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ANALYSIS OF RELIEF CHARACTERISTICS USING DIGITAL ELEVATION MODEL: A CASE OF DUMKA UPLAND, JHARKHAND, INDIA.

Sayan CHOUDHARY[1], Vibhash Chandra JHA[2]

[1,2] Faculty of Geography, Visva-Bharati University, India
Email: sayanchoudhary@gmail.com, vcjha@asia.com

Abstract: Analysis of relief characteristics is an important part of terrain analysis. Morphometric analysis based on geospatial technology has several advantages over manual methods based on conventional data bases such as topographical maps. Firstly, being fully automated process, it has very less scope for subjectivity, omission or commission errors. Secondly, it is much easier to acquire geospatial data than topographical maps. There are various authoritative sources that provide free geospatial data on global and regional scales. Hence, it is much easier to work on global or regional scales cutting across international boundaries. In this paper ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) digital elevation model (DEM) has been used for the analysis of relief characteristics.

Keywords: *Relief analysis; Terrain analysis; Geospatial Technology; ASTER; DEM.*

I. INTRODUCTION

Relief is defined as the elevation difference over a predetermined area. The term 'relief' can be used in relative as well as in absolute sense. In relative sense it refers to the difference of elevation between highest and lowest point in a given area, while in absolute sense it refers to the highest elevation with reference to sea level. Differences in relief are attributed to the interaction between rate of uplift and rate of erosion.

Local relief is scale dependent. The larger the grid over which it is measured, the larger the relief (Montogomery, 2006, p. 840).

Smith (1935) distinguished between 'local relief' and 'relative relief' in his paper 'Relative Relief of Ohio'. According to him, the difference in elevation between highest and lowest points within a limited area may be regarded as the absolute and local relief of that area. The term 'relative relief' is used to imply regional comparison. Therefore, in this approach relation between areas and delineation of regions with similar relief becomes important objectives (Smith, 1935, p. 273).

Nir (1957) in his classic paper on 'The Ratio of Relative and Absolute Altitude of Mt. Carmel', felt the inadequacy of commonly used methods of giving absolute heights, as they fail to give clear-cut morphological expression. One way to expressing relief morphology is the 'relief energy' cartogram in which the difference of altitude between highest and lowest points within an area is taken into consideration. However, critics of this method objected to lack of uniformity in the size of squares and scale of maps which were used to prepare these cartograms. Nir (1957) used squares of one kilometre to divide the area into equal grids and instead of giving the relative altitude within a grid he employed ratio of maximum relative altitude and maximum absolute altitude within it. He also employed correlation and regression methods to classify the area and compare with other areas statistically (Nir, 1957, p. 564).

II. STUDY AREA

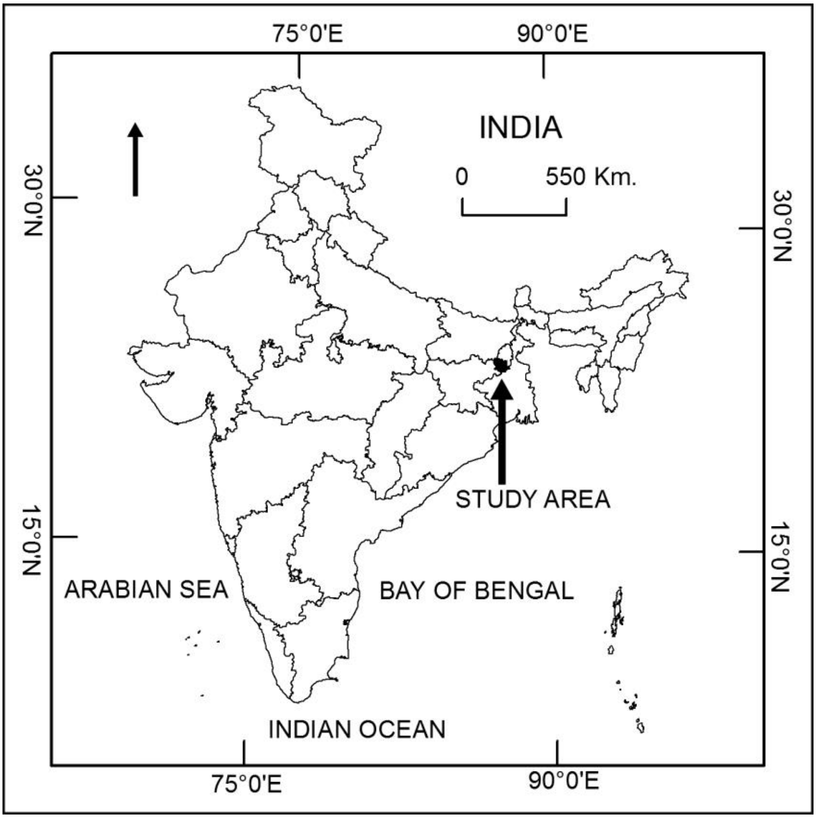

Fig. 1 Location of the study area

II.1. Location

Dumka Upland is a part of the Eastern India Shield. It lies between 230 59/ N- 240 40/ N and 86055/ E - 87045/ E. It belongs to the state of Jharkhand, India. It has an area of 3760.30 square kilometres. The study area is bounded by Godda district in the North, Sahibganj and Pakur district in the North East, Jamtara and Deoghar districts in the South and West respectively. On the Eastern side is Birbhum district of West Bengal and on the North Western side is Banka district of Bihar. Dumka has ten blocks viz. Dumka, Jama, Jarmundi, Saraiyahat, Ramgarh, Katikund, Gopikander, Shikaripara, Ranishwar and Masaliya. Hansdiha, Nunihat and Masanjore are other important places of the study area. Dumka or Naya Dumka, is the administrative headquarter of the district (Fig. 1).

II.2. Geologic and tectonic background

Geologically, Dumka upland is chiefly represented by the ancient rocks of diverse origin, most of which were subjected to intense metamorphism. Tectonically, it is part of the Eastern Indian Shield which has virtually remained unaffected by the tectonic forces since the close of the Precambrian Era. The later changes suffered by the shield, are mainly of the nature of normal and block faulting. The depressions caused by these faulting received detritus of vegetation and sediments during the Tertiary period and gave rise to the very famous coal bearing seams, known in geology of India, as the Gondwana formations. The Dumka upland experienced successive uplifts during Mid-Miocene and volcanic eruptions forming the Rajmahal highlands as a consequence of the Himalayan orogenesis.

THE ARCHAEN SYSTEM

The Archaen systems are the oldest rocks of the earth's crust. They are azoic, thoroughly crystalline, contorted, faulted and intruded by plutonic intrusions. The system is also known by the names of 'Fundamental complex', the 'basement complex' etc. There is a great ambiguity regarding the formation of the Archaen system. Some are considered to be the first formed crust of the earth by the consolidation of magma. Some are believed to the earliest sediments deposited in the Primeval Ocean and latter subjected to extreme metamorphism. Some are considered to be the large plutonic masses subjected to deformations and while others are also considered to be the result of consolidation of original heterogeneous magma erupted in the crust (Wadia, 1919, p. 48).

The most common Archaen rock is gneiss. The mineral composition may vary from granite to gabbro, but possesses a constant, more or less foliated or banded structure, called gneissic. This banded or streaky appearance may be either due to an alternation of bands of different constituent minerals of rocks or due to the association of layers of rocks of varying mineral composition. The gneiss shows varying character over wide areas. Besides composition, almost all gradations are present, from thoroughly acid to intermediate and basic composition. The rock varies from granite-gneiss, syenite-gneiss, diorite-gneiss to gabbro-gneiss (Wadia, 1919, p. 51).

The gneissic Archaen rocks of India are classified into three groups viz. the Bengal gneiss, the Bundelkhand gneiss and the Charnockite series. However, they do not represent any definite succession in time.

BENGAL GNEISS

Bengal gneiss is very finely foliated, of heterogenous composition. A striking feature of this gneiss, and one which is of great importance in the present research, is the frequent occurrence of low, rounded hills. It is because of this character that it is also called 'dome gneiss'. It has a peculiar habit of weathering into dome like hummocks and large, ellipsoidal masses of bare due to massive sheeting. The gneiss resembles intrusive character with well marked zone of contact-metamorphism in the surrounding gneisses and schists. It also contains autoliths and xenoliths, which indicates its plutonic character (Wadia, 1919, p. 55).

In mineral composition the dome gneiss shows that rock is granitite being composed of quartz and microcline with smaller quantities of oligoclase, biotite, hornblende and accessory sphene, apatite and zircon (Holland, 1902, p. 47).

Besides the above mentioned type others petrological types are also found in the Bengal gneiss, the most important being the Sillimanite-gneiss and Sillimanite-schist of Orissa, known as Khondalites (from the khond inhabitants of Orissa) (Wadia, 1919, p. 55).

BUNDELKHAND GNEISS

The name 'Bundelkhand gneiss' has been proposed by F.R.Mallct (unpublished report) from the state of that name for a gneiss possessing the characters of coarse pink granite of constant composition and almost devoid of accessory minerals. Foliation is not well developed. Pegmatite veins and quartz reefs are common. Previously it was considered as the oldest gneiss in India. However, this view is no longer tenable, as its intrusive characters are well recognised (Holland & Tipper, 1913, pp. 29-30).

CHARNOCKITE SERIES

The charnockite series include pyroxene bearing forms varying in composition from hypersthenes-granite (charnockite) to pyroxenite and are regarded as part of the Archaen System in India. The name 'charnockite series' has been proposed by (Holland, 1900, pp. 120, 242). Previously it was named 'Nilgiri or Mountain gneiss' by (King, 1880, p. 125).

In Dumka upland, there are exposures of charnockite rocks on the Satgarh hills near Masanjor. These rocks have similarities with the charnockite-series rocks of south India, but seem to have been formed by the process of charnockitization of pre-existing rocks by the formation of hypersthene, blue-quartz and microperthitic feldspar rather than from direct crystallization of charnockite magma

(Roychaudhury, 1965, p. 15). Another significant exposure of the rock is near Nunihat, where a group of hills comprise Charnockite rocks. Important peaks are the Makarkenda pahar (436 m), the Pokhuria pahar (413 m), the Basko pahar (440 m), the Ghanti pahar (467 m), the Baramasia pahar (412 m), the Lito pahar (411 m) and the Nandankop pahar (388 m).

GONDWANA SYSTEM

The term ‘Gondwana system’ was originally proposed by H. B. Medlicott in 1872 and later revived by O. Feistmantel in 1876. The Gondwana system is composed of conglomerates, sandstones, shales and coal measures which indicate its fluvial origin. The beds range in age from Upper Carboniferous to Jurassic and are contemporaneous to the Karroo System of South Africa. The base of the system (Talchir stage) was considered to have formed in Permian. From a consideration of fossil flora, it was moved up to the Trias. However, recent studies indicate that the characteristic fossil plants of the Lower Gondwana to be not younger than Upper Carboniferous. From economic considerations, the Gondwana system is of great significance as it is the main source of coal in India (Holland & Tipper, 1913, pp. 50-51).

In Dumka upland, the best exposure of the Gondwana system is found along the famous Rajmahal hills. The rock-groups occurring in the Rajmahal hills are in descending order as follows:

ALLUVIUM
LATERITE
GONDWANA SYSTEM
- Rajmehal groups
- Dubrajpur Group
- Barakar group (Damuda Series)
- Talchir group

METAMORPHIC SERIES

III. MATERIALS & METHOD

In the present paper ASTER DEM has been used for relief analysis. ASTER (Advanced Spaceborne Thermal Emmission and Reflection Radiometer) is a joint project between Ministry of Economy, Trade and Industry of Japan (METI) and National Aeronautics and Space Administration (NASA). It is an Erath observing sensor developed in Japan onboard the satellite ‘Terra’. It is in operation for more than ten years since its launch in December 1999. DEM is generated from stereo pair of images acquired with nadir and backward angles over the same area. ASTER GDEM is developed based on these data. Global Digital Elevation Model Version 2 (GDEM V2) has been released on October17, 2011. DEM processing and preparation of layouts have been carried out using ArcGIS ® 10.0 software.

IV. RESULTS & DISCUSSION

IV.1. Absolute relief

In the present study ASTER DEM (30 m resolution) has been used for analysis of relief characteristics. The study area has been divided into squares of one kilometre. A moving window of one square kilometre has been prepared to scan the entire study area and to obtain highest elevation in each cell. Squares were classified according to the highest elevation obtained in them (Fig. 2).

Terrain classified in this way greatly exaggerate altitude, as a cell containing a high altitude within a small area is classified as the same category as one in which the same altitude occupies a larger area. Bringing out of high points may 'help to indicate ancient erosion levels, since this cartogram largely eliminates dissection caused by stream beds, and it makes possible the construction of secondary classification of landscapes' (Nir, 1957, p. 565).

Table 1. Classification of absolute relief in Dumka upland

Absolute relief (metres)	Area (Km^2)	Percentage area	Class
< 120	356.77	9.49	Very low
120-200	1538.60	40.92	Low
200-280	1580.71	42.04	Moderately low
280-360	180	4.79	Moderate
360-440	82.73	2.20	Moderately high
> 440	21.27	0.57	High

DISTRIBUTION OF ABSOLUTE RELIEF IN DUMKA UPLAND

i. Very Low absolute relief (< 120 m)

This category comprises 356.77 km2 (9.49 %) of the Dumka upland and chiefly confined in south-eastern part of the study area along the Mayurakshi river, the Dwarka river and the Brahmani river (Table 1). A small portion of this category is found in the north – eastern part of the study area along the Bansloi river.

ii. Low absolute relief (120-200 m)

This category comprises 1538.60 km2 (40.92 %) area and is the second predominant relief category in Dumka upland. It prevails over the central, eastern and southern part of the study area along the Mayurakshi river, the Brahmani river and the Siddeswari river. A small portion of this category is also found along north-eastern part of the study area along the Brahmani river.

iii. Moderately low absolute relief (200 - 280 m)

This category comprises 1580.71 Km2 (42.04 %) area and it is the predominant category in Dumka upland. It prevails over north-western, north, north-eastern part of study area. Scattered patches are also found in western, southern and south-eastern part. Domes and tors prevail in this relief category.

iv. Moderate absolute relief (280-360 m)

This category of absolute relief comprises 179.95 Km2 (4.78 %) area of Dumka upland.

v. Moderately high absolute relief (360-440 m)

This category of absolute relief comprises 82.73 Km2 (2.20 %) area of Dumka upland.

vi. High absolute relief (> 440 m)

This category of absolute relief comprises 21.26 Km2 (0.57 %) area of Dumka upland. The above mentioned last three categories of absolute relief viz. moderate absolute relief (280-359 m), moderately high absolute relief (360-439 m), and high absolute relief (440-579 m) are confined to the residual hills. Among the important peaks of the Rajmahal hills which are in Dumka upland, Mahuagarhi (494 m) is the highest. Other important peaks include Kolha pahar (457 m), Sarkhi Pahar (436 m), Dewas pahar (460 m), Silingi pahar (450 m), Champa pahar (396 m), Karam Pahar (321 m), Chaparia pahar (450 m), Bhuibhanga pahar (377 m), Bhilai pahar (353 m), Sarwan pahar (364 m), Bijaypur pahar (381 m), Lakraphela pahar (453 m), and Chaudhari pahar (355 m).

In the south east of Dumka upland, south of the Brahmani river, there is a small range of hills known as the Ramgarh Hills. These hills are an extension of the Rajmahal Hills, but are much lesser in elevation and have an undulating configuration. Karakata (290 m) is the highest peak.

Two parallel ranges run on either side of Masanjor reservoir. The range along its western flank is known as the Satgarh group. It comprises the Satbar pahar, the Jhandi pahar (428 m), the Agwanduari pahar (416 m), the Rakshi pahar (396 m), the Doman pahar (403 m), and finally merges into the Sapchala hills, where Thilua (402 m) is the highest. In the east of Masanjor reservoir the hills are of comparatively low elevation compared to their western counterpart.

In the northern part of Dumka upland, near Nunihat, there is a group of hills comprising Charnockite rocks. Important peaks are the Makarkenda pahar (436 m), the Pokhuria pahar (413 m), the Basko pahar (440 m), the Ghanti pahar (467 m), the Baramasia pahar (412 m), the Lito pahar (411 m) and the Nandankop pahar (388 m). Apart from these hill ranges, there are numerous isolated domes and tors scattered across Dumka upland. Among these isolated hills, Lagwa pahar (456 m), near Nunihat, is the highest. Others important hills include Bandarjora pahar (394 m), the Harida pahar (278 m), the Mahulbon pahar (368 m), Sundari pahar (312 m), Gumra Pahar (277 m), Kaswa pahar (275 m), Nakti pahar (239 m), Jamua pahar (338 m) etc.

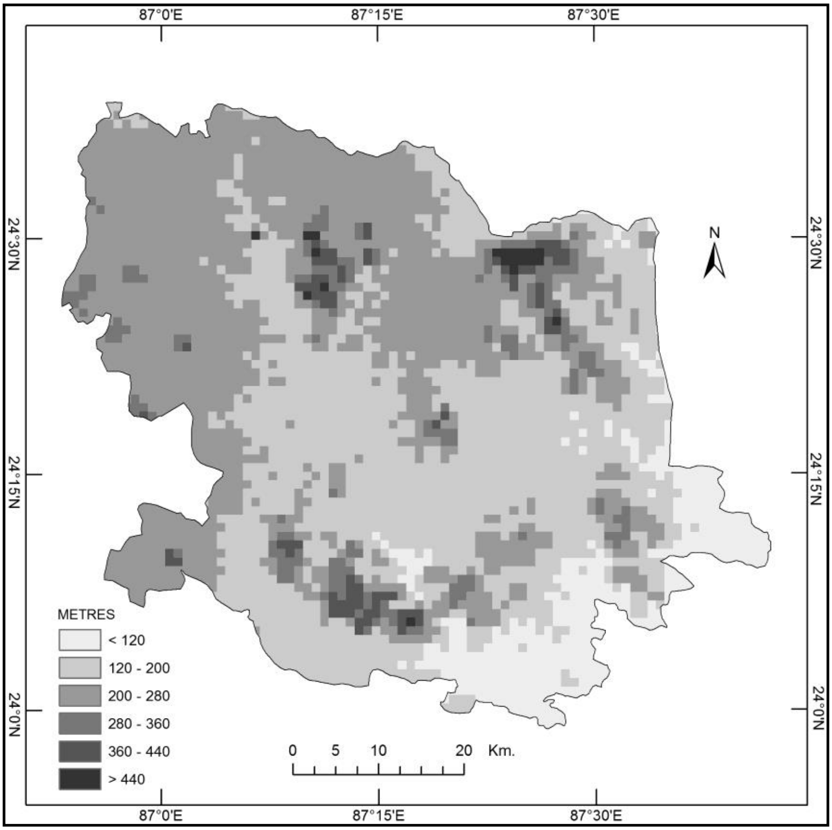

Fig. 2 Absolute relief of Dumka Upland, Jharkhand, India

IV.2. Relative relief

A moving window of one square kilometre has been prepared to scan the entire study area and to obtain difference of elevation between highest and lowest value in each cell. Squares were classified according to the values of relative relief. The relative relief is calculated for the same squares as used for calculation of absolute relief (Fig. 3). The area containing highest absolute altitude may have only a medium relative altitude. This is typical of medium-high mountains in which summit are a region of low rounded hilltops. Whereas, relief may appear sharpest on the margin of the mountain, and wherever stream beds cut across. Hence, this cartogram is an improvement over absolute relief. Further, the correlation between relative and absolute altitude can be used as an expression of relief energy and has got potential for further research (Nir, 1957, pp. 565-568).

Table 2. Classification of relative relief in Dumka upland

Relative relief (metres)	Area (Km^2)	Percentage area	Class
< 60	2757.07	73.32	Very low
60-120	680.35	18.09	Low
120-180	220.35	5.86	Moderately low
180-240	79.00	2.10	Moderate
240-300	21.27	0.57	Moderately high
> 300	2.03	0.05	High

IV.3 Distribution of relative relief in Dumka upland

i. Very low relative relief (< 60 m)

This category comprises 2757 Km2 (73.32 %) area and is the predominant category in Dumka upland (Table 2). It prevails in north, west, central and southern part of Dumka upland except where residual hills interrupted the monotony of the landscape.

The following five categories of relative relief occur in close proximity.

ii. Low relative relief (60- 120 m)

iii. Moderately low relative relief (120-180 m)

iv. Moderate relative relief (180-240 m)

v. Moderately high relative relief (240-300 m)

vi. High relative relief (> 300 m)

The above mentioned last five categories of relative relief are confined to the residual hills over the Rajmahal hills which are in Dumka upland, on the Ramgarh Hills, two parallel ranges run on either side of Masanjor reservoir. Near Nunihat, on the the Makarkenda pahar (436 m), the Pokhuria pahar (413 m), the Basko pahar (440 m), the Ghanti pahar (467 m), the Baramasia pahar (412 m), the Lito pahar (411 m) and the Nandankop pahar (388 m). Apart from these hill ranges, the above mentioned last five categories of relative relief are found over numerous isolated domes and tors scattered across Dumka upland. Among these isolated hills, Lagwa pahar (456 m), near Nunihat, is the highest. Others important hills include Bandarjora pahar (394 m), the Harida pahar (278 m), the Mahulbon pahar (368 m), Sundari pahar (312 m), Gumra Pahar (277 m), Kaswa pahar (275 m), Nakti pahar (239 m), Jamua pahar (338 m) etc.

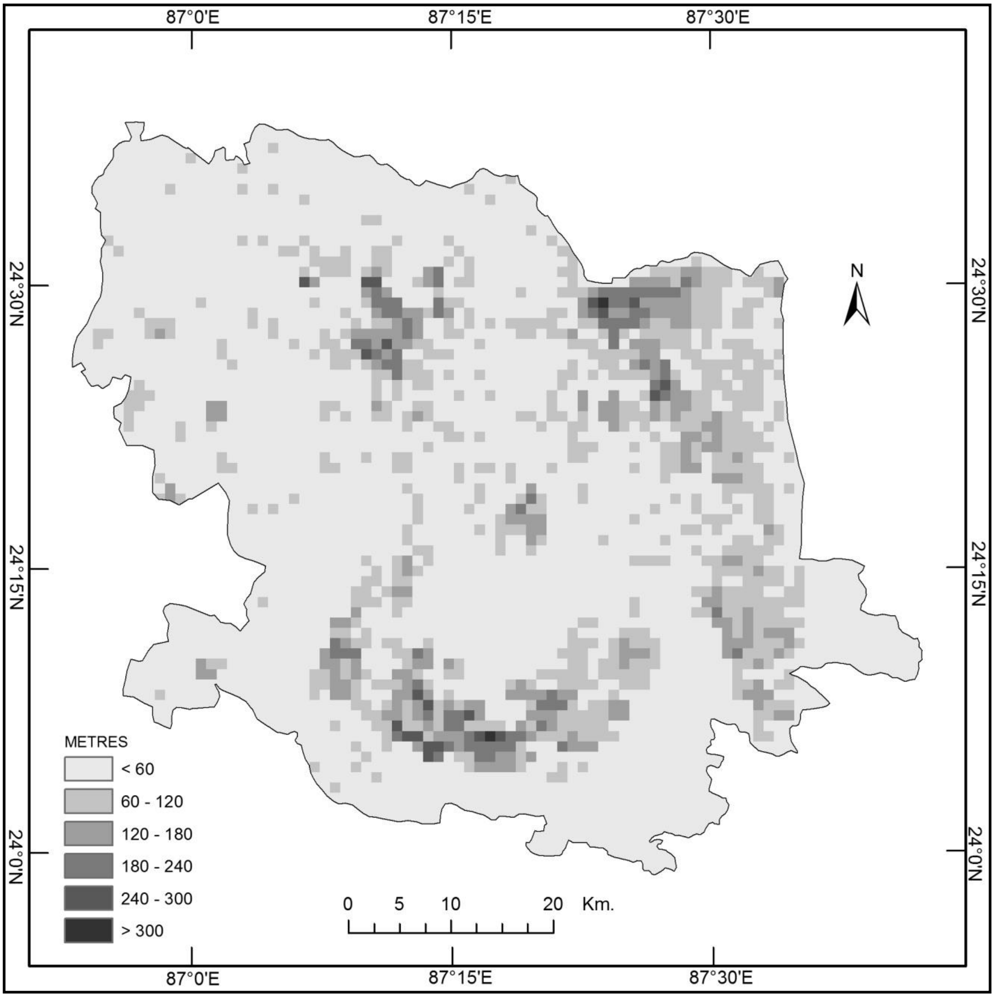

Fig. 3 Relative relief of Dumka Upland, Jharkhand, India

IV.4. Dissection index

A moving window of one square kilometre has been prepared to scan the entire study area and to obtain absolute relief and relative relief for each cell. In order to obtain dissection index for each cell, relative relief has been divided with absolute relief. Squares were classified according to the values of dissection index. The dissection is calculated for the same squares as used for calculation of absolute relief and relative relief (Fig. 4).

Nir (1957, p. 568) felt the inadequacy of relative altitude as a criterion of relief energy. Equal relative altitude may not be of equal importance as the absolute altitude on the basis of which it has been calculated may differ. Therefore the inference drawn for this method is only partial as it fails to take into account the vertical distance from the erosion base or the dynamic potential of the area. In order to overcome this problem of relief expression, the writer suggested the use of ratio between maximum relative altitude and maximum absolute altitude. The ratio ranges from 1 to 0 both designates extreme cases. On one extreme is the vertical cliff at seashore and on the other there is complete absence of dissection. A general and objective index is obtained having universal application. The writer termed it 'dissection index'.

Table 3. Classification of dissection index in Dumka upland

Dissection Index	Area (Km^2)	Percentage area	Class
< 0.13	22.34	0.59	Very low
0.13 - 0.26	1495.65	39.78	Low
0.26 - 0.39	1404.82	37.36	Moderately low
0.39 - 0.52	625.80	16.64	Moderate
0.52 - 0.65	191.20	5.08	Moderately high
> 0.65	20.25	0.54	High

IV.5 Distribution of dissection index in Dumka upland

1. Very low dissection index (< 0.13)

This category occupies 22.34 Km2 (0.59%) area of Dumka upland and restricted to the Masanjor Dam only (Table 3).

2. Low dissection index (0.13 – 0.26)

This category occupies 1495.65 Km2 (39.78%) area of Dumka upland and predominates in western and northern parts which acts as water divide between the Mayurakshi river and the adjacent Ajai river. This category again occurs in the central part forming water divide between the Mayurakshi and the Brahmani river.

3. Moderately low dissection index (0.26 – 0.39)

This category occupies 1404.82 Km2 (37.36%) area of Dumka upland and predominates in the central and southern part.

The following five categories of relative relief occur in close proximity.

4. Moderate dissection index (0.39 – 0.52)

5. Moderately high dissection index (0.52 – 0.65)

6. High dissection index (> 0.65)

The above mentioned last five categories of dissection index are confined to the residual hills. The above mentioned last five categories of relative relief are confined to the residual hills over the Rajmahal hills which are in Dumka upland, on the Ramgarh Hills, two parallel ranges run on either side of Masanjor reservoir. Near Nunihat, on the the Makarkenda pahar (436 m), the Pokhuria pahar (413 m), the Basko pahar (440 m), the Ghanti pahar (467 m), the Baramasia pahar (412 m), the Lito pahar (411 m) and the Nandankop pahar (388 m). Apart from these hill ranges, the above mentioned last five categories of relative relief are found over numerous isolated domes and tors scattered across Dumka upland. Among these isolated hills, Lagwa pahar (456 m), near Nunihat, is the highest. Others important hills include Bandarjora pahar (394 m), the Harida pahar (278 m), the Mahulbon pahar (368 m), Sundari pahar (312 m), Gumra Pahar (277 m), Kaswa pahar (275 m), Nakti pahar (239 m), Jamua pahar (338 m) etc.

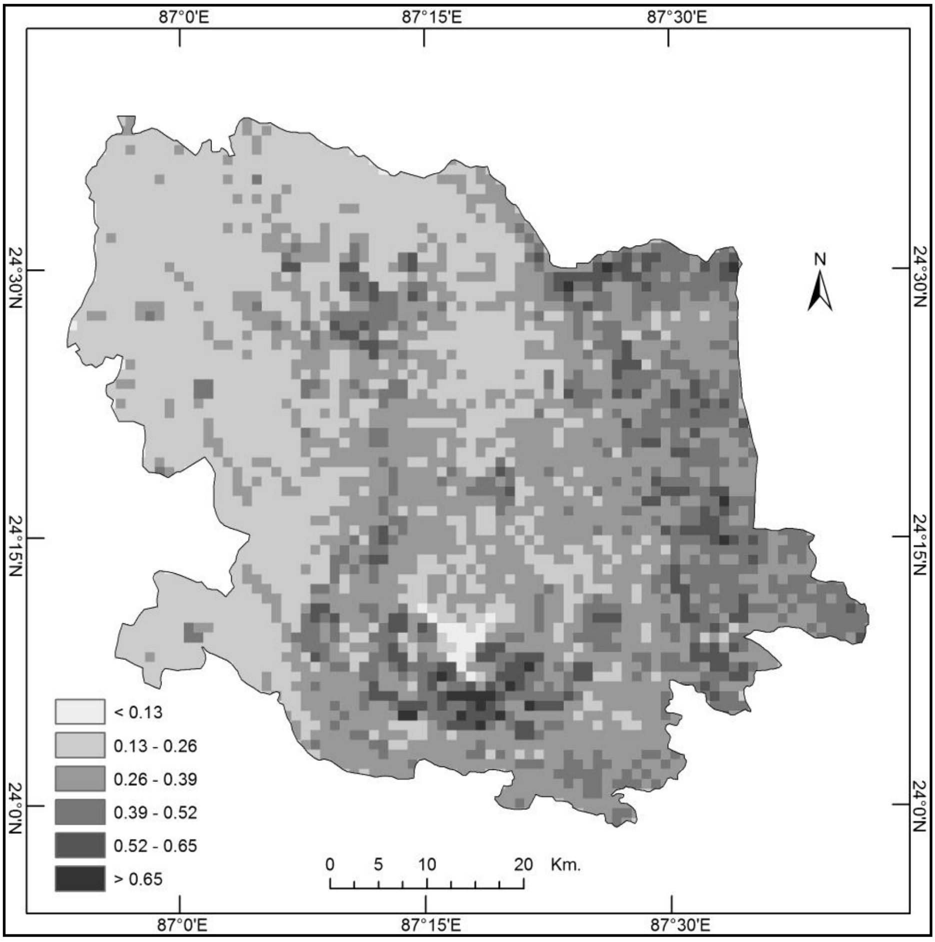

Fig. 4 Dissection index of Dumka Upland, Jharkhand, India.

IV. 6. Slope

Slope has been calculated using slope tool in ArcGIS. The slope tool calculates the maximum rate of change in value from that cell to its neighbours. The steepest downhill decent from the cell is determined by the maximum change in elevation over the distance between the cell and its neighbour cells (Fig. 5).

Conceptually, the tool fits a plane to the Z-value of a 3/3 cell neighbourhood around the processing cell. The slope value of this cell is calculated using average maximum technique. If there is a cell in the neighbourhood with No Data z-value, the z-value of the central cell will be assigned to that cell. At the edge of the raster, at least three cells will contain No Data value. These cells will be assigned central cell's z-value. This results in flattening of the 3/3 plane fitted to this edge cells, which leads to a reduction in the slope. The output slope raster can be expressed in either degrees or percent (Burrough & Mc Donnel, 1998, p. 190).

Table 4. Classification of slope in Dumka upland

Slope (Degrees)	Area (Km^2)	Percentage area	Class
< 4	52.97	1.41	Level
4 – 8	3093.71	82.28	Gentle
8 – 12	449.62	11.96	Moderate steep
12 – 16	123.24	3.28	Moderate steep
16 – 20	33.42	0.89	Moderate steep
> 20	7.09	0.19	Steep

IV.7 Distribution of slope in Dumka upland, Jharkhand

1. Level slope (< 40)

This category occupies 52.97 Km2 (1.41 %) of the study area and confined in the Masanjor Dam area only (Table 4).

2. Gentle slope (4 – 80)

This is the dominant category of slope and occupies 3093.71 Km2 (82.28 %) of the study area.

The following four categories of slope occur in close proximity.

3. Moderately steep slope (8 – 120)

4. Moderately steep slope (12 - 160)

5. Moderately steep slope (16 – 200)

6. Steep slope (> 200)

The above mentioned last five categories of dissection index are confined to the residual hills. The above mentioned last five categories of relative relief are confined to the residual hills over the Rajmahal hills which are in Dumka upland, on the Ramgarh Hills, two parallel ranges run on either side of Masanjor reservoir. Near Nunihat, on the the Makarkenda pahar (436 m), the Pokhuria pahar (413 m), the Basko pahar (440 m), the Ghanti pahar (467 m), the Baramasia pahar (412 m), the Lito pahar (411 m) and the Nandankop pahar (388 m). Apart from these hill ranges, the above mentioned last five categories of relative relief are found over numerous isolated domes and tors scattered across Dumka upland. Among these isolated hills, Lagwa pahar (456 m), near Nunihat, is the highest. Others important hills include Bandarjora pahar (394 m), the Harida pahar (278 m), the Mahulbon pahar (368 m), Sundari pahar (312 m), Gumra Pahar (277 m), Kaswa pahar (275 m), Nakti pahar (239 m), Jamua pahar (338 m) etc.

Table 5 shows high correlation among absolute relief, relative relief and slope. However, relation between absolute relief and dissection index is very low.

Table 5. Correlation matrix

Variable	Absolute relief	Relative relief	Dissection index	Slope
Absolute relief	1			
Relative relief	0.72	1		
Dissection index	0.11	0.74	1	
Slope	0.74	0.89	0.59	1

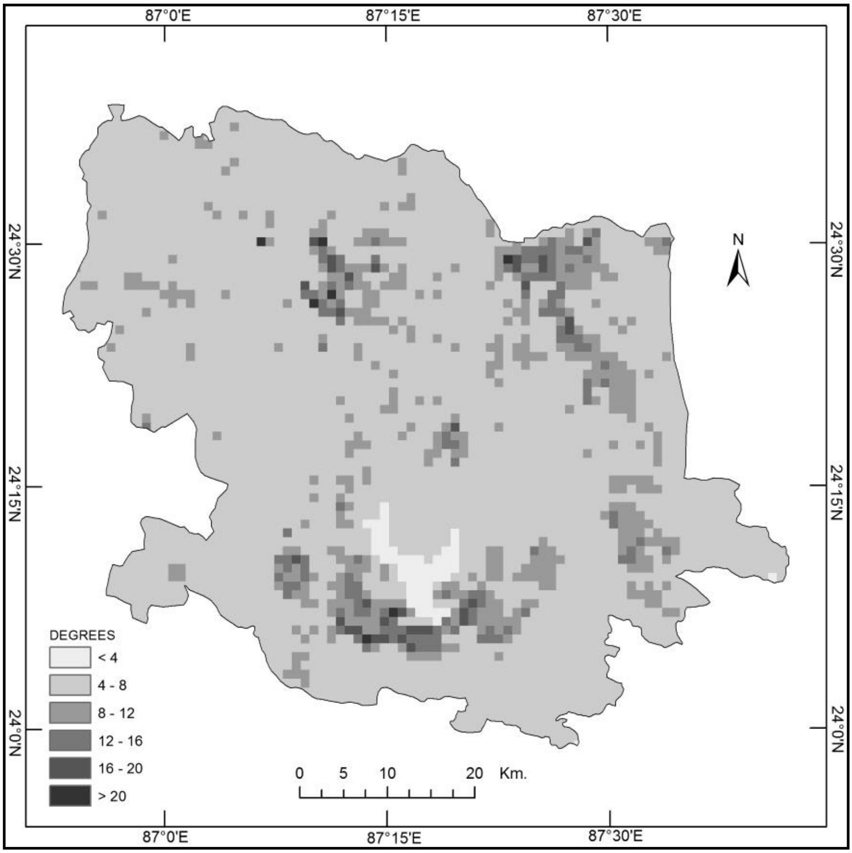

Fig. 5 Slope of Dumka Upland, Jharkhand, India

V. CONCLUSIONS

Analyses of relief characteristics using digital elevation models (DEMs) have several advantages over manual methods. The process being fully automated is free subjective bias and it is much faster, accurate and reliable. Local relief is scale dependent. The larger the grid over which it is measured, the greater the relief and vice versa. The choice of grid is dependent on two factors; on the scale of enquiry and on the resolution of the DEM. For regional level enquiry, one square kilometre grid is the most preferred choice. In the present paper, a moving window of one square kilometre has been prepared to scan the ASTER DEM and to obtain various relief parameters. A result of this window, minor topographic details have been subdued and more dominant features becomes discernible. The grids having higher absolute relief also have higher relative relief and steeper slopes. Grids having higher altitudes have greater potential for relief development. Higher altitudes also support steeper slopes. Hence, high correlation can be seen among absolute relief, relative relief and slope. However, relation between absolute relief and dissection index is very low. In Dumka, high absolute relief, high relative relief and steep slopes are found mainly over the summits of residual hills, which have survived dissection because of their structural resistance.

References

Burrough, P. A., & Mc Donnel, R. A. (1998). Principles of Geographical Information Systems. New York: Oxford University Press.

Holland, T. H. (1900). Mem. Geol. Surv. Ind. XXVIII. Calcutta: Govt. of India.

Holland, T. H. (1902). Mem. Geol. Surv. Ind. XXXIV. Part 2. Calcutta: Govt. of India.

Holland, T. H., & Tipper, G. H. (1913). Mem. Geol. Surv. Ind. XLIII. Part 1. Calcutta: Govt. of India.

King, W. (1880). Mem. Geol. Surv. Ind. XVI. Calcutta: Govt. of India.

Montogomery, D. R. (2006). Relief. In A. S. Goudie, Encyclopaedea of Geomorphology (pp. 840-842). Taylor and Francis e-library.

Nir, D. (1957). The Ratio of Relative and Absolute Altitudes of Mt. Carmel: A Contribution to the Problemof Relief Analysis and Relief Classification. Geographical Review , 564-569.

Smith, G. H. (1935). The Relative Relief of Ohio. Geographical Review , Vol. 25, No. 2, 272-284.

Wadia, D. N. (1919). Geology of India: For Students. London: Macmillan and Co., Limited.

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