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MORPHOMETRIC ANALYSIS OF BHIRAL KHAD SUB –WATERSHED OF PALAMPUR AREA OF HIMACHAL PRADESH BY USING REMOTE SENSING AND GIS TECHNIQUES

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ABSTRACT

In present study the morphometric analysis of Bhiral Khad Sub Watershed of Palampur area of Himachal Pradesh by using remote sensing and GIS Techniques. Detailed drainage map is prepared from SOI toposheets. This drainage map is used for the morphometric analysis the watershed. Geographical Information System (GIS) has proved to be an efficient tool in delineation of drainage pattern and water resources management and its planning. GIS techniques are adopted for the identification and analysis of morphological features. The basin morphometric parameters such as linear and aerial aspects of the sub watershed were determined and computed. Majority of the areas have low relief, high permeability indicating sparse drainage network which favours ground water recharge. These areas have softer and more permeable rock formation, low surface runoff and hence are less prone to soil erosion. The structural disturbances have not distorted the drainage pattern in the region. The areas are elongated and the drainage pattern is mostly parallel type. The drainage density is mostly moderate to low. Low drainage density is a prima facie evidence of youth. Hence the area has highly permeable subsoil material under dense vegetative cover and low relief. It leads to coarse drainage texture allowing for longer residence time and slow response time to runoff. The Moderate drainage density indicates the basin has highly permeable subsoil and vegetative cover indicating good ground water potential areas.A1, A2, A3, A5 have a positive correlation in the watershed indicating increase in stream population with respect to increase in drainage density. The stream frequency is high in micro watersheds (A1, A2) indicating impermeable subsurface material, sparse vegetation, high relief and low infiltration capacity of bedrock. Micro watershedsA5 and A6 show high value. A1 shows moderate value of 0.398 whereas A2 and A3 show the low values. The basins with low value have quicker surface runoff and leads to the development of the high drainage density. It is seen that the bifurcation ratio of 1st and 2nd order stream is higher than the other ratio. The bifurcation ratio of the lower order shows a higher value. This reflects the high dissection in the upland area. The higher Bifurcation ratio suggests that the area is tectonically active. It indicates there may be some structural distortion in that basin area. Lower values have less structural disturbances. Higher values strong structural control. Moderate values indicate drainage pattern is not largely affected by structural disturbances.

INTRODUCTION

Morphometry is defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimension of its landforms (Clarke, 1966). Morphometric methods, though simple, have been applied for the analysis of area-height relationships, determination of erosion surfaces, slopes, relative relief and terrain characteristics, river basin evaluation, and watershed prioritization for soil and water conservation activities in river basins (Kanth, 2012). The morphometric analyses of different basins have been done by various scientists using conventional methods (Horton, 1945; Smith, 1950; Strahler, 1957, Melton, 1958, Pakhmode, *et al.,* 2003, Kumar, Mallick *et. al.,* 2012, Kumar, Parveen and Mallick, 2012; Parveen and Kumar, 2012. and Gangalakunta, GIS generated more precise data on morphometric parameters (Srivastava, 1997, Agarwal, 1998, Nag, 1998, Das and Mukherjee, 2005) and earth observation data and GIS methods (Narendra and Rao, 2006). The use of GIS technique in morphometric analysis has emerged as a

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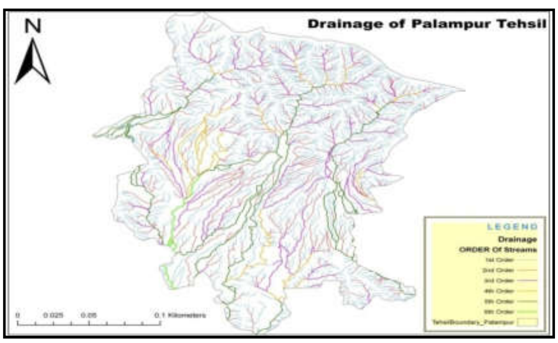
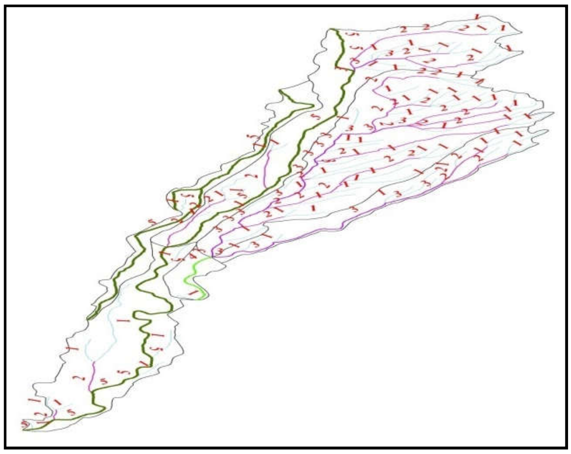
powerful tool in recent years particularly for watershed and remote areas with limited access. A watershed is a natural geo-hydrological unit of land, which collects water and drains it through a common point by system of streams. Obtaining information related to watersheds require delineation of the drainage system, which includes the stream channel network and smaller catchments within the basin. In addition, every watershed can be characterized by geometric properties related to its linear, areal and relief properties. It is a natural convergent mechanism which consists of a network/ branch of streamlets converging into a major stream. Studies of morphometry and hydrologic analysis on different watersheds have been carried out in many parts of the world. Relief and climate are the key determinants of running water ecosystems functioning at the basin scale (Lotspeich and Platts 1982, Frissel *et al*. 1986). These properties are related to the position of a stream within the watershed, and can be used to compare watersheds. GIS technology has been used in this study of watershed sciences, to delineate the drainage watersheds and drainage network of Palampur area of Kangra district in Himachal Pradesh, India.

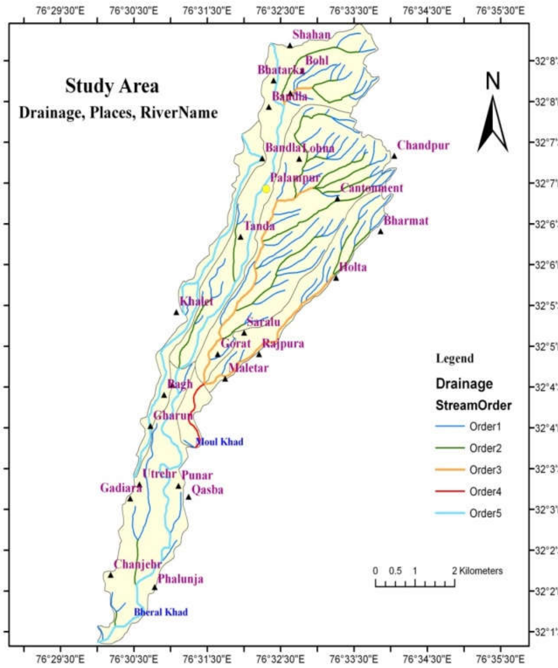
The present paper describes the drainage characteristics of Bhiral Khad Sub Watershed of Palampur district Kangra of Himachal Pradesh obtained through GIS based morphometric analysis. It is felt that the study will be useful to understand hydrological behaviour of watershed. This study depicts the process to evaluate the various morphometric parameters of Bhiral Khad Sub Watershed using Geographic Information Systems (GIS) techniques various morphometric parameters such as drainage pattern, stream order, bifurcation ratio, drainage density and other linear aspects are studied using Geographic Information Systems (GIS) techniques by Arc Map version 9.3software.

Study Area

The micro watersheds of drainages in the vicinity of Palampur city were targeted for drainage morphometric analysis. The study area falls in the Survey of India toposheet number 52d12 on a scale of 1:50,000. The study area lies between latitudes 31^{o}57'36" N to 32^{o}17'38.4" N and longitude 76 ° 24' 14.4" E to 76^o 39' 36" E in the Kangra district of HP and it covers a geographical area of 27 km^2. The altitude varies from 777 m to 2200 m, average temperature is 19.1 °C and average rainfall: 2500 mm. Palampur is surrounded by tea gardens, pine forests and Dhauladhar ranges and is called the Tea capital of NorthWest India.







Map of Study Area

METHODOLOGY

The remotely sensed data coupled with topographical data analysis procedures have made satellite sensor data based morphometric analysis a highly effective tool to understand and manage the natural resources. Integration of remotely sensed data and GIS provides an efficient way in analysis of morphometric parameters and landform characteristics for resource evaluation, analysis and management. The drainage have been delineated using Cartosat DEM satellite data on 1:50,000 scale and SOI toposheets have been used as a ground reference. The study area has been divided into six Micro watersheds (Fig.2) that ranges in size from **0.684** km^2 to **9.063** km^2. The associated drainage networks were digitized using ArcGIS and the stream orders were calculated using the method proposed by Strahler (1964).

Parameter	Definition & Formula	Consequences
Bifurcation Ratio (Rb)	• **Computed as the ratio between the number of streams of any given order to the number of streams in the next higher order.** **Rb = Nu / Nu+1** Where Nu=Number of stream segments present in the given order , Nu+1= Number of segments of the next higher order	Ranges from **3.0 to 5.0** • **2 :** flat or rolling • **3 or 4:** for mountainous or highly dissected drainage basins •The **higher** bifurcation ratio indicates there may be some structural distortion in that basin area; also **elongated** shape of basin. It also indicates **high structural complexity ,low permeability** and high average **flood potential.** • **Lower** value suggests drainage pattern has **not been distorted** and watersheds have suffered **less structural disturbances**
Relief (H)	• **Difference in the elevation between the highest point of a watershed and the lowest point on the valley floor** • **Relief plays an important role for computing surface and sub-surface water flow, permeability, landform development** **H = Maxi Elevation - Mini Elevation**	• **High** value indicates the gravity of water flow, **low infiltration** and **high runoff** conditions. • **Low** relief is associated with **low drainage density** High Relief **> =400m** Moderate **>300 and < 400m** Low Relief < **300m**
Relief Ratio (Rh)	**Ratio between the total relief of a basin and the longest dimension of the basin parallel to the main drainage line.** **Rh = Bh / Lb** Where Bh=Basin relief Lb=Basin length	•**High value** indicates the gravity of water flow, **low infiltration** and **high runoff** conditions. • **Low value** of relief ratios are mainly due to the **resistant** basement rocks of the basin and **low degree of slope**

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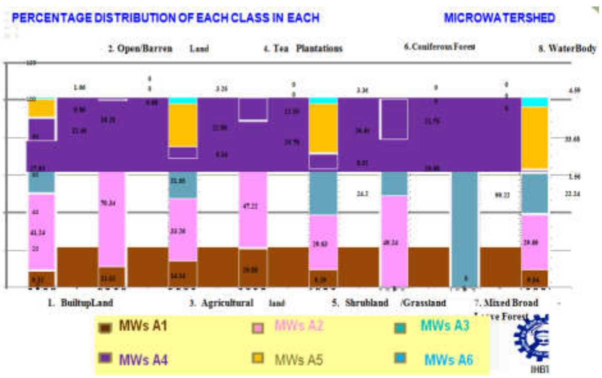
Parameter	Definition & Formula	Consequences
Ruggedness number (R)	• Ruggedness number combines the qualities of slope steepness and length • It indicates the structural complexity of the terrain R = Bh×Dd Where Bh= Basin relief Dd=Drainage density	• **High values** reflect that the areas are highly susceptible to erosion. • Higher ground slopes specify lower time of concentration of overland flow and possibility of soil erosion is higher
Form Factor (Rf)	• Ratio of basin area to square of the basin length. T • The value of form factor is generally less than 0.754 (for a perfectly circular watershed). • The smaller the value of form factor, more elongated will be the watershed. $Rf = A/(Lb)^2$ Where A=Area of basin, Lb=Basin length	• Smaller the value of form factor, more elongated will be the watershed. • **Low** (form factor) Rf has **less side flow** for shorter duration and **high main flow** for longer duration. •**High** (form factor) Rf, **high side flow** for longer duration and **low main flow** for shorter duration causing **high peak flows** in a shorter duration
Circularity Ratio (Rc)	• Ratio of watershed area to the area of a circle having the same perimeter as the watershed. $Rc=(4*3.14*A)/P^2$ Where A=Area of basin, P= Perimeter of the basin	• **0** (line)-**1**(circle) • **0.4 to 0.5** :elongated and highly permeable homogenous geologic materials. • **(0.60):** basin is rectangular, high relief and drainage system is structurally controlled

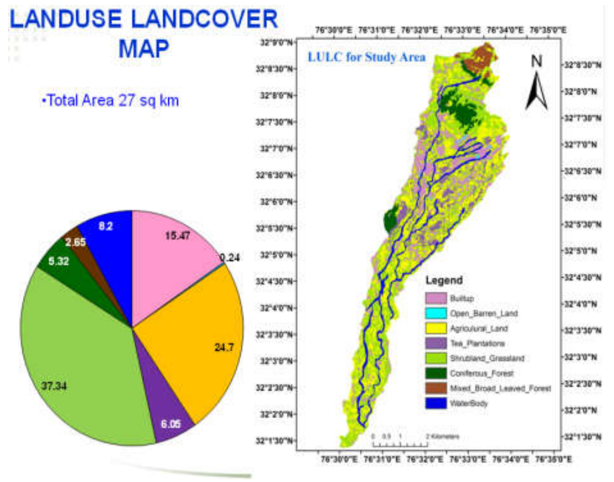
Parameter	Definition & Formula	Consequences
Elongation Ratio (Re)	• **Ratio of circle of the same area as the basin to the maximum basin length** **Re = 2√(A/Pi)/Lb** Where A=Area of basin, Pi = 3.14 Lb=Basin length	• **0** (in highly elongated shape) to **1** (in the circular shape) • **0 - 0.6** indicate roundity and low degree of integration within a basin • **0.8-0.7**: Less elongated indicate moderate to slightly steep ground slope and area • **0.9-0.8:** Oval • **>0.9 Circular** : more efficient in run-off discharge than an elongated basin • **Unity(1)** correspond typically to regions of low relief.
Length of Overland Flow (Lg)	• **It is the length of water over the ground surface before it gets concentrated into definite stream channel.** **Lg= ½ * Dd** Where Dd = Drainage density	• Its values range between **0.1-0.6** • **More** the value represents **long time** of flow in the basin which is **elongated** and has a high length of course. • The basins with **low value** have **quicker surface runoff** and leads to the development of the high drainage density.
Texture Ratio (T)	•**It is the relative spacing of drainage lines.** **T = N1/P** Where N1=Total number of first order stream, P=Perimeter of basin	• Indicates **infiltration capacity** • **High texture ratio** means **lower** infiltration capacity **higher** runoff • **Low texture ratio** means **low** surface runoff

RESULT

For calculating the landuse pattern of 2015, LANDSAT image and toposheets are used. Total eight categories are identified in the 2015 map. Some of the salient features are:

The grassland/shrub land occupies 37.34 percent of the total area. They are intermingled with forest and agriculture land The forest cover is 7.97 percent of the total area out of which 5.32 percent is Coniferous forest (Main species: *Pinus roxburgii*) and 2.65 percent is mixed broad-leaved forests (Main species: *Quercus leucotrichophora* and *Rhododendron arboreum*). The Mixed broad-leaved forests in the Birni area that lies in the micro watershed A3 is dominated by *Quercus leucotrichophora* and holds the recharge zone (or high infiltration zone) for Bohal springs. The Bohal natural water springs cater to the drinking water requirements of nearly 5,000 residents and 10,000 daily floating population in Palampur. Agricultural land is 24.7 percent and Tea plantation covers 6.05 percent of entire area. The Rabbi crops are generally grown during January to March, while Kharif crop is cultivated in the month of September in this region. Wheat, rice and maize are main crops grown in study area, whereas oilseeds, fruits and vegetable crops are non-food grain crops of the study area. The study area is mainly drained by perennial and snow-fed water body. The micro watersheds A1, A2 and A6 are fed by Moul Khad whereas Bhiral Nala feeds the micro watersheds A3 and A5. Chauki Nala feeds micro watershed A4. The water body in the study area covers 8.2 percent of the area.





The linear, areal and relief morphometric parameters and their values for the targeted study area are given in the table below: The size of the entire area of interest is 27 km^2. The results of drainage morphometric analysis showed that the total number of streams in the area is 103 where the highest order was 5^{th} order. The study area is characterized by parallel drainage pattern. Parallel patterns form where there is pronounced slope to the surface leading to a situation where tributary streams tend to stretch out in parallel like fashion following the slope of the surface.

Linear Morphometric Parameters		*Areal Morphometric Parameter*		*Relief Morphometric Parameters*	
Stream Order (SO)	Upto 5^{th} order	Drainage Density (D)	4.2	Relief (H)	1423m
Bifurcation Ratio (Rb)	3.34	Drainage Texture (Rt)	2.71	Ruggedness Number (Rn)	5.98
Stream Length (Lc) (kilometr)	113.36	Circulatory Ratio (Rc)	0.00016	Relief Ratio	0.094
Mean Stream Length (Lcm)	1^{st} : 628.22 2^{nd} : 1406.7 3^{rd} : 1586.9 4^{th} : 6815.8 5^{th} : 13329.6	Elongation Ratio (Re)	0.014		
Stream Frequency	3.82	Form Factor Ratio (Rf)	0.0005		
Stream Number	1st : 79 2nd : 17 3rd : 4 4th : 1 5th : 2	Length of Overland Flow (Lf)	0.48		
		Texture Ratio (T)	2.07		

Majority of the areas have low relief, high permeability indicating sparse drainage network which favors ground water recharge. These areas have softer and more permeable rock formation, low surface runoff and hence are less prone to soil erosion**.** The structural disturbances have not distorted the drainage pattern in the region. The areas are elongated and the drainage pattern is mostly parallel type. The drainage density is mostly moderate to low. Low drainage density is a prima facie evidence of youth. Hence the area has highly permeable subsoil material under dense vegetative cover and low relief. It leads to coarse drainage texture allowing for longer residence time and slow response time to runoff. The Moderate drainage density indicates the basin has highly permeable subsoil and vegetative cover indicating good ground water potential areas. The low values of drainage texture indicate high hydrological potential zone with low surface runoff.

Stream Frequency and Drainage Density: A1, A2, A3, A5 have a positive correlation in the watershed indicating increase in stream population with respect to increase in drainage density. The stream frequency is high in micro watersheds (A1, A2) indicating impermeable subsurface material, sparse vegetation, high relief and low infiltration capacity of bedrock. The low values in micro watersheds (A3, A4, A5 and A6) indicate low relief and high permeability, sparse vegetation, drainage network favoring ground water recharge.

Drainage Density and Drainage Texture: All micro watersheds except A2 show very coarse drainage texture indicating softer and more permeable rock formation. A2 has coarse texture indicates moderate drainage texture. No micro watershed has a higher value which indicates no area has hard rock lithology.

Texture Ratio: All micro watersheds show very low values of texture ratio. Thus have low surface runoff. Micro watershed A2 comparatively has higher value than other micro watersheds thus the chances of erosion are more in this area as compared to others.

Length of Overland Flow: Micro watershedsA5 and A6 show high value. A1 shows moderate value of 0.398 whereas A2 and A3 show the low values. The basins with low value have quicker surface runoff and leads to the development of the high drainage density.

Elongation Ratio: Low values **(0.08-0.3)** indicate highly elongated areas. These are less efficient in run-off discharge than a circular basin (higher values). These have low degree of integration within the basin. Due to low elongation ratio the area is indicated to have high relief and steep slope.

Circularity Ratio: The circularity ratio

0.01: which indicates that the basin is oval/pear shape tending towards elongation with high level of integration.
0.2-0.3 : Micro watersheds are mostly elongated.
0.4-0.5: strongly elongated, extremely permeable homogenous geologic materials.

High value: maturity stage of topography.
In micro watersheds (A1 to A5) the values range from **0.08-0.3**: The values indicate that the areas are elongated and have high level of integration.

Form Factor*:* The elongated basin with low form factor indicates that the basin will have a flatter peak of flow for longer duration. Flood flows of such elongated basins are easier to manage than of the circular basin. The micro watersheds (A1-A6) have low values.

Ruggedness Ratio: The A1,A4,A5,A6 basins show a low value of ruggedness number, A2 basins shows a moderate value whereas the A3 basins shows a high value of ruggedness number. Low values imply area is less prone to soil erosion; has integral structural complexity with respect to drainage density and relief .Higher ground slopes specify lower time of concentration of overland flow and possibility of soil erosion is higher.

Bifurcation Ratio: It is seen that the bifurcation ratio of 1st and 2nd order stream is higher than the other ratio. The bifurcation ratio of the lower order shows a higher value. This reflects the high dissection in the upland area. The higher Bifurcation ratio suggests that the area is tectonically active. It indicates there may be some structural distortion in that basin area. Lower values have less structural disturbances. Higher values strong structural control. Moderate values indicate drainage pattern is not largely affected by structural disturbances.

Relief: The high values indicate steep slope and high relief as indicated by areas A2 and A3. Increasing relief is associated with increasing stream densities .High value indicates the gravity of water flow, low infiltration and high runoff conditions. As the Micro watersheds have low to moderate relief, it indicates presence of lower degree of slope. The areas A1, A4, A5 and A6 have low and moderate values of relief having lower degree of slope. Low relief is associated with low drainage density.

Relief ratio*:* The low relief ratio is due to high erodibility of rock type. The areas with low to moderate relief and slope have: moderate values of relief ratios. Low value: resistant basement rocks and lower degree of slope. Higher values indicate steep slope and high relief.

Recommendations

- The drainage morphopmetric analysis carried out in this study provided soil erosion potential, flooding possibilities during peak flow, ground water recharge conditions and terrain characteristics of different micro-watersheds in the study area. The result obtained in this study can further be analyzed in conjunction with land use land cover, soil and geology of the study area.
- The protective conservation measures can be taken in the vulnerable areas identified through this study.
- The groundwater potential mapping and soil erosion susceptibility maps of micro-watersheds can be prepared using geo-spatial techniques.
- Field surveys can be conducted to validate the results and to correlate the outcomes of the present morphometric analysis with the actual ground conditions.

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