# Watershed Characterization and Prioritization using Geomatics Technology for Natural Resources Management

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**Abstract:** ***Watershed management is the process of formulating and carrying out a course of action involving manipulation of natural system of a watershed to achieve specified objectives. This implies the proper use of land and water resources of watershed for optimum production with minimum hazard to natural resources. Remote sensing and GIS techniques have emerged as powerful tools for watershed management programmes. The quantitative analysis of drainage system is an important aspect of characterization of watersheds. Morphometry ismeasurement and mathematical analysis of landforms. The present study is an attempt to evaluate the drainage morphometrics of Getalsud region using Remote Sensing and GIS approach. The low values of bifurcation ratio and drainage densitysuggest that the area has not been much affected by structural disturbances. The study reveals that the different geomorphic units in the study area i.e. Structuralhills, Pediments, Valley fills, Pedi plains formed under the influence of permeable geology, are moderate on early level plains, with medium to low drainage density(<2.0) & low cumulative length of higher order streams. Such studies can be of immense help in planning and management of river basins.***

## 1. Introduction

A watershed is an area covering all the land that contributes runoff water to a common point. It is a naturalphysiographic or ecological unit composed of interrelated parts and function. Each watershed has definitecharacteristics such as size, shape, slope, drainage, vegetation, geology, soil, geomorphology, climate and land use. Watershed management implies the proper use of all land and water resources of a watershed for optimum production with minimum hazard to natural resources. A comprehensive watershed management programme mayhave multiple objectives such as controlling damaging runoff and managing and utilizing the same for usefulpurposes, controlling erosion and reduction in the sediment production, enhancing ground water storage andappropriate use of the land resources in the watershed (Sebastian et al., 1995). The quantitative analysis of drainagesystem is an important aspect of characterisation of watershed (Strahler, 1964). The quantitative analysis of thedrainage basin and channel networks were pioneered by Horton (1932). Remote sensing and GIS techniques haveemerged as powerful tools for watershed management programmes. Remote sensing data can be used in conjunctionwith conventional data for delineation of ridge lines, characterization, priority evaluation, problem identification,assessment of potentials and management needs, identification of erosion prone areas, evolving water conservation strategies, selection of sites for check dams and reservoirs etc.(Dutta et al., 2002). Anand (2004) demonstrated the use of remote sensing and geographic information system for runoff estimation by SCS curve number method and also to suggest alternate land use classification, while Ravikumar (2001) explained the potential use of remotesensing and geographic information system for runoff estimation for identifying the land suitability for different crops based on available natural resources within the watershed.

## 2. Study Area

Ranchi is the capital of the Indian state of Jharkhand, and now it is the most populous city of the state. Ranchi was the centre of the Jharkhand movement, which called for a separate state for the tribal regions of South Bihar, northern Orissa, western West Bengal and the eastern area of what is present-day Chhattisgarh. Getalsud is an artificial reservoir situated in Ormanjhi, Ranchi, and Jharkhand. It was constructed across the Subarnarekha River and was opened in 1971. It is a popular picnic spot for the residents of Ranchi and Ramgarh District. The dam provides a small-scale fishing opportunity to the local people of Rukka. The main purpose of the dam is to fulfil the drinking water requirements of the residents of Ranchi. Apart from that, it is also used for industrial purposes and generating electricity.

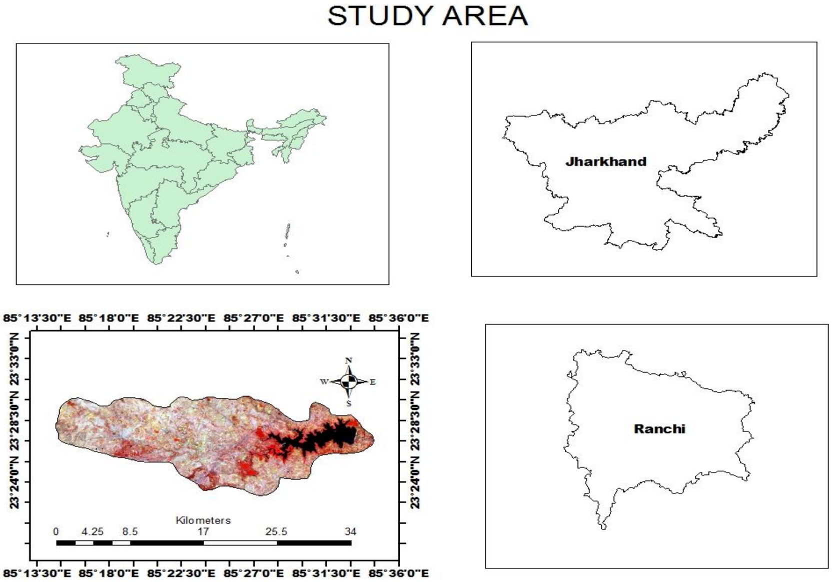


**Figure 1:** Location map of the Study Area

## 3. Material and methods

***Remote sensing data***

Satellite images used for this study include Landsat 8 OLI image of 2018 year with a spatial resolution of 30m.Drainage networks and other baseline information of thewatershed were prepared from the Survey of India top sheets on 1:50,000 scale and were further updated using satellite data. Landsat 8 OLI data of study areaco-registered to Survey of India toposheet was used for displacement in the crust of the earth and have an important role to play in development of drainage network ofthe region. The area has experienced structural disturbances leading to development of well marked set ofjoints and fractures. ASTER 30 m DEM was also used for thestudy. Using the DEM slope map of the watershed wasprepared.In GIS the channel segments were ordered numericallyas order number 1 from a stream's headwaters to a pointdownstream. The stream segment that results from thejoining of two first order streams was assigned order 2and so on. Watershed parameters, such as: Basin area (A), Basin perimeter (P), Basin length (Lb), Stream length (L), and Stream order (N) were calculated. These parameters are used to determine other influencing factors, such asbifurcation ratio, stream frequency, and drainage density.

## 4. Results & Discussions

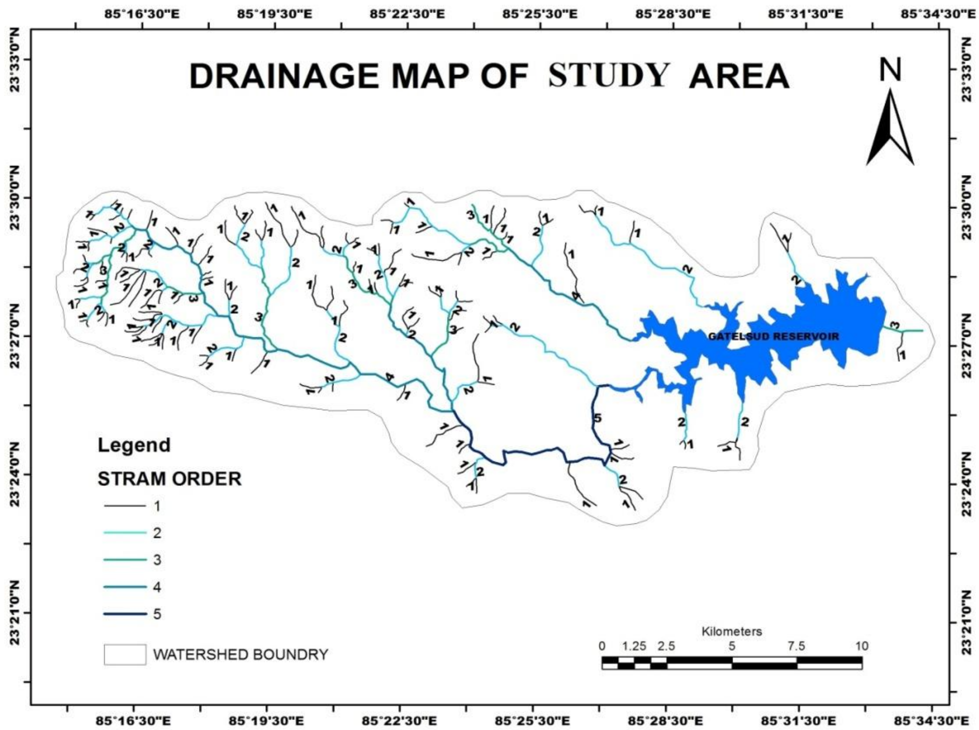


**Figure 2:** Drainage map of the Study Area

### Stream Order (Nu)

The designation of stream order is usually seen as the first step in drainage basin analysis. Stream order has been defined as a measure of the position of a stream in the hierarchy of tributaries. Hierarchical ordering of streams is necessary to assess hydrodynamic character of a drainage basin. In the present study, the various stream segments of the drainage basin have been ranked according to Strahler's stream ordering system. According to, the smallest fingertip tributaries are designated as first stream order. Where two first stream orders meets, a second stream order is formed; where two second stream order meets, third stream order is formed and so on. The stream order of Getalsud region is presented in Table 1.The total number of stream segments is found to decrease as the stream order increases in the basin. The study reveals that the development of1st order streams is maximum in the basementcomplex area and minimum in the alluvial plains(Table 1). The number of 1$^{st}$ stream order in a basin of a given size is dependent upon a number of factors which include climatic, geologic and hydrologic. The trunk stream through which all discharge of water and sediment passes is therefore the stream segment of the highest order Getalsud region which is the trunk in the study area is of the fifth order.

### Stream Length (Lu)

The total length of individual stream segments of each order is the stream length of that order. Stream length measures the average (or mean) length of a stream in each orders, and is calculated by dividing the total length of all streams in a particular order by the number of streams in that order. The stream length of the various stream orders in Getalsud region is presented in Table 1. Stream length is one of the most important hydrological features of the basin as it reveals the surface runoff characteristics. Streams of relatively smaller lengths are characteristics of areas with larger slope and finer textures. Streams with longer lengths are generally the characteristics of flatter surface with low gradients. Usually, the total length of stream segments is highest in first stream orders and decreases as the stream order increases. The number of streams of various orders in the basin was counted and their lengths measured from the mouth to the divide of the drainage basin. Stream length is a revelation of the chronological developments of the stream segments including interlude of tectonic disturbances.

### Mean stream length

The mean stream length is a characteristicproperty related to the drainage networkcomponents and its associated basin surfaces. The mean stream length is calculated by dividing the total stream length of given order bynumber of stream of that order as shown in Table 1. The value for any given order is greaterthan that of the lower order and less than that ofits next higher order in the whole drainage basin.

**Table 1:** Stream orders, stream number, stream length in the study area.

| Serial No | Stream Order | Stream Number | Total Stream Length (Km) | Mean Stream Length | Bifurcation Ratio |
|---|---|---|---|---|---|
| 1. | 1$^{st}$ order | 131 | 101.62 | 0.77 | - |
| 2. | 2$^{nd}$ order | 40 | 56.75 | 1.41 | 3.2 |
| 3. | 3$^{rd}$ order | 11 | 21.15 | 1.92 | 3.6 |
| 4. | 4$^{th}$ order | 03 | 29.52 | 9.84 | 3.6 |
| 5. | 5$^{th}$ order | 01 | 12.27 | 10.05 | 3.0 |

### Bifurcation ratio (Rb)

Bifurcation ratio is related to the branchingpattern of a drainage network and is defined asthe ratio between the total numbers of streamsegments of one order to that of the next higherorder in a drainage basin [36]. Bifurcation ratios usually range between 3.0 – 3.6 for study area in which the geologic structures do not distort the drainage pattern. The Rb values of the studyarea (Table 1) indicates that there is a uniformdecrease in the Rb values from the first streamorder to the fourth stream order. The Rb values in the study area ranges from 3.0 to 3.6. The sumof all the bifurcation ratios in the study area wasdivided by the number of bifurcation ratios to givethe mean bifurcation ratio of the basin. Thecalculated mean bifurcation ratio for the studyarea is 2.68; an indication that the study area is alowland area. This suggests that the study areahas low potentials for discharge compare tothose of highland areas with bifurcation ratio of 3.6.

### Areal Aspects

The areal aspects of drainage basin includedifferent morphometrics parameters, like drainage density (Dd), stream frequency (Fs). The values ofthese parameters were calculated and resultsare presented in Table 2.

**Table 2:** Areal Aspects of the study area

| Serial no | Parameter | Calculated value |
|---|---|---|
| 1. | Drainage density | 0.78 |
| 2. | Stream frequency | 0.66 |

### Drainage area (Au)

The drainage area is the entire area drained by astream or system of streams such that allstreams flow originating in the area is dischargedthrough a single outlet. In other words, thedrainage area is defined as a collecting areafrom which water would go to a river. Theboundary of the area is determined by the ridgeseparating water flowing in opposite directions. The total area of the study area is 280.32 km2. Basin area has been identified as the most important of all the morphometrics parameters controlling catchment runoff pattern. This is because, the larger the basin, the greaterthe volume of rainfall it intercepts, and the higherthe peak discharge that result. Themaximum flood discharge per unit area isinversely related to the size of the basin.

### Drainage density (Dd)

By definition drainage density of a basin is the total length of the streams of all orders per drainage area. Dd is expressed as the ratio of the total sum of all channel segments within a basin to the basin area i.e., the length of streams per unit of drainage density. It is a dimension inverse of length. Drainage densities can range from less than 5 km/km2 when slopes are gentle, rainfall low and bedrock permeable (e.g. sandstones), to much larger values of more than 500 km/km2 in mountainous areas where rocks are impermeable, slopes are steep and rainfall totals are high . The drainage density (Dd) of the study area is 0.78 km/km2. Thus, in this study, the drainage density falls less than 5km/km2 which indicates that the area has a gentle slope, low rainfall and permeable bedrock.

**Stream frequency (Fs)**

The stream frequency (Fs) or channel frequency or drainage frequency of a basin may be defined as the total number of stream segments within the basin per unit area. The stream frequency value of the study area is 0.66 indicating very low stream frequency (Fs) which can be attributed to the low relief and high infiltration capacity. The low stream frequency of the basin is indicating low relief and permeable sub surface material. The existence of less number of streams in a basin indicates matured topography, while the presence of large number of streams indicates that the stream is youthful and still undergoing erosion. It is an index of the various stages of landscape evolution. Number of streams in each order varied because of the physiographic conditions of particular area.

**LU/LC of the study area**

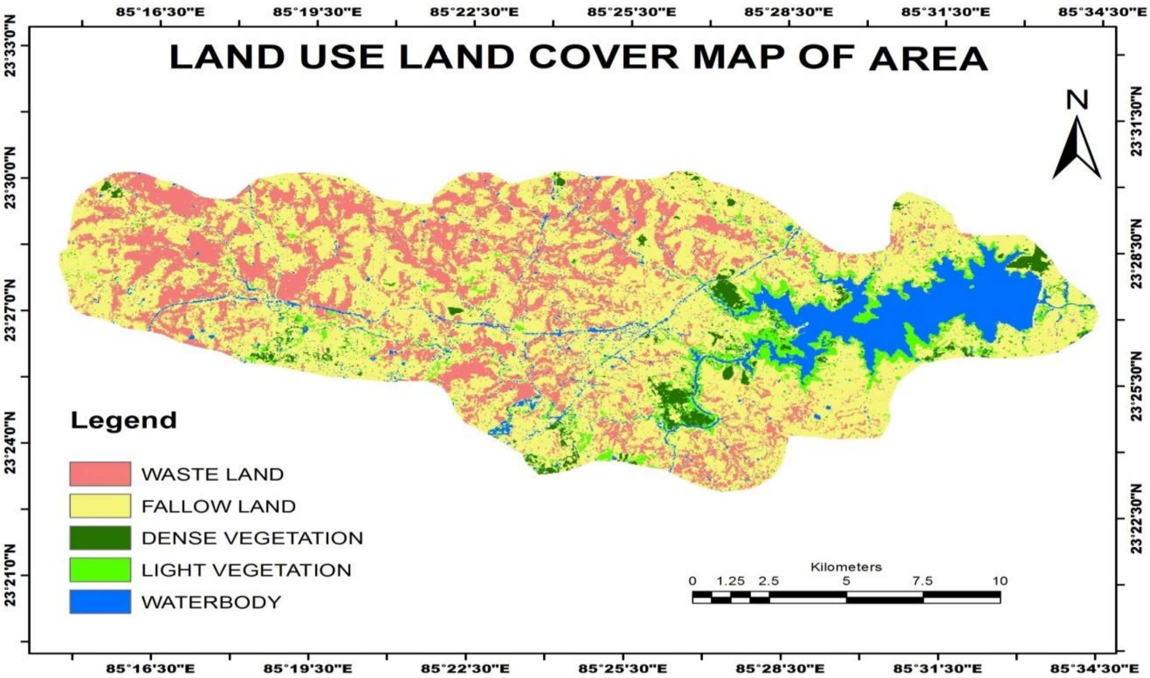


**Figure 3:** LU/LC of the Study Area

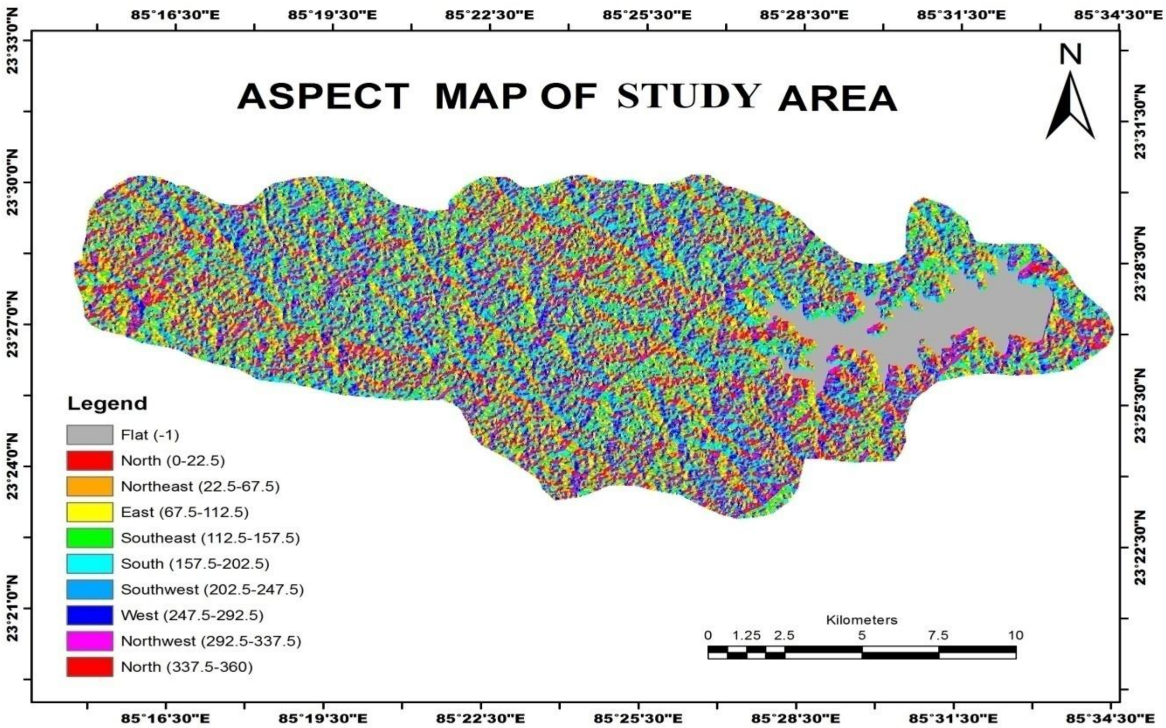


**Figure 4:** Aspect Map of the Study Area

International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

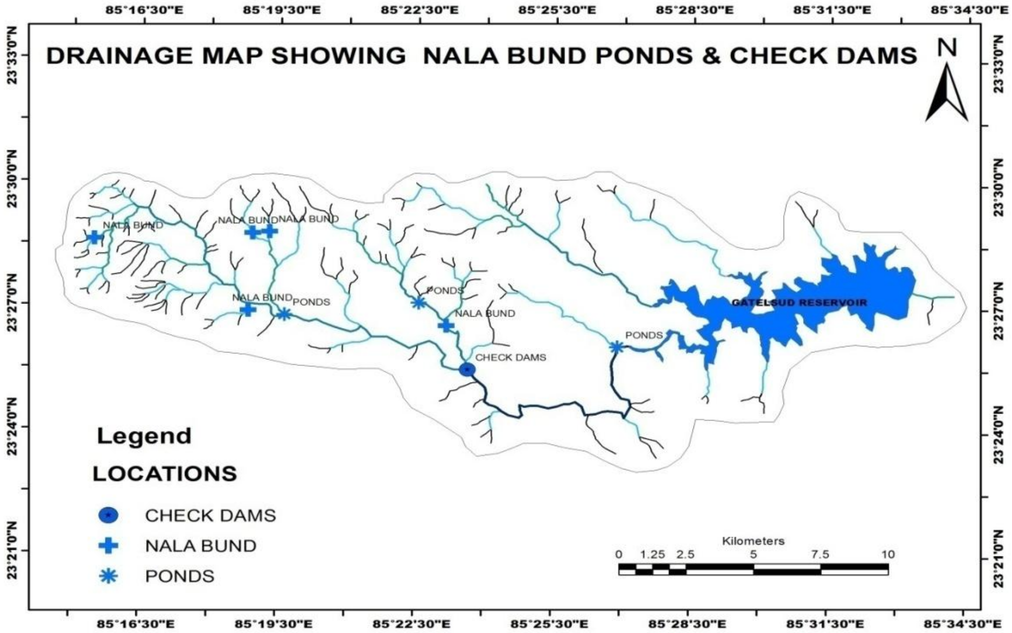


**Figure 5:** Harvesting structure of the Study Area

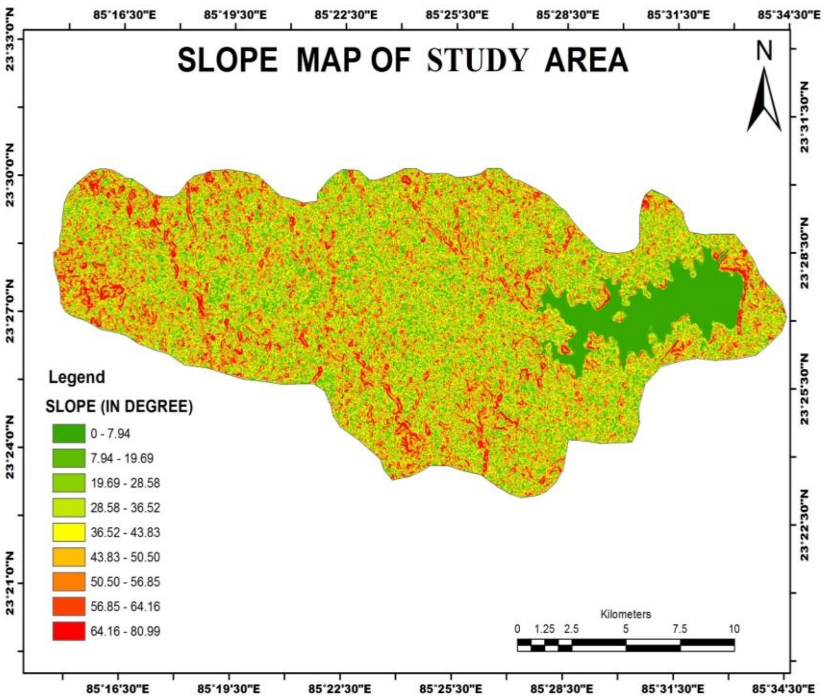


**Figure 6:** Slope Map of the Study Area

## 5. Conclusion

The study reveals that GIS and remote sensing can bevery useful in evaluation of various morphometrics parameters and its influence on landforms. Interpretation ofsatellite images can help delineate lithological and geomorphic units. GIS facilitates analysis of various morphometric parameters and acts as an effective tool in establishing relationship between drainage Morphometry and properties of landforms. The study also reveals thatDEM can useful in studying the topography within GIS environment. Geomorphological study of an area is thesystematic study of present day landforms, related totheir origin, nature, development, geologic changes recorded by the surface features and their relationship to other underlying structures.

A particular watershed may get the top priority due to variou s reasons, but, often, the intensity of land degradation is take n as the basis. The assessment of the physical parameters of t he land is possible by analyzing the slope, soil, geomorpholo gy, land use; terrain parameters etc. are very much amenable to GIS analysis.

ISSN: 2319-7064
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