watershed and its Geomorphological Features

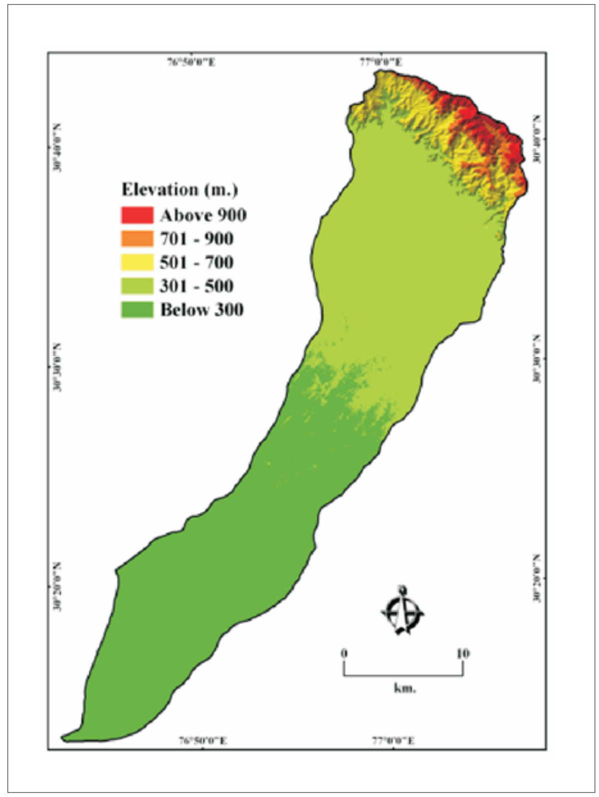

Fig. 2 Absolute Relief of Tangri Watershed

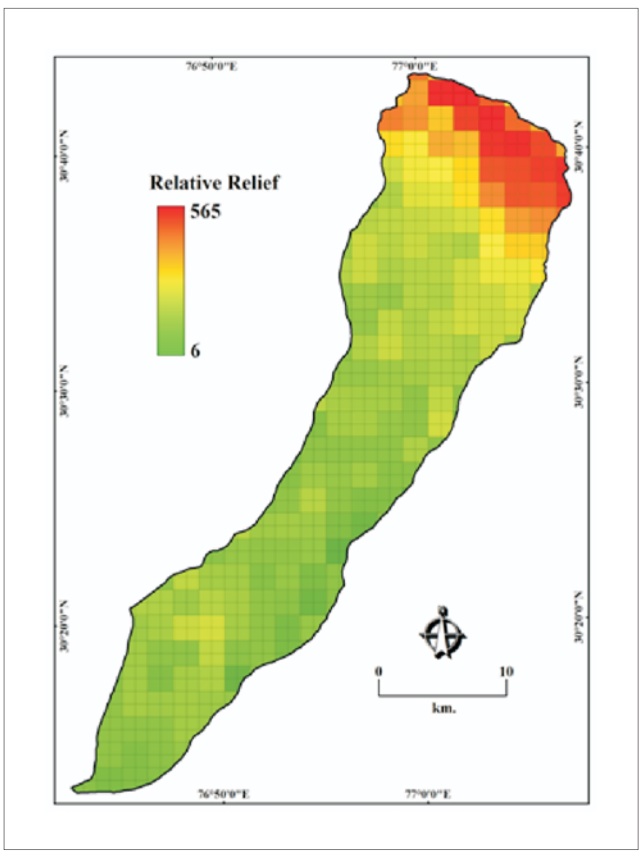

Fig. 3: Relative Relief of Tangri Watershed

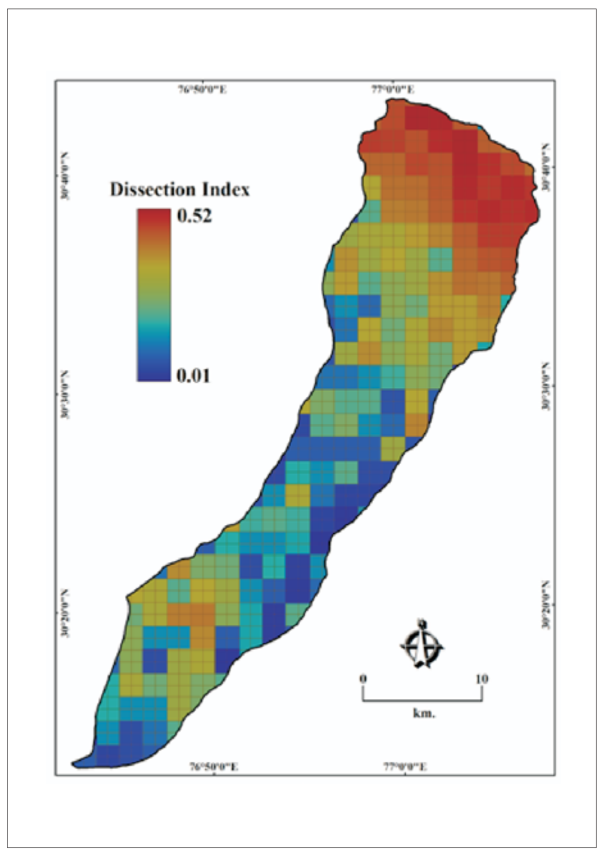

Fig.4. Dissection Index of Tangri Watershed

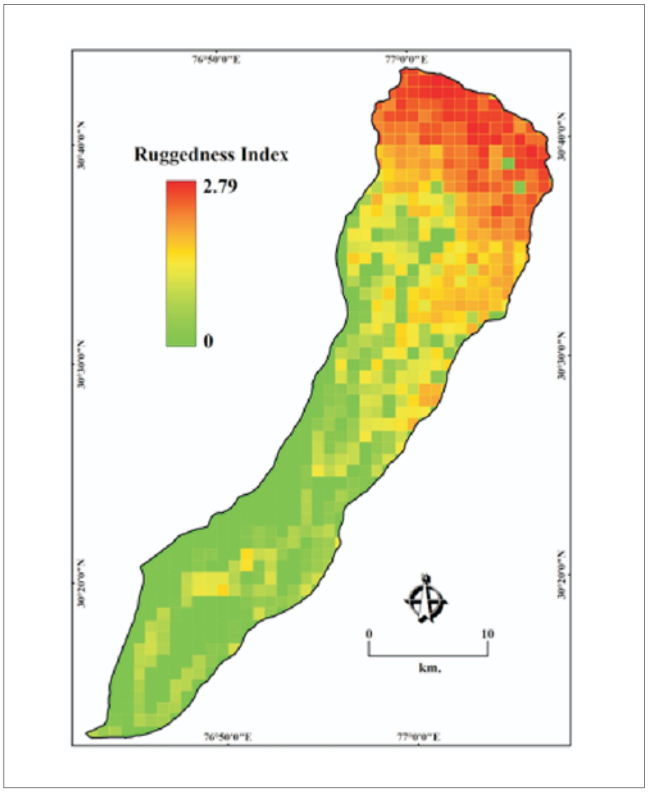

Fig. 5. Ruggedness Index of Tangri Watershed

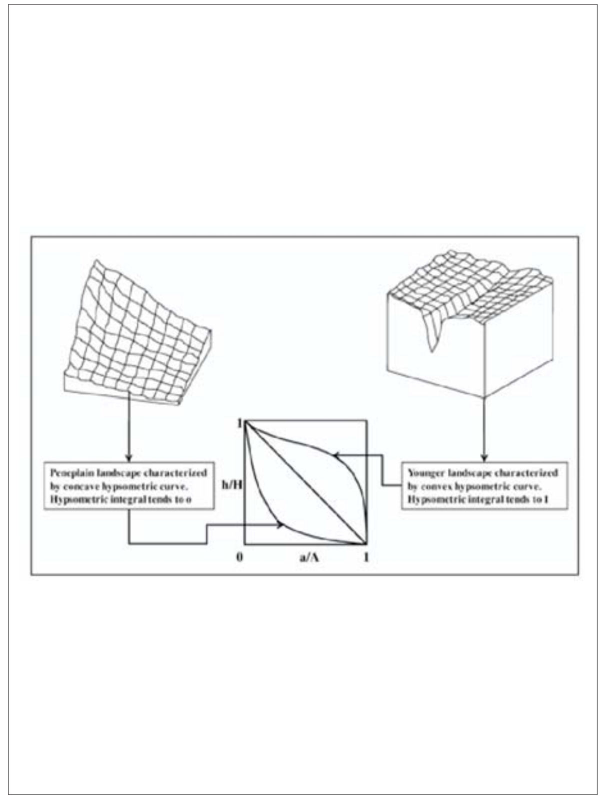

Fig. 6. Watershed Morphology and HI

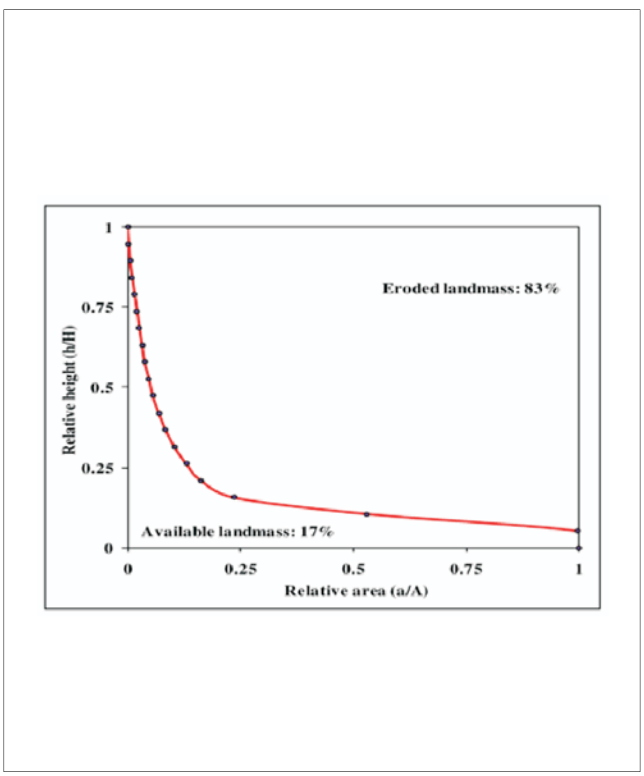

Fig. 7. Hypsometric Curve of Tangri Watershed

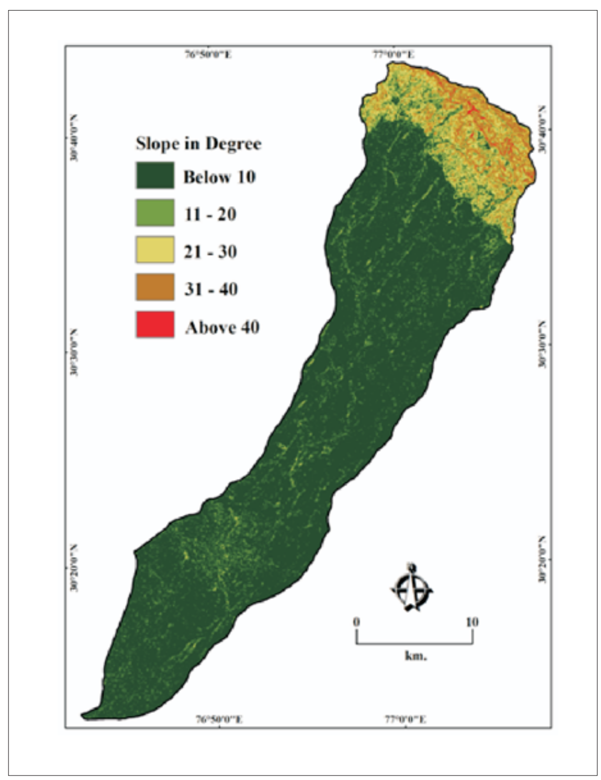

Fig. 8. Slope Map of Tangri Watershed

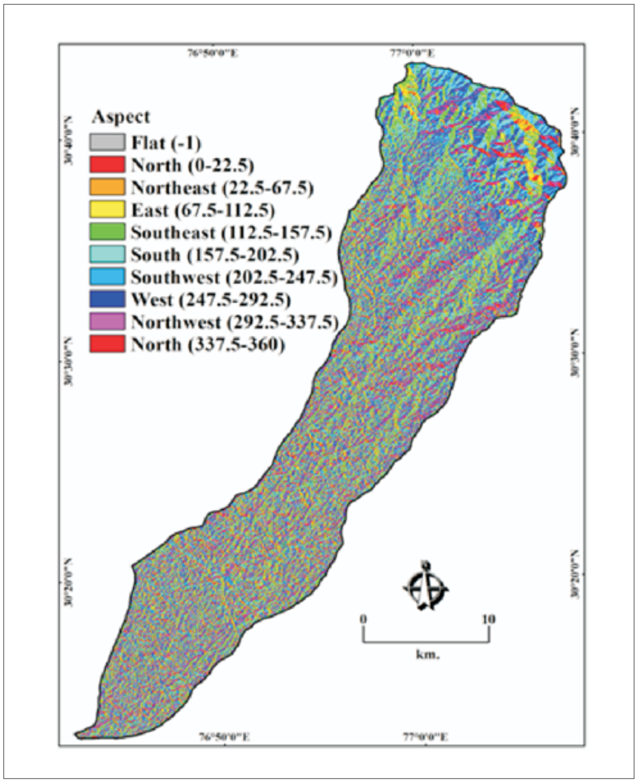

Fig. 9. Aspect Map of Tangri Watershed

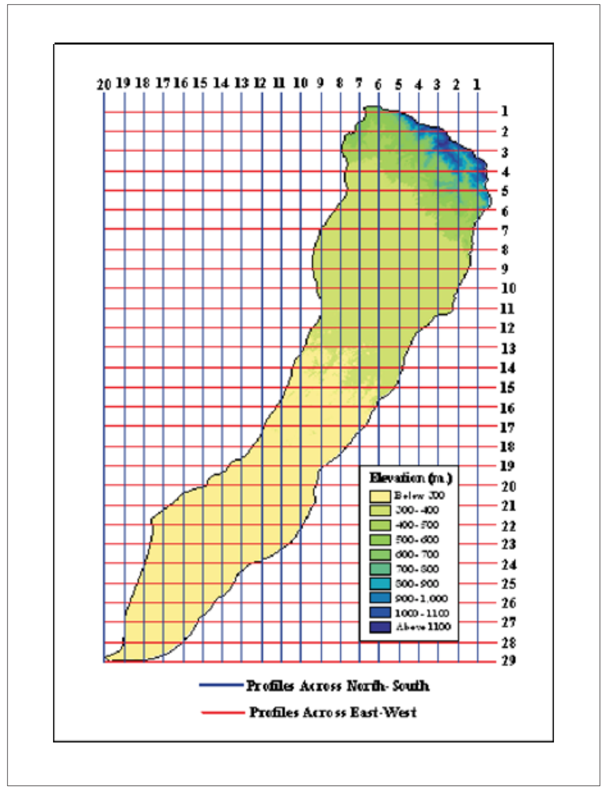

Fig.10. Plan of Profile Lines of Tangri Watershed

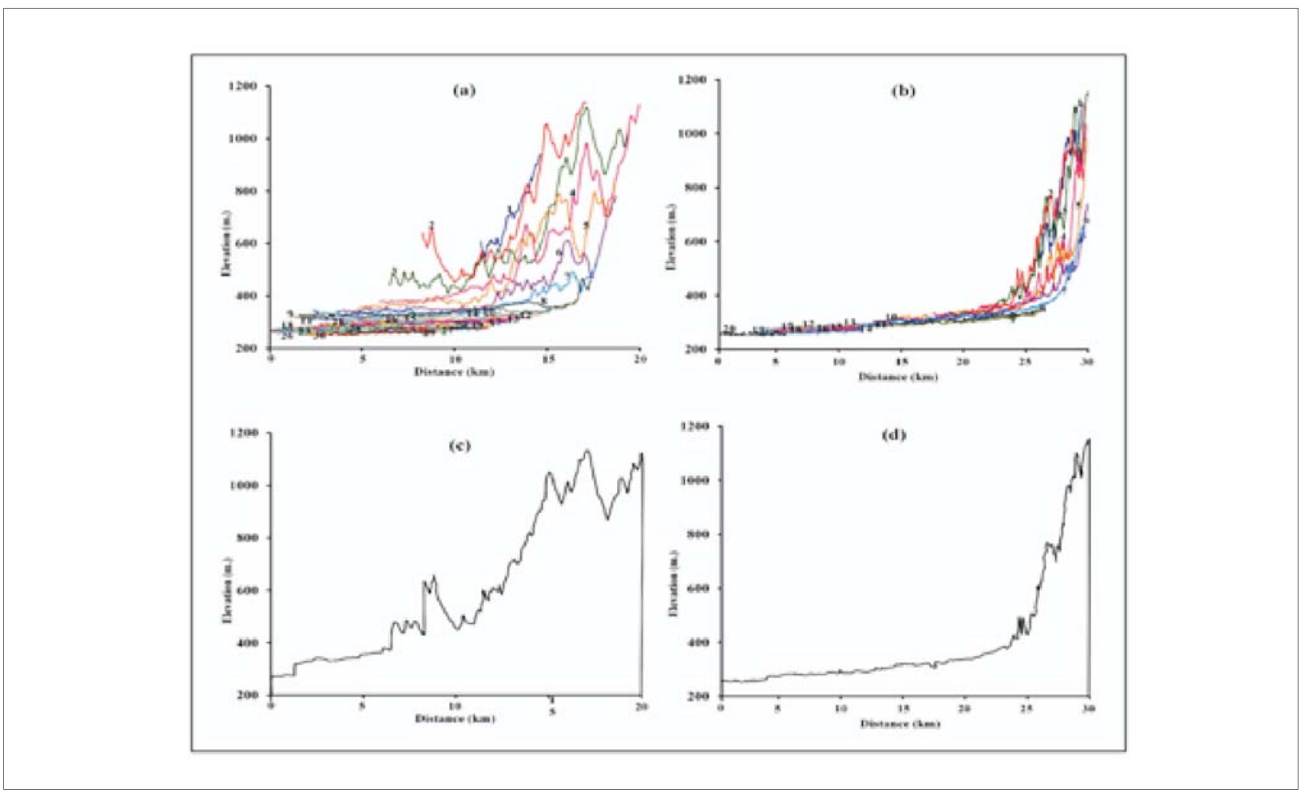

Fig.11. Landscape Profiles of Tangri R.

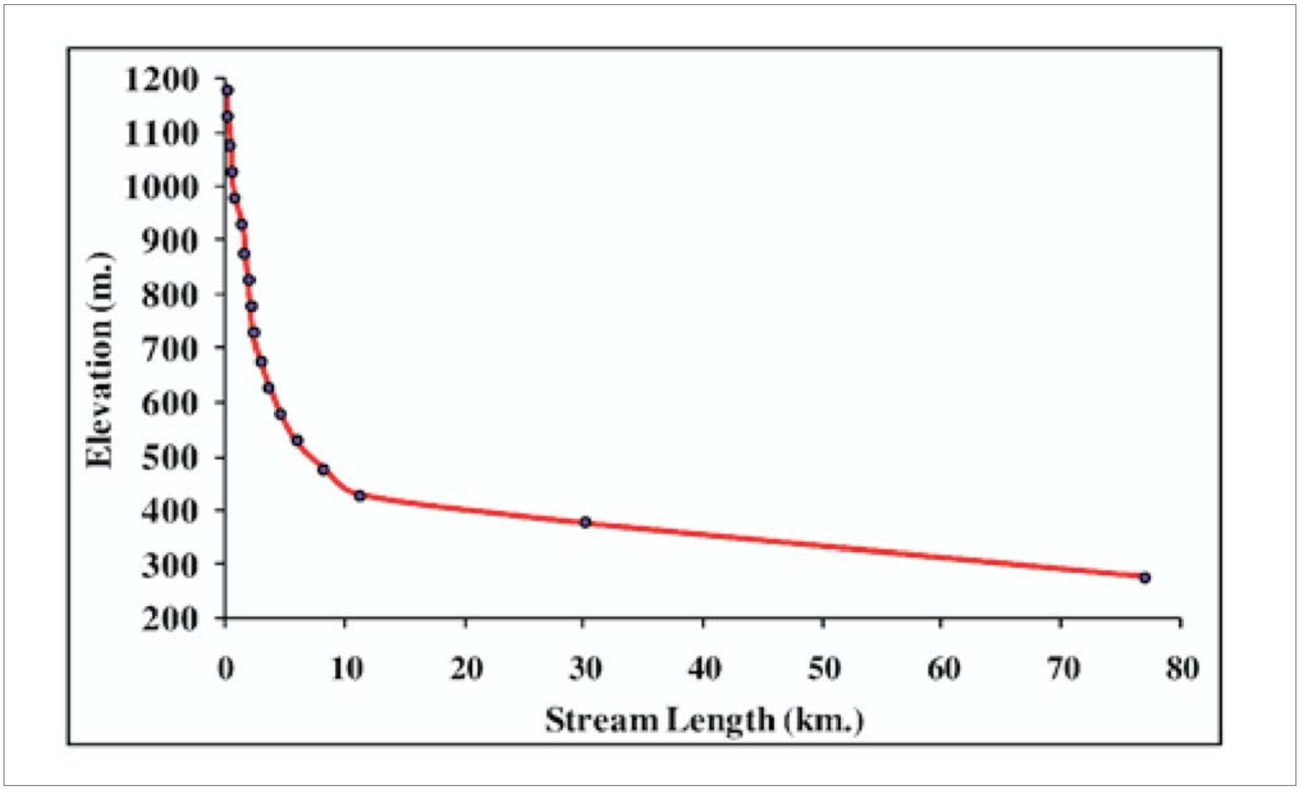

Fig. 12. Longitudinal Profile of Tangri River

Tejpal
Research Scholar, Department of Geography, Kurukshetra University, Kurukshetra-136119, India.
Email: tpjangid@gmail.com