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Assessment of Erosion Susceptibility Zones in Diring-Thanglong Watershed North Eastern Hill Regions of Assam using GIS Techniques

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Abstract: Assessment of erosion susceptibility zones has gained importance in natural resources management. The present study deals with erosion susceptibility zones through characterization of drainage morphometric parameters of Diring-Thanglong watershed of Assam state using Geographic Information System (GIS). The watershed showed high drainage density (2.75), bifurcation ratio (2.99) and stream frequency (3.59) and low circulatory ratio (0.58), elongation ratio (0.63) and length of overflow (0.18) with 5th order drainage stream, explaining the complex geomorphic processes occurring in the region due to variability in geological formations. Landform analysis was carried out through generation of various surface features *viz.,* digital elevation model (DEM), slope, hill shade as well as by interpretation of satellite imageries and vigorous ground truth collections. Nine geomorphic units were identified in the watershed. Erosion susceptibility zones were recognized in various geomorphic units based on ranking of morphometric parameters. Severe to very severe erosion susceptibility was observed on valleys and piedmonts, whereas, moderate erosion susceptibility was observed on steep hills, isolated hillocks and foot hill plains. Rapid stream response was responsible for severity of erosion, whereas, dense vegetative/ forest cover was responsible for controlling the risk of erosion.

Key words*: Drainage morphometry, erosion susceptibility, geomorphic units, landform, watershed*

Introduction

The North-Eastern Hill Region of India is characterized by heavy soil erosion, loss of top soil fertility and exploitation of forests by primitive agricultural practices like *jhumming,* denting sustainability of natural resources, acute environmental degradation and severe ecological imbalance (Sachchidananda 1989). One of the effective techniques in assessing erosion risk at watershed level is the watershed prioritization through morphometric analysis (Biswas *et al.* 1999; Javed *et al.* 2009). A number of studies have been accomplished in this regard to ascertain erosion risk zones at different scales *viz.,* watershed, sub watershed and drainage basins. Dutta and Roy (2012) assessed the erosion surfaces and stages of evolution of Sangra drainage basin in Giridih district, Jharkhand. Sarmah *et al.* (2012) characterized the drainage morphometry of a highland watershed in East Khasi Hills district of Meghalaya. Bagyaraj and Gurugnanam (2010) established the significance of morphometry studies of Kodaikanal Hills, Western Ghats towards comprehending the erosion and landform processes using Remote Sensing and GIS. It is apparent that GIS based erosion risk assessment gives quick information on the estimated value of soil loss or any part of the investigated area (Shinde *et al.* 2010). The objectives of the present endeavour are to characterize the drainage morphmetry of Diring-Thanglong watershed, Assam and to assess the erosion susceptibility zones of the watershed.

Materials and Methods

Study area

Diring-Thanglong watershed is situated in the geographic extent of 26°33' N to 26°37' N latitude and 93°26' E to 93°31' E longitude covering a total area of 2369.4 ha, in the border of Karbi-Anglong and Golaghat districts of Assam as shown in Fig. 1. It has been specified as “3B2E3”, where, '3' describes Brahmaputra and N.E. states rivers as Region, 'B' defines left bank of Brahmaputra as Basin, '2' denotes Kalong to Dhansiri confluence as Catchment, 'E' depicts along the left bank of

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Brahmaputra as Sub catchment and finally, '3' represents as Watershed as per Watershed Atlas of India (MOA 1990). Humid sub-tropical type of climate prevails in the watershed with agro-ecological sub region of 17.1 characterized by hot moist sub humid eco-region with length of growing period of 270-300 days. The watershed comprises complex geological formations where, ferruginous sandstones and shales are interspersed with Archean gneissic materials in the southern and central parts. The northern most part of the watershed lies under Golaghat area with flood plain developed on Brahmaputra alluvium of *Quaternary deposits* (GSI 2009).

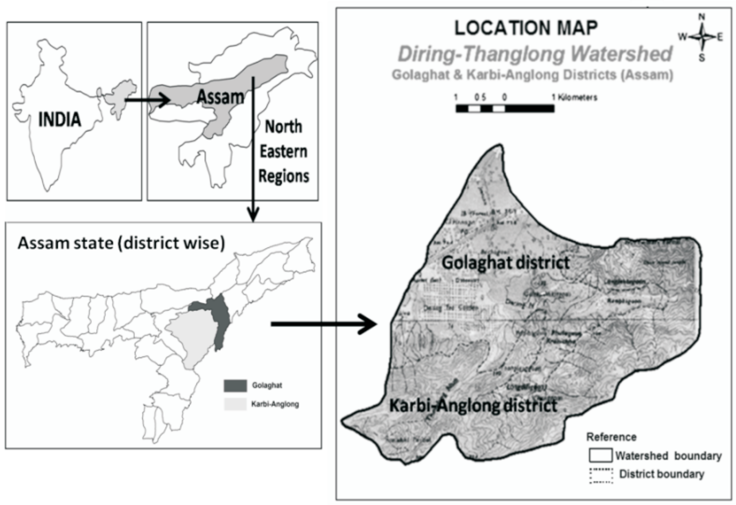

Fig. 1 Location map of Diring-Thanglong Watershed, Assam

Soils
The soils occurring on the hills and piedmonts are deep, well drained, loamy to clay loam in surface and clay loam to clayey texture in sub surface, extremely to strongly acidic in reaction and susceptible to moderate to severe erosion and are classified as Dystrudepts, Hapludalfs and Hapludults, whereas, the soils occurring on valleys and plains are very deep, somewhat poorly drained, silt loam to silty clay loam in surface and silty clay loam to silty clay texture in sub surface, moderately to weakly acidic in reaction with slight to moderate erosion susceptibility (Vadivelu *et al.* 2004).

Data used
Precision geo-coded IRS-P6 LISS-IV imageries (with 4, 3, 2 band combination in False Colour Composite) (22nd December, 2010) in Geo-Tiff format acquired from NRSC (ISRO, Govt. of India, Hyderabad) along with Survey of India (SOI) Toposheet (83 F/6) were used as base maps to identify major geomorphic features and to study the drainage morphometry of the watershed. The base map of the watershed is shown in Fig. 2.

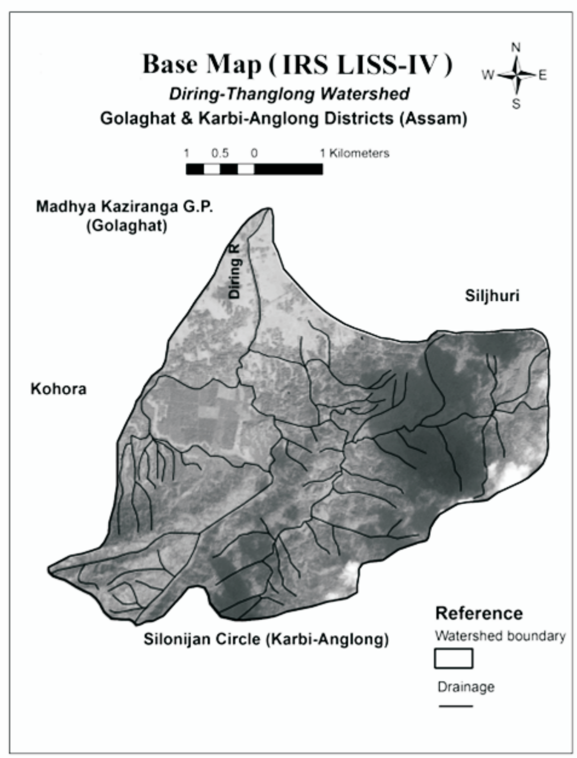

Fig. 2 IRS-P6 LISS-IV imagery (Base map) of Diring-Thanglong Watershed, Assam

GIS work

The GIS work was performed in *Arc GIS Ver. 10.0* software. At first, separate *shape files* were generated for watershed boundary, drainage streams and contour lines in *Arc Catalogue*. The boundary of the watershed along with drainage streams and contour lines (20 m interval) has been delineated in the Survey of India (SOI) Toposheet (83 F/6) and digitized in *Arc Map (Arcinfo)*. The geometry of shape file was polygon in case of watershed boundary and polylines in case of drainage and contours. The *Universal Transverse Mercator (UTM)* Projection system was used with the *Projected Coordinate UTM zone of 46 (N) Northern Hemisphere*. The geographic coordination system and the *datum* were chosen as *WGS 1984*. The order of each drainage stream (on hierarchical basis) and of contour lines (on elevation basis) were recorded against respective *FID* in the attribute tables of *Arcinfo*. The digitized contours were put to *Topo to Raster* operation using *Raster Interpolation* technique to obtain DEM of the watershed. From DEM, hill shade and slope maps were generated by *Surface Analysis* using *Spatial Analyst Tool*. The slope map was reclassified using *raster classification* technique into various slope gradient classes and verified further by groundtruthing. The geometry of different shape files (including areas and perimeters) were calculated using the projected coordinate system as the data source.

Landform analysis

Ground truth verification was done using precision geo-coded IRS-P6 LISS-IV FMX imageries along with Survey of India (SOI) Toposheet (83 F/6) on 1: 50000 scale for image interpretation and as per standard protocol (Gautam 2006). The geomorphic map of the watershed was finalized after interpretation of DEM, hillshade and slope maps and their validation by repeated field checking.

Drainage morphometry

Morphometry is the measurement and mathematical analysis of configuration of the earth surface and the shape and dimensions of its landforms (Thornbury 1969). Various linear, relief and aerial parameters of drainage morphometry were determined in GIS environment as per standard methods (Horton 1945; Miller 1953; Rekha *et al.* 2011; Schumn 1956; Strahler 1964) as described in Table 1. The drainage layer has been clipped with geomorphic unit layer by *Extraction* technique using *Analysis Tool* of *Arcinfo* to obtain distribution of drainage morphometric parameters on different geomorphic units of the watershed.

Table 1. Descriptions of morphometric parameters of the watershed

	Parameter	Descriptions	Reference
Linear	Stream Order	Hierarchical Order	Strahler 1964
	Stream length (Lu)	Length of Steams	Horton 1945
	Mean Stream Length (Lsm)	Stream length of order U/ Total no. of stream segments of order U	Horton 1945
	Basin Length (Lb)	The length of the river basin	Horton 1945
	Stream Length Ratio (Rl)	Total stream length of order U/ Stream length of next lower order.	Horton 1945
	Bifurcation Ratio (Rb)	Total number of stream segment of order U/ Number of segment of next higher order	Schumn 1956
Relief	Basin Relief (Bh)	Vertical distance between the lowest and highest points of watershed	Schumn 1956
	Ruggedness Number (Rn)	Basin relief × Drainage density	Schumn 1956
Aerial	Drainage Density (Dd)	Total length of streams/ Area of watershed	Horton 1945
	Stream Frequency (Fs)	Total number of streams/ Area of watershed	Horton 1945
	Texture Ratio (Ts)	Total number of first order streams/ Perimeter of watershed	Horton 1945
	Form Factor (Rf)	Area of watershed/ Square of Basin length	Horton 1932
	Circulatory Ratio (Rc)	4л × Area of watershed/ Square of Perimeter of watershed	Miller 1953
	Elongation Ratio (Re)	2 × √(Area of watershed/ л)/ Basin length	Schumn 1956
	Length of overflow (Lof)	1/ (2 × Drainage density)	Horton 1945
	Constant Channel Maintenance (C)	1/ Drainage density	Horton 1945

The drainage parameters like drainage density, bifurcation ratio and stream frequency were regarded as direct erosion influencing parameters (*i.e.* higher the values of these parameters, higher will be the erosion susceptibility) (Biswas *et al.* 1999) and circulatory ratio, texture ratio and length of overflow were regarded as indirect factors influencing erosion (*i.e.* lower the value higher will be the erosion susceptibility) (Nuka Ratnam *et al.* 2005).

Each parameter was given the ranking of 1 to 9 considering rank 1 for highest susceptibility for erosion and rank 9 for the lowest one. The compound parameter (CP) for each geomorphic unit was derived based on averaging the sum value of all ranks of considered parameters. The rank values of compound parameter was used to prioritize erosion susceptible zones considering that lower the rank value of compound parameter higher is the susceptibility to erosion. Similar studies were conducted in Kanera watershed of Guna district of Madhya Pradesh by Javed *et al.* (2009) and in Vena basin of Nagpur district of Maharashtra by Reddy *et al.* (2004). In the present study, the erosion susceptible zones were assessed and mapped in the watershed.

Results and Discussion

Interpretations of various surface features

Digital Elevation Model (DEM): The DEM of the watershed is shown in Fig. 3. The surface elevation of the watershed ranges from 80 m to more than 400 m above mean sea level (MSL). The elevation was found lowest in the northern parts (80 m) with gradual increase to the southern direction of the watershed which indicated flow directions of drainage streams of Diring and Thanglong rivers from southern to northern parts of the watershed, which, finally converges with *Domjan lake* located in the north-frontier part of the watershed.

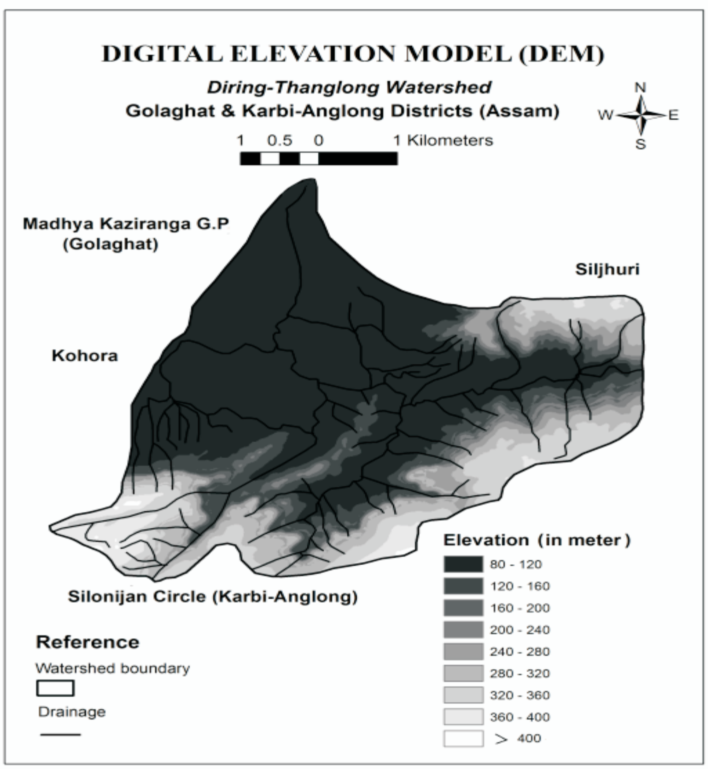

Fig. 3 Digital Elevation Model (DEM) of Diring-Thanglong watershed, Assam

Hill shade: The hillshade map (Fig. 4) has the legend with 256 numbers of illumination values (on 0 to 255 scales). The higher the value of illumination, the plainer is the surface and *vice versa*. The surface features appear planar in the northern parts, whereas, dissected and undulated in the central parts and steep with formation of ridges in the southern parts of the watershed as described in the hill shade map. Formation of isolated hillocks was recognized from hillshade map which has further been confirmed in the toposheet (83 F/6) after ground truth verification.

Slope: The slope map of the watershed showed five classes of slope gradient was *viz.,* very gently sloping (1-3%) covering 27.9% of total geographical area (TGA), gently sloping (3-5%) covering 17.8% of TGA, moderately sloping (5-10%) covering 4.0% of TGA, moderately steeply sloping (10-15%) covering 3.2% of TGA and steeply sloping (>15%) covering 47.1% of TGA as described in Table 2 and Fig. 4.

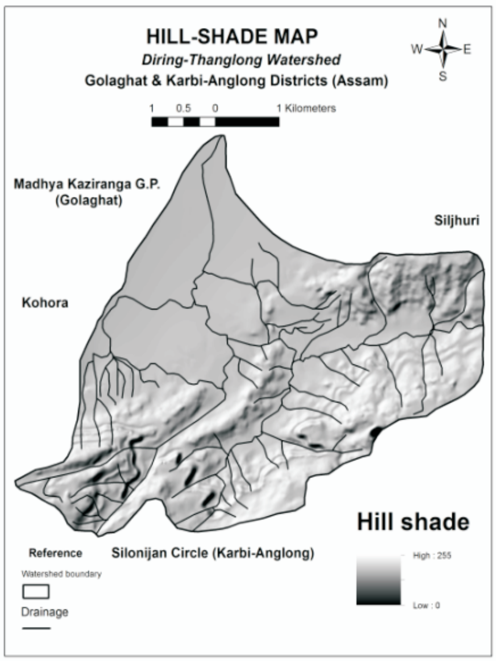

Fig. 4 Hill shade map of Diring-Thanglong Watershed, Assam

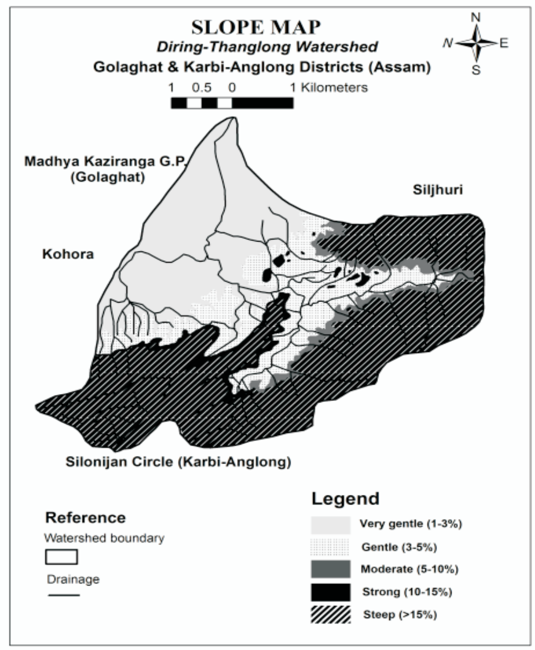

Fig. 5 Slope map of Diring-Thanglong Watershed, Assam

Table 2. Slope gradient classes of the watershed

Slope gradient (%)	Area (ha)	% of TGA
Very gently sloping (1 -3)	659.75	27.9
Gently sloping (3-5)	423.41	17.8
Moderately sloping (5-10)	94.20	4.0
Moderately steeply sloping (10-15)	75.94	3.2
Steeply sloping (>15)	1116.10	47.1
Total	**2369.40**	**100.0**

Delineation and characterization of landforms

The geomorphic units were characterized by their spectral signatures through interpretation of tone, texture, size, shape pattern and association. The spectral characteristics of geomorphic units are depicted in Table 3.

Nine geomorphic units were identified in the watershed as shown in Fig. 5 and Table 4. It was noticed that steep hills were densely covered with mixed deciduous forest vegetation occupying 47.1% of area, whereas, isolated hillocks with tea and rubber plantations constitute only 0.7% of area. Upper and lower piedmonts occupy 6.5% and 11.9% of area, respectively, with bamboo and homestead tea plantations, whereas, 8.9% of area was under gently sloping uplands with tea plantations. Inter-hill valley and narrow valley were paddy cultivated comprising 5.9% and 2.4% of area, respectively, whereas, foot hill plains and flood plains were also paddy cultivated occupying 4.1% and 12.5% of area, respectively. Similar kind of geomorphic features in Golaghat and Karbi-Anglong district of Assam were described in Assam District Gazetteers Report (1979)

Table 3. Spectral characteristics of geomorphic units

Geomorphic units	Spectral Signatures					
	Tone	Texture	Shape	Size	Pattern	Association
Steep hills -- forest vegetation	Dark reddish	Rough	Irregular	Large & extensive	Indefinite	Associated with inter-hill valleys
Isolated hillock -- tea & rubber plantation	Mixed red & green	Rough	Partially rounded	Small & scattered	Indefinite	Associated with upper & lower piedmonts
Upper piedmont -- homestead bamboo plantation	Mixed red & green	Rough	Irregular	Large & extensive	Indefinite	Associated with steep hills and inter-hill valleys
Lower piedmont -- homestead tea plantation	Mixed red & green	Partially smooth	Irregular	Medium	Indefinite	Associated with steep hills Upper piedmont and valleys
Inter-hill valleys -- paddy cultivation	Bluish green with patchy reddish	Partially smooth	Channel like shape	Large & extensive	Elongated	Associated with steep hills and upper piedmonts
Narrow valleys -- paddy cultivation	Mixed bluish green and red	Rough	Irregular	Small	Partially elongated	Associated with lower piedmont
Gently to very gently sloping uplands -- tea plantation	Combination of green and red	Smooth	Rectangular	Large	Definite	Associated with foot hill plains and flood plains
Very gently sloping foot hill plains -- paddy cultivation	Combination of bluish g reen and reddish	Rough	Irregular	Large	Indefinite	Associated with flood plains
Very gently sloping flood plains -- paddy cultivation	Bluish green with scattered reddish	Partially smooth	Partially triangular	Large & extensive	Indefinite	Associated with foot hill plains and uplands

Table 4. Geomorphic units of the watershed

Geomorphic units	Area (ha)	% of TGA
Steep hills -- forest vegetation	1116.10	47.1
Isolated hillock -- tea & rubber plantation	15.48	0.7
Upper piedmont – homestead banmboo plantation	154.66	6.5
Lower piedmont -- homestead tea plantation	281.73	11.9
Inter-hill valleys -- paddy cultivation	210.82	8.9
Narrow valleys -- paddy cultivation	141.68	5.9
Gently to very gently sloping uplands -- tea plantation	57.35	2.4
Very gently sloping foot hill plains -- paddy cultivation	96.32	4.1
Very gently sloping flood plains -- paddy cultivation	295.26	12.5
Total	**2369.40**	**100.0**

The steep hills in the southern part of the watershed is formed as a continuation of Karbi-Anglong Proper (Mikir Hills) which represents the detached part of peninsular shield with Archean gneissic formations. This group of hills is of relict type and is subjected to extreme denudation. As a consequence, the terrains on this broad physiography are extremely rugged and highly dissected. However, the upper and lower piedmonts are formed as depositional parts of the same. However, in the central and eastern parts of the watershed isolated hillocks and gently to very gently sloping uplands are developed on the eroded remnants of Panbari Parbat which represents Purvanchal Hills of ferruginous sand stones and shale formation. The inter-hill valleys and narrow valleys are formed as a result of rapid stream flows of Diring and Thanglong rivers. The flood plains are formed in the northern parts of the watershed as Quaternary deposits of Brahmaputra alluvium, whereas, foot hill plains are formed under the influence of both Quaternary deposits and as well as ferruginous materials of Purvanchal hills.

Characterisation of Morphometric Parameters

Evaluation of morphometric parameters involves the measurement and analysis of various stream attributes. Quantitative description of the watershed morphometry requires measurement of linear, relief and areal features, gradient of channel network and contributing ground slopes. Morphometric analysis in GIS is of immense help in understanding its interactive impacts on landforms, soils, hydrology and other environmental parameters. The drainage network map is shown in Fig. 6 and results of various drainage morphometric parameters are described in Table 5.

Table 5. Results of morphometric parameters of the watershed

Morphometric Parameter		Results
Stream Orders	1^{st} Order	55 (64.7%)
	2^{nd} Order	18 (21.2%)
	3^{rd} Order	7 (8.2%)
	4^{th} Order	4 (4.7%)
	5^{th} Order	1 (1.2%)
Linear	Length of Steams (Lu)	65.09 km
	Mean Stream Length (Lsm)	0.77 km
	Basin Length (Lb)	8.66 km
	Stream Length Ratio (Rl)	1.01
	Bifurcation Ratio (Rb)	2.99
Relief	Basin Relief (Bh)	0.33
	Ruggedness Number (Rn)	0.91
Aerial	Drainage Density (Dd)	2.75
	Stream Frequency (Fs)	3.59
	Texture Ratio (Ts)	2.43
	Form Factor (Rf)	0.32
	Circulatory Ratio (Rc)	0.58
	Elongation Ratio (Re)	0.63
	Length of overflow (Lof)	0.18
	Constant Channel Maintenance (C)	0.36

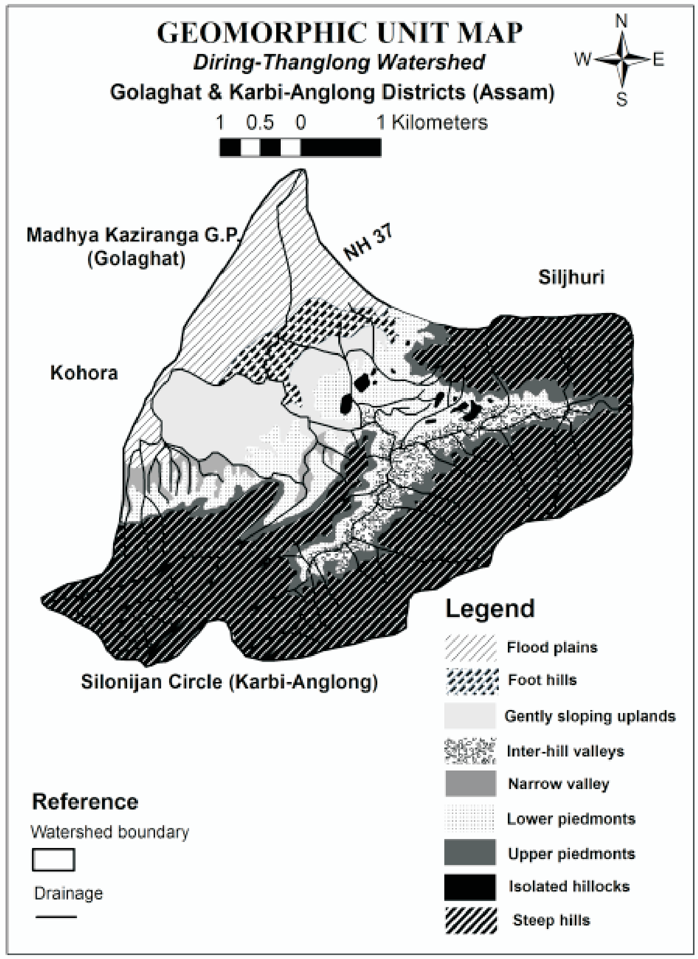

Fig. 6 Geomorphic unit map of Diring-Thanglong Watershed, Assam

Linear Parameters

Stream orders: The watershed has 5th order drainage morphometry. Generally, the total length of stream segments is the maximum in first order streams and decreases with an increase in the stream order for any ideal drainage stream network. Similar findings have also been observed in the watershed (Rekha *et al.* 2011). There are total 85 stream segments recognized in the watershed, out of which, 64.7% (55 no.) belonged to 1st order, 21.2% (18 no.) to 2nd, 8.2% (7no.) to 3rd, 4.7% (4 no.) to 4th and 1.2% (1 no.) belonged to 5th order.

Stream length: In the watershed, the total stream length was calculated as 65.09 km with mean stream length of 0.77 km and basin length was 8.66 km. The average stream length ratio was 1.01. The mean stream length is a characteristic property related to the drainage and its associated surfaces.

Drainage shape: The watershed has a pear shape (partially circular) with circulatory ratio of 0.58 with an elongation ratio of 0.63 showing the direction of flow of rivers from south to north. The value of elongation ratio generally varies from 0.6 to 1.0 (Javed *et al.* 2009) and a value of elongation ratio of less than 0.7 signifies less elongated nature of the watershed.

Relief Parameters

Basin relief: The watershed has low basin relief (0.33) as in the basin areas (flood plains) the slope gradient is less (only 1-3%) and permeability and infiltrations are high due to weak geological formations.

Ruggedness number: High ruggedness number (0.91) indicated highly dissected terrain formation rising sharply from the surrounding plains (Strahler 1964). It also signifies the gradual increase of slope gradients of the watershed from north to south.

Aerial Parameters

Form factor: A low form factor (0.32) of the watershed indicates less elongated nature, which in turn, indicates the less duration of horizontal flow and more duration of vertical flow of the streams in the low lying basin areas (flood plains).

Drainage pattern: the watershed has complex drainage pattern being partially parallel and partially dendritic indicating structural complexity due to occurrence of variable geological formations. This sort of drainage patterns also indicates the pronounced slope of the surface. Tributary streams tend to stretch out in a parallel following the slope of the surface.

Bifurcation ratio: It shows a small range of variation for different regions or for different environment except those where the powerful geological control dominates. The Rb is not the same from one order to its next order. These irregularities are dependent on geological and lithological development of the drainage basin (Strahler 1964). A high overall bifurcation ratio (2.99) of the watershed indicates structural disturbance owing to complex geological formations. It further indicates less structural control of the watershed on the drainage development. Highest bifurcation ratio was observed in upper piedmonts (4.39) and lowest in isolated hillocks (0.33) indicating that upper piedmont is of high erosion prone zone compared to isolated hillocks with least risk of erosion.

Drainage density: The watershed has over all high drainage density (2.75) emphasizing rapid-streams response from Diring and Thanglong rivers. This is further indicative of the regions of impermeable sub surface materials, sparse vegetation, and high relief features of the watershed. Drainage density was highest in narrow valleys (10.54) with high risk of erosion and lowest in isolated hillocks (0.75) with least risk of erosion.

Stream frequency: The watershed has high overall stream frequency (3.59) indicating that high relief and low infiltrations in the hill slopes with impermeable sub surface materials. This is also attributed to the complex geological formation of the watershed. Highest stream frequency was observed in upper piedmonts (44.69) indicated high risk of erosion.

Texture ratio: An overall texture ratio of 2.43 indicates fine drainage texture of the watershed due to its geological complexity. It was observed that texture ratio was lowest in isolated hillocks (0.19) and highest in upper piedmonts (1.37), which, indicates fine drainage texture in upper piedmonts with more erosion susceptibility and comparatively coarse drainage texture in isolated hillocks with relatively less risk of erosion.

Length of the overland flow and Constant channel maintenance: Low length of overflow (0.18) and low constant channel maintenance (0.36) indicated the structural complexity of the watershed with high surface runoff and low permeability in hill slopes due to presence of hard and impervious rocks. It has been noticed that values of length of overflow and constant channel maintenance were lowest in narrow valleys (0.05 and 0.10, respectively) and highest in isolated hillocks (0.67 and 1.34, respectively).

Prioritization of morphometric parameters: The compound parameters with rank values ranging from 3.00 to 4.00 were ranked as priority zone 1, and the zone comprising that rank value was designated as very severely susceptible to erosion. Similarly, compound parameters with rank values ranging from 4.00 to 5.00 were ranked as priority zone 2 and the zone was designated as severely susceptible to erosion, the zone with rank values ranging from 5.00 to 6.00 was ranked as priority zone 3 and designated as moderately severe susceptible to erosion, the zone with rank values ranging from 6.00 to 7.00 was ranked as priority zone 4 and designated as moderately susceptible to erosion and the zone with value more than 7.00 was ranked as priority zone 5 and designated as slightly susceptible to erosion. The prioritization of morphometric parameters is depicted in Table 6 and the erosion susceptibility zones of the micro watershed is described in Table 7. The erosion susceptibility map of the watershed is shown in Fig. 7.

Table 6. Prioritization of morphometric parameters of the watershed

Geomorphic units	Dd	Rb	Fs	Ts	Rc	Lof	CP	Priority ranking	Erosion susceptibility
	Values of parameters (Ranking)								
Steep hills	2.14 (7)	4.05 (2)	4.57 (8)	1.08 (8)	0.10 (6)	0.19 (7)	6.33	4	Moderate
Isolated hillocks	0.75 (9)	0.33 (9)	13.33 (5)	0.19 (1)	0.07 (5)	0.67 (9)	6.33	4	Moderate
Upper piedmont	6.57 (3)	4.39 (1)	44.69 (1)	1.37 (9)	0.01 (1)	0.08 (3)	3.00	1	Very severe
Lower piedmont	3.31 (5)	2.79 (5)	13.48 (4)	0.72 (5)	0.03 (2)	0.15 (5)	4.33	2	Severe
Inter-hill valleys	6.66 (2)	1.87 (6)	16.23 (3)	0.73 (6)	0.06 (3)	0.07 (2)	3.33	1	Very severe
Narrow valleys	10.54 (1)	3.15 (4)	24.39 (2)	0.85 (7)	0.05 (4)	0.05 (1)	3.17	1	Very severe
Gently to very gently sloping uplands	3.35 (4)	1.58 (7)	7.11 (6)	0.35 (3)	0.13 (7)	0.16 (6)	5.50	3	Moderately severe
Very gently sloping foot hill plains	3.25 (6)	1.5 (9)	5.19 (7)	0.27 (2)	0.22 (9)	0.14 (4)	6.17	4	Moderate
Very gently sloping flood plains	1.85 (8)	1.75 (8)	4.06 (9)	0.45 (4)	0.21 (8)	0.26 (8)	7.50	5	Slight

Table 7. Erosion susceptibility zones of the watershed

Erosion susceptibility zones	Area (ha)	% of TGA
Slight	295.26	12.5
Moderate	1227.90	51.9
Moderately severe	210.82	8.9
Severe	281.73	11.9
Very severe	154.66	6.5
Total	**2369.40**	**100.0**

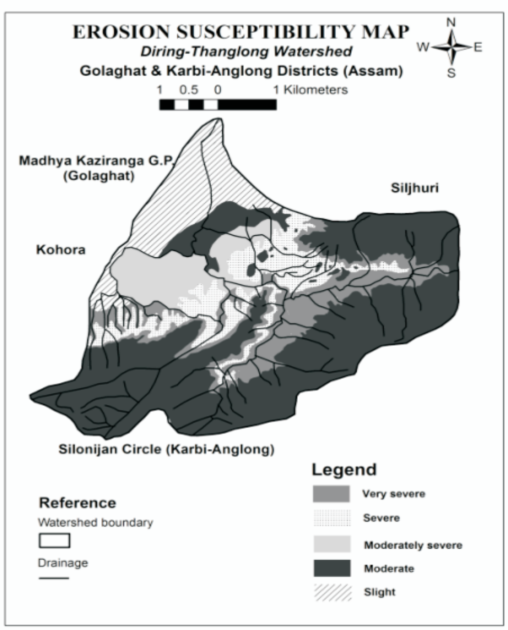

Fig. 7 Erosion susceptibility zone map of Diring-Thanglong Watershed, Assam

Interpretations: It has been noticed that erosion susceptibility is slight on flood plains, moderate on foot hill plains, moderately severe on gently to very gently sloping uplands, severe on lower piedmonts and very severe on upper piedmonts indicating gradual increase of severity of erosion with increasing elevation, slope and dissected nature of the terrain. With increasing slope and elevation of the terrains the stream response also increases with high run off potential as evidenced from high drainage density, high bifurcation ratio, high stream frequency and low circulatory ratio and low length of overflow. On the contrary, it has been observed that on steep hills and isolated hillocks erosion susceptibility was moderate whereas, on inter-hill and narrow valleys the same was very severe. Very severe erosion susceptibility in inter-hill valleys and narrow valleys is due to rapid stream response and high runoff potentials of upcoming streams of Diring and Thanglong rivers which practically truncate the surface soil materials from valley zones and deposit on flood plains. This is further been evidenced from high drainage density, high stream frequency and low length of overflow and low circulatory ratio in the valley zones. The reason behind the moderate erosion susceptibility on steep hills is the dense vegetative cover on steep hills and on isolated hillocks due to organized tea and rubber plantations restricting the risk of erosion to a great extent. The North-Eastern Hill Regions of India represent variable soil-landform relationships because of versatile geology, physiography and agro-climatic situations. The study on geology by Assam District Gazetteers, (1979) and Geological Survey of India (2009) revealed that there is a close association of two different geological formations in the district of Karbi-Anglong *viz., Purvanchal Hills of ferruginous sandstones and shales of Tipam and Dihing group* with an intrusion of *Karbi-Anglong proper of granite-gneissic* formation of *Archean group*. Hence, the complex and ambiguous morphometic behavior of the watershed is due to the complex geological formation where both the *Purvanchal Hills* and the *Karbi-Anglong proper* have their influence in weathering and soil formation.

Conclusions

Characterization and landform analysis of the watershed through drainage morphomertric parameters revealed high values of drainage density, bifurcation ratio, stream frequency and low values of circulatory ratio, elongation ratio and length of overflow indicating the complex morphometry of the watershed with rapid stream response and high run off potentials on hills, piedmonts, valleys and upland zones. Landform analysis also revealed the formation of versatile geomorphic units in the watershed with variable slope gradients from very gentle to steep. Erosion susceptibility in various geomorphic units was assessed in GIS environment based on ranking of morphometric parameters. Very severe erosion susceptibility was assessed on valleys and upper piedmonts owing to rapid stream response of Diring and Thanglong rivers, whereas, dense forest vegetation was responsible to check the risk of erosion on steep hills. The watershed represents two distinct geological formations in close proximity *viz., Purvanchal Hills* and the *Karbi-Anglong proper.*

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