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Topographical Characteristics of Lower Barakar Basin: A Geospatial Approach

Surbhi Sinha[1] and Vinay Kumar Rai[2]
[1]Research Scholar, Department of Geography, Institute of Science,
Banaras Hindu University, Varanasi
[2]Professor, Department of Geography, Institute of Science, Banaras Hindu University, Varanasi
(Corresponding author's email: sinha.surbhii001@gmail.com)

Abstract

The evolution and development of a drainage network largely depends upon the surface topography of a landscape. Even topographic attributes such as overland flow, sub-surface flow, stream flow etc. are highly determined by the relief and slope aspects of the basin area. Topography influences evolution of landforms, soil development, vegetation growth, types of settlement, agricultural pattern etc. So it becomes very important to quantify different topographical parameters so that proper watershed management can be done. This work is an attempt to evaluate existing topography of study area using topographical sheets and SRTM DEM data. For calculation and analysis of data MS Excel is used while Geographical Information System (GIS) is used for mapping purpose. Present work provides better understanding of surface and relief aspects of landforms in Lower Barakar basin.

Key words: topography, DEM, relief, GIS, watershed management, drainage, landforms

Introduction

Topographical characteristics and its description are very important phenomenon to understand the denudational chronology of present terrain as well the evolution of drainage network within an area. It conveys direct, immediate and overall impression of a landscape in one frame. It also plays vital role in the spatial and temporal behaviour of the hydraulic heads of ground water body. Even socio-economic pattern and cultural aspects of any area is strongly determined by peculiarity of its topography. Topographical characteristics of an area are reflected by its slope, aspect, hillshade, relief, dissection index, ruggedness number etc. Distribution and utilization of land and water resources are primarily dependent upon the nature of terrain as dissimilar landforms control differently the surface and sub-surface flow of water, landuse pattern and livelihood structures in any region. Terrain along with its undulating continuous land surface has been subject of mapping for hundreds of years. But in the late 20th century, demands for data on topography and specific themes of the earth's surface, such as natural resources, have accelerated greatly (Burrough et al., 1998). Map makers have introduced various techniques for terrain mapping among which geospatial technique has made it easier to incorporate terrain mapping and analysis into applications ranging from wildlife habitat analysis to hydrologic modelling (Chang et al., 2006). Geospatial approach has allowed photogrammetrists to map large area with high accuracy. The benefits associated with the use of this technique in watershed and hydraulic analysis include the improved accuracy, less duplication, easier map storage, more flexibility, ease of data sharing, timeliness and greater efficiency when compared to other existing techniques (Ogden et al., 2000).In present work, various aspects of topographic properties of Lower Barakar Basin have been studied in order to evaluate the existing topographic condition, its nature and pattern of regional variability.

Study area

The Barakar river is the principal tributary of Damodar river. It originates from the Hazaribagh plateau near Padma in Hazaribagh district of Jharkhand. It flows for about 225 km across the northern part of Chotanagpur plateau and mostly in west to east direction before joining the Damodar river at Disergarh in Bardhaman district of West Bengal. Tillaiya and Maithon dams are constructed on upper and lower part respectively of this river. On left bank Usri and on right bank Barsoti are its two major tributaries. The Barakar basin is located between 230 45'N to 24̊ 20'N latitudes and 85̊ 08'E to 87̊ 00' E longitudes.

The whole basin covers an area of 7032 sq

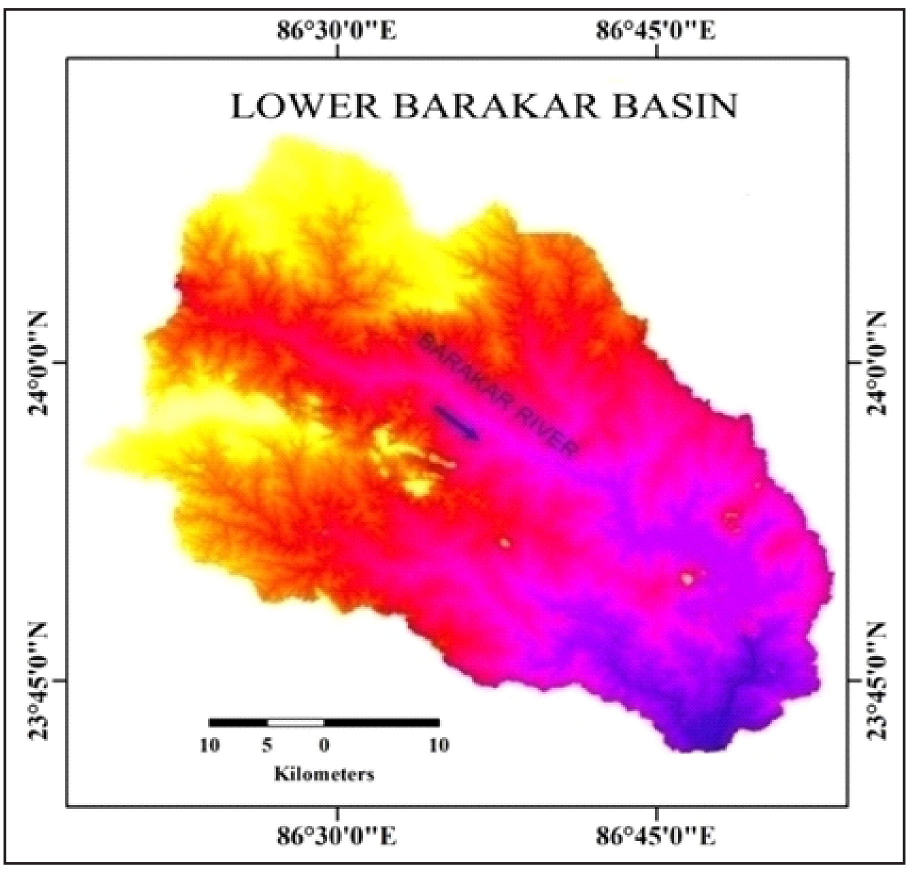

Figure 1: Location of study area

km in which the Lower Barakar basin covers about 1204 sq km area and is extended between 23°41'N to 24°10' N latitudes and 86°19'E to 87° 00'E longitudes. The soil in the study area is mainly red soil and red loamy soil of the Chotanagpur gneiss and granite surface. The elevation varies from 150 m to 400 m above the mean sea level in the study area. The general slope of the basin is towards east and south-eastward direction. The basin area enjoys a humid subtropical monsoon climate with the rhythm of weather with an annual rainfall of 2200mm (Biswas et al., 2016). The daily temperature ranges from a minimum of 3°C to a maximum of 40°C. The daily mean relative humidity varies from a maximum of 40% in the month of April to maximum of 85% in the month of July (figure 1).

Data and methodology

In the present study, the Shuttle Radar Topography Mission (SRTM) DEM data having spatial resolution of one arc sec. is downloaded from USGS website. Topographical sheets of study area having toposheet numbers 72H/7, 72H/8, 72H/11, 72H/12, 72H/15, 72H/16, 72L/4, 72L/8, 72L/12, 73I/5, 73I/19, 73I/10, 73I/13, 73I/14 on 1:50,000 scale is downloaded from Nakshe website of Survey of India (SOI). These SOI topographical sheets are geometrically rectified and georeferenced by taking ground control points (GCPs) and using Universal Transverse Mercator (UTM) projection and WGS84 datum. Further, all geocoded topographical sheets are mosaicked with the help of Arc GIS 10.5 software. The SRTM DEM data is firstly filled for splitting tall cells or filling the sinks. Then on filled DEM, flow direction is calculated for each pixel. After that, with the help of flow direction data, flow accumulation is calculated and threshold value 100 is given on flow accumulation data in order to extract stream network. Finally, watershed of Barakar Basin and its sub-basins are delineated by giving outlets or pour points. The slope, aspect and curvature of the study area is calculated pixel-by-pixel within a moving 3×3 window in Arc GIS 10.5. Then average slope, aspect and curvature are computed with the help of arc tool box. Absolute relief and relative relief are determined by dividing the whole study area into grid of 1 sq km through fishnet command in Arc GIS 10.5. Further, Zonal Statistics as Table operation is performed on SRTM DEM data in Arc environment to calculate areas covered by them. Maximum value obtained from the table operation has been considered for absolute relief and the range for relative relief. After getting the point values of surface and relative relief properties, IDW interpolation method is used for mapping. Data calculation and analysis is done on MS Excel while the layout of maps is prepared on Arc GIS 10.5.

Geology and geomorphology

Being part of Chotanagpur plateau, Barakar River is characterized by very complex structural geology and several geomorphological features. In the context of stratigraphic analysis, the Barakar river basin formation is related to the Vindhyan and Gondwana Super Group of Palaeozoic era and Chotanagpur Gneiss and Granophyre with the capping of laterite at some places (Biswas, 2016). This Barakar formation of Gondwana Super Group is made up of coarse, soft, and white to fawn coloured massive sandstone, shale with coal seams as bed grit with conglomerate and a bed of shale (Wadia, 1975). In the southern portion of the Barakar basin, close to Damodar River, some boundary faults of Gondwana Super Group are distinct whose general trend is ESE-WNW to ENE-WSW. Due to Rajmahal volcanism, some regional upliftment occurred which further generated tensional stress and this became the prime factor for the occurrence of faults (Mahadevan, 2002). Several patches of basic and ultra-basic rocks are found in upper section of Barakar basin while little patches of Dhanoji Lava/Basic rocks are found in the lower section. The sedimentary rocks are deposited in the faulted trough or drainage basin. The sandstone contains decomposed feldspar and its uneven hardness and weathering with rough surface create potholes in the channel bed. Several grooves of varying sizes are also prominent with the presence of inner channel that hardly gets any type of flow except during the monsoon season (Biswas et al., 2016).

The undulating physiography of Chotanagpur plateau in the upper section is active in denudation with the presence of several narrow, incised valleys. The general slope of the basin or orientation of the major axis of the basin is towards east and south-east. The river is more powerful in the upper part of the basin with marked topographic features of rugged banded gneisses. The middle section of the basin has a large size of interfluves that have significant characteristics of increased water volume and eroding capacity. While in the lower part of the basin, the Barakar river flows through joints having steep sided granitic and gneiss walls, and the presence of gneissic banding in a small patch. The Barakar River is mainly characterized by wide, shallow channel over the flat plateau, and is marked by steep sided, narrow valleys. The profile of the river is marked by several rapids. Paleochannel study reveals that the width of Barakar River was 235-415 m and 3.7-5.5 m depth and flowed on a slope of 0.00035. Most of the rivers of the Barakar basin are full of rounded and semi-rounded coarse sand, granules and pebbles of various sizes (Biswas et al., 2016).

Landscape profile

A landscape profile shows the change in elevation of the land surface along vertical scale. In present work, the profile is generated from SRTM DEM data, drawn (with the help of 3D Analyst tool in Arc GIS 10.5) diagonally in NW-SE direction from location 86°21’55”E and 23°57’57”N to location 86° 53’ 28”E and 23°48’24”N. The profile shows larger variation in relief near Parasnath hills while near Maithon reservoir it is less undulated. From north-west to south-east elevation is gradually decreasing. The hilly region is highly breached by streams and thus, several denuded and dissected uplands are formed. While lower parts of the basin experience heterogeneous rolling and flat surfaces.

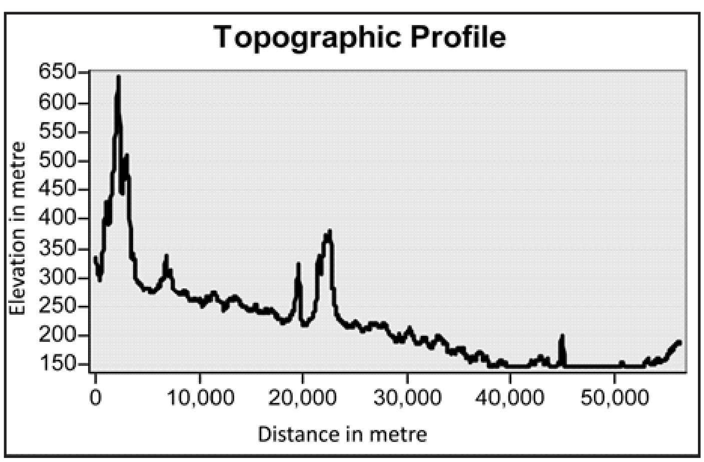

Figure 2: Topographic Profile

Results and discussion

Topographic Characteristics: The nature, characteristics and distribution of various topographic attributes are discussed under two headings viz. surface properties and relief properties.

Surface properties

Average Slope (AS): Slopes are defined as angular inclinations of terrain between hill-tops and valley bottoms, resulting from the combination of many causative factors like geological structure, absolute and relative reliefs, climate, vegetation cover, drainage texture and frequency, dissection index etc (Singh et al., 1984). It is the result of endogenetic and exogenetic forces working on the earth surface. In Fluvial Geomorphology, the slope is considered as an integral part of drainage basin as it largely influences and controls water and sediment input to a particular stream as well as transportation of them are also affected by channel slope (Chorley et al., 1985). Slope is computed with two measurement units (percentage and degree). In present study, slope is calculated both in degree and percentage.

The average slope (degree) of Lower Barakar Basin ranges from 0 to 60.60. Most of the areas (75.8%) come under <2° of slope which is categorized as very gentle slope. It is widely distributed in flood plain area of Barakar River and near Maithon dam (figure 3). About 13.8% of the study area comes under gentle slope category (2° - 8°). It is specifically found on areas of Asan, Jangalpur, Jamtara, Chengaidi, Sonbad etc. Moderate slope (8°-15°) accounts for 5.9 % of the study area. It is concentrated in upland areas of Gobindpur, Purananagar, Mohanpur, Barapahari, Loharangi etc. About 4% of the study area comes under moderately steep slope category (15° - 30°) which is mostly found in Jamkol, Tundi, Pahar, Chunukdiha, Mangridi, Domura and Paharpur.

Steep slope (>30°) is observed only on 0.5 % of the study area and is closely associated with high uplands of study area such as eastern part of Parasnath hill, Tundi, Korea, Ludhuria and Chaldhoa. Some highlands of north western part of Maithon dam such as Raghunathpur and Kanjapahar also comes under this category (figure 3).

Aspect: It is the compass direction that a slope faces. It is represented in eight major compass directions. The direction a slope faces can affect its physical and biotic features. It can also make very significant influences on local climate. As the sun's rays are in the west at the hottest time of the day in the afternoon, in most cases a west facing slope will be warmer than the sheltered east facing slope (unless large scale rainfall influences). In northern hemisphere, a south facing slope (more open to sunlight and warm winds) will generally be warmer and drier due to higher level of evapotranspiration than a north facing slope and vice versa. In present study, aspect grid is divided into 9 groups, eight directional and one class representing the flat terrain. Since, flat areas correspond to very negligible part of the basin so this class has been ignored. The Aspect map (figure 3) is classified at 45° interval which represents eight major directions of the slope of the basin. Among the eight groups, most of the slope faces are directed towards south, followed by south-east, south-west, east, north-east, west, north-west and north. Aspect also indirectly influences drainage development as the growth of vegetation largely depends upon the orientation of the slope faces towards the direction of direct sun rays. Direct sun rays favour large plants growth and where vegetation is higher; density of drainage tends to be lower.

Curvature: The curvature function displays the shape of the slope. A part of the surface can

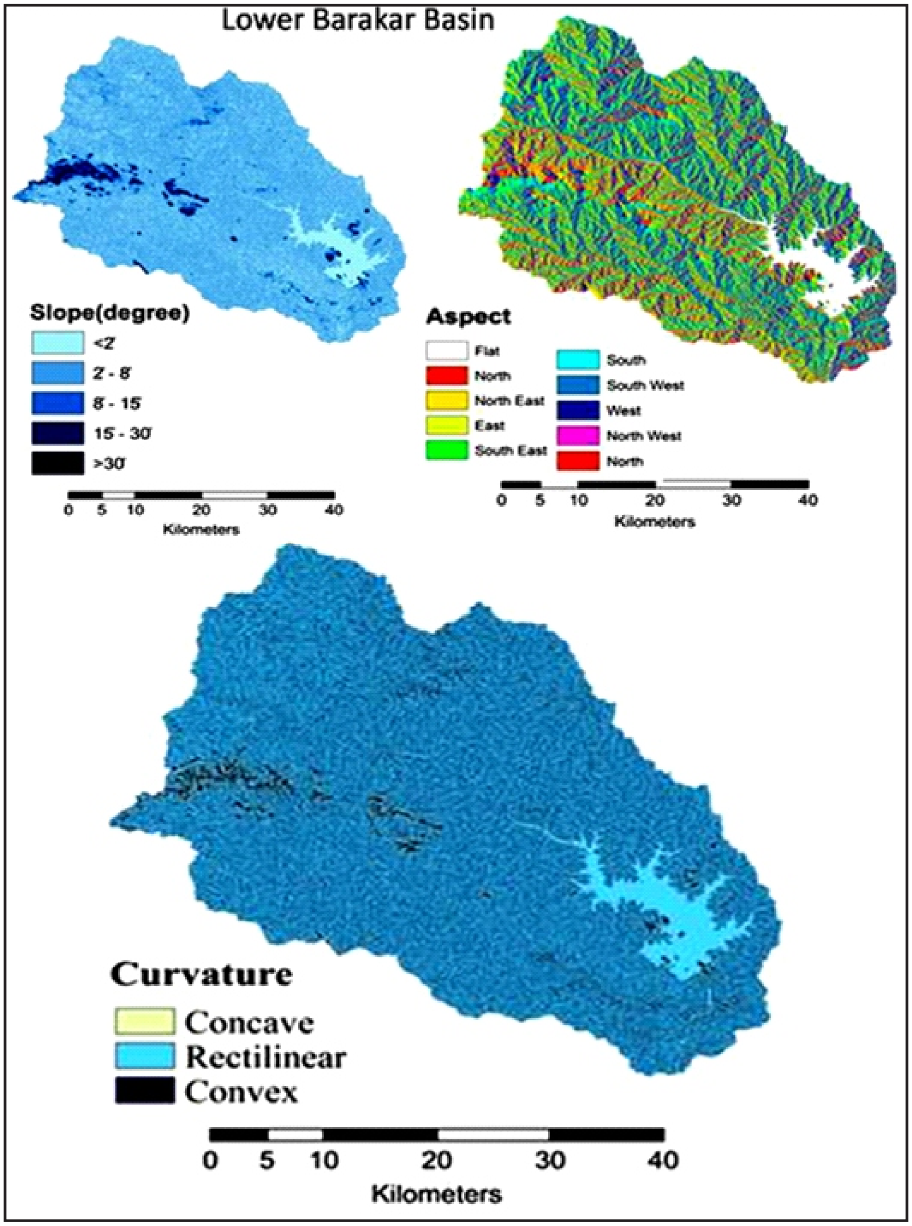

Figure 3: Slope, aspects and curvature of the study area

be convex, concave or rectilinear. The curvature is calculated by computing the second derivative of the surface. The output of the curvature function can be used to describe the physical characteristics of a drainage basin in an effort to calculate the erosion or runoff process. The curvature value can be used to find soil erosion patterns as well as the distribution of water on land. The profile curvature affects the acceleration or deceleration of flow and therefore, influences erosion and deposition. While Plan curvature relates to the convergence and divergence of flow across a surface. In present work, plan curvature is computed for the study area. A positive value of plan curvature denotes concavely upward surface while negative curvature denotes convexity. A zero value of convexity represents perfectly rectilinear surface. About 13.8% of the study area exhibits rectilinear surface while 23% shows concavity and 63.20% shows convexly upward surface (figure 3).

Relief properties

Absolute Relief (AR): It refers to the maximum height of any region above mean sea level. It is function of geotectonic and constructive and destructive processes. To determine the erosional surfaces with respect to the present day landforms, knowledge of absolute relief becomes very important. It is used to estimate the intensity of denudational processes operating on any surface. It also provides impetus to assess the landscape evolution of any surface (Mukherjee, 2016).

The absolute height of the Lower Barakar Basin ranges from the 67 m to 731 m above MSL. The altitude increases rapidly from south to northwards along the valley and the valley sides. The study area is divided into five altitudinal zones of 100m contour interval. About 1.29% of the study area comes under very low absolute relief (below 100 m) category. 47.82% areal coverage is observed in low absolute relief (100-200 m) category. Maximum areal coverage is found within moderate absolute relief category (200-300 m), which accounts for 49.31% of study area. Nearly 0.09% area lies within the category of moderately high absolute relief (300-400 m). Above 400 m category of high absolute relief corresponds to the crest of hills and water divides of study area and accounts for 1.49% of total area (figure 4).

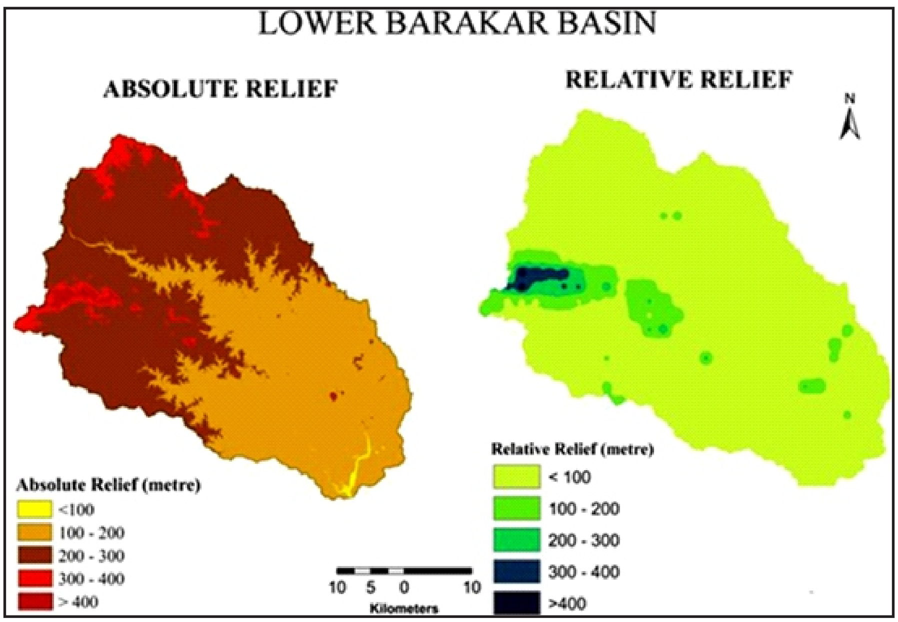

Figure 4: Distribution of absolute and relative relief in study area

Relative relief (RR): The difference in altitude between the highest point and the lowest point in a unit area is defined as relative relief. It is an important morphometric variable which is used for overall assessment of the morphological characteristics of terrain. The total basin relief of any area is defined as the difference in elevation between the highest point on the source and the mouth of the river basin. Relative relief is one of the techniques which is effectively capable of presenting the relief characteristics without considering sea level (Singh, 1994). The study area has been covered by the grid of 1 sq km which is here considered as the smallest unit of the region. For each grid, the difference between the highest and the lowest point has been computed which shows the spatial relative relief height. The average rise in the surface is 664 m relative relief. The map (figure 4) of relative relief of study area portrays the real distribution of such variations which has been further divided into five categories. Maximum area (89.98%) of the basin is characterized with very low relative relief (<100m). Low relative relief (100-200m) accounts for 6.99% of study area. About 1.85% of Lower Barakar basin comprises moderate relative relief (200-300m). Moderately High relative (300-400m) relief is observed in 0.98% area of the basin. High relative relief area accounts for only 0.2% area and majorly found on north western parts of study area.

Conclusion

The use of Geospatial approach for executing present work has provided increased efficiency and accuracy in computation and analysis of topographic characteristics which becomes very difficult through manual methods. The study reveals that Lower Barakar Basin exhibits contrasting topography while moving from north to south. Surface and relief properties show remarkable variation between Parasnath hills and Maithon dam. Major part of the study area has very gentle slope and most of the slopes face south and south east direction. Maximum area of slope curvature experiences convexly upward surface. The absolute relief of the basin area varies from 67 m to 731 m above MSL. High absolute relief is found on uplands of Parasnath hill. These hilly areas are also associated with steep slopes and moderate to high relative relief. Valley slopes and nearly plain regions are characterized with lower absolute relief and relatively lower relative relief. Overall, the study reflects that topographic variability largely affects the nature and variation of surface and relief properties of a drainage basin. This work will be useful to create a wholesome idea of topography in Lower Barakar Basin and may further help planners to execute water resource management at micro level in study area.

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