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ACKNOWLEDGEMENTS. We thank the Director, NIO, Goa for permission to publish this work. We also thank the anonymous reviewer for constructive comments that helped improve the manuscript. Discussions with Dr B. Nagender Nath (NIO, Goa) have enhanced our understanding on phosphorus cycling. This is NIO's contribution No. 6013.

Received 3 March 2016; revised accepted 14 March 2017

doi: 10.18520/cs/v113/i03/473-478

Estimation of geomorphic threshold in permanent gullies of lateritic terrain in Birbhum, West Bengal, India

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The present geomorphic study focusses on predicting threshold conditions and vulnerable locations where gully heads might develop in the lateritic terrain, located at the eastern plateau fringe of Rajmahal Basalt Traps, Birbhum, West Bengal, India. The modern concept of geomorphic threshold is applied here on gully erosion hazard to identify the critical slope of gully head (S) and upstream drainage area (A) with a core relationship of $S = aA^{-b}$. Based on 118 gully heads we have statistically derived significant relationships between slope and drainage area ($r = -0.55$); overland flow (Q) and slope length (L; $r = 0.694$); relative shear stress (τ) and slope ($r = 0.915$); as well as overland flow detachment rate (H) and eroding force of overland flow (F; $r = 0.980$). The established S–A critical relationship, as geomorphic threshold, is expressed as $S = 17.419A^{-0.2517}$, above which gully initiation occurred on the laterites. This equation can be used as a predictive model to locate the vulnerable un-trenched slopes (i.e. potential gully erosion locations) in other lateritic areas of West Bengal. The constant b value (0.2517) and Montgomery-Dietrich envelope suggest a relative dominance of overland flow (52.51% of sample gully heads) in the erosion processes. The result of erosion model predicts an annual soil loss of 2.33–19.9 kg m^{-2} year^{-1} due to overland flow above the gully heads.

Keywords: Geomorphic threshold, gully, laterite, overland flow.

SOIL erosion is an issue where the adage 'think globally, act locally', is clearly applicable. Land degradation due to soil erosion is a momentous hazard in India[1] and gully erosion (i.e. extreme form of accelerated soil erosion) already engulfs about 3.975 million ha of land in India[2–4]. It is estimated that soil erosion takes place at the rate of 16.35 tonne ha^{-1} year^{-1} in India, and about 29% of total eroded soil is lost permanently to sea and 10% is deposited in reservoirs[5–8].

Loss of soil is accelerated due to gully erosion which represents a major sediment producing process, generating between 10% and 95% of total sediment mass at catchment scale, whereas gully channels often occupy less than 5% of total catchment area[9–11]. A gully is defined as an

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ephemeral or permanent channel with minimum cross-section of 930 cm^2 (ref. 12). It is mentioned that a gully is relatively deep (>0.6 m), recently formed eroding channel (with ephemeral flow) on valley sides and on valley floors where no well-defined channel previously existed and it has steep sides, low width–depth ratio and stepped profile (presence of knick points), characteristically with a headcut (with plunge pool) at the upslope end, dominated by the processes of surface flow, piping and mass movement[13–17].

Gully initiation by surface hydro-geomorphic processes has been recognized as a threshold phenomenon related to the size of the contribution drainage area and its slope[18–20]. A geomorphic threshold is one that is inherent in the manner, within the geomorphic system, by changes in the morphology of the landform itself through time[21]. It is a threshold of landform instability[18] that is exceeded either by intrinsic change (e.g. slope steepness and soil cohesion) of the landform or by a progressive change of an external variable (e.g. extreme rainfall event, land-use conversion, climate change and neo-tectonic uplift)[21–29]. The significance of the geomorphic threshold concept for this study is that it makes us aware that abrupt erosional and depositional changes in the badlands can be inherent in the normal development of a landscape and that change in an external variable is not always required for a geomorphic threshold to be exceeded and for a significant geomorphic event to ensue. From the experimental studies in parts of Africa, Asia, Europe and North America, it is observed that maximum contributing drainage area above gully head is considered as the most influential positive factor to develop gully[25–29].

The prime objective of this study is to investigate geomorphic threshold of permanent gullies and to estimate the responsible factors of erosion on the least explored lateritic terrain of West Bengal. It is hypothesized that the gullies over laterites develop when the geomorphic thresholds (extrinsic or intrinsic) are transgressed due to either a decrease in the resistance of materials (i.e. erodibility) or an increase in the erosivity of runoff or both.

The study area (about 176 sq. km) is situated between the adjoining region of western Rampurhat I block of Birbhum district, West Bengal and eastern Shikaripara block of Dumka district, Jharkhand (encompassed by 24°08′–24°14′N and 87°38′–87°44′E) (Figure 1). This geomorphic unit is recognized as an elevated interfluve of laterites (Rarh Bengal)[30,31] between Brahmani (north) and Dwarka (south) rivers and is the eastern plateau fringe of Rajmahal Basalt Traps (~118 Ma)[30]. Elevation of this unit ranges from 20 to 80 m, having an average slope of 2.17° towards south-east. The *in situ* primary laterites (Pliocene to Early Pleistocene) and *ex situ* secondary laterites (Early to Late Pleistocene) are simultaneously found in this eastern fringe of Rajmahal Basalt Traps (Early Cretaceous)[30] (Figure 2). The climate of this region is sub-humid and subtropical monsoon type, receiving mean annual rainfall of 1437 mm. The monsoon and cyclonic rainfall intensity of 21.51–25.51 mm h^{-1} is the most powerful climate factor to develop these lateritic badlands. The thin ferruginous soil is loamy-skeletal and hypothermic (weak fine crumb and granular structure, 2–5 mm size of manganese nodules, >2 mm size of ferruginous nodules with goethite cortex, 30–80% coarse fragments) in nature, developing in the barren lateritic wastelands and forest areas with sparse bushy vegetation.

Base map of the study area is prepared from SOI (Survey of India) topographical sheet of 1 : 25,000 scale (72 P/12/NE and 72 P/16/NW, 1979–1980) using Erdas 9.1 and ArcGIS 9.3 software. The regional elevation information is collected from USGS (United States Geological Survey, earth explorer) and ASTER (*Advanced Spaceborne Thermal Emission and Reflection* Radiometer) data of 2011 having 30 m of spatial resolution. All the maps are geo-referenced in UTM (universal transverse mercator) projection with WGS-84 (world geodetic survey, 1984) datum. The locations of laterite exposures and gullies are mapped on the basis of field expeditions, toposheets, survey points of Gramin GPS (global positioning

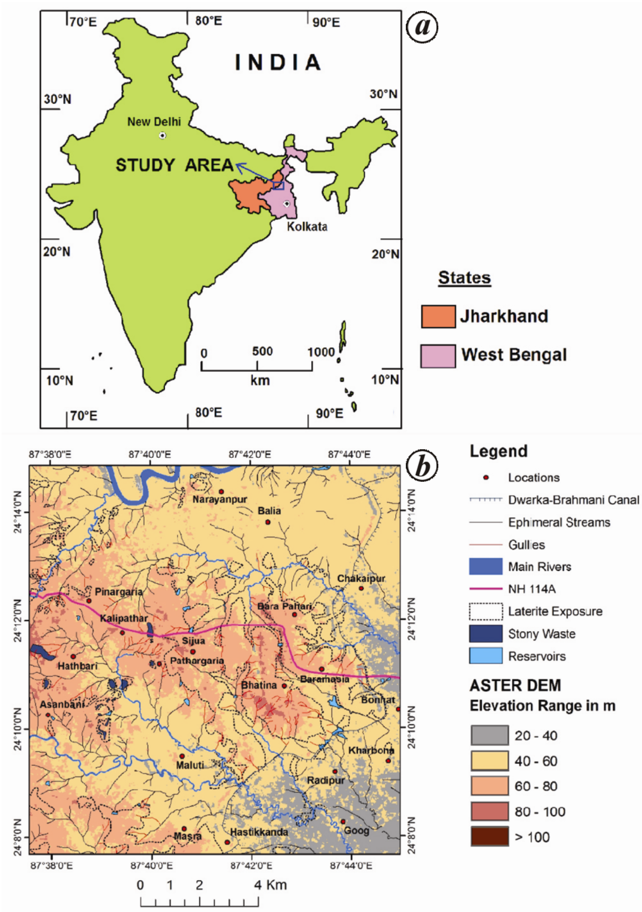

Figure 1. ***a***, Location of study area in India. ***b***, Spatial distribution of elevation, location of permanent gullies, streams and reservoirs, and exposures of laterites in the study area.

Figure 2. ***a***, Collection of sediment at the base of gully head at Maluti, Jharkhand. ***b***, Barren lateritic upstream landscape of gully-head catchment at Bhatina, West Bengal. ***c***, downstream dissection of laterites by deeply incised gully and expansion gully heads at Bhatina, West Bengal.

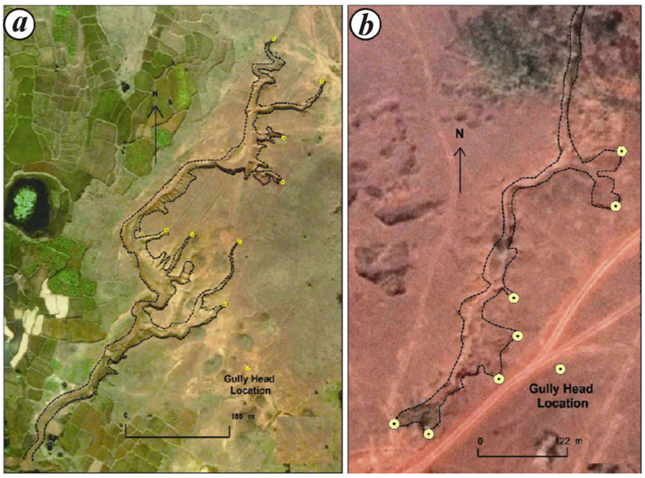

Figure 3. Spatial extent of two gullies and sample locations of gully heads in the areas of (***a***) Maluti (24°09′45″N, 87°41′14″E) and (***b***) Bhatina (24°10′25″N, 87°42′33″E) (Google Earth imagery date: 13/01/2014).

system) 76CSx receiver (horizontal accuracy of ±3 m), Google Earth Map and GSI (Geological Survey of India) district resource maps of Birbhum and Dumka. The relationships between variables are examined by performing Pearson's product moment correlation (r), coefficient of determination (R^2), nonlinear regression analysis and statistical tests and finally depicting graphically on the scatter diagrams to get the overall picture. The spatial scale used to study the erosion process is plot-scale (10–10 sq. m) and field scale (100–10,000 sq. m). To understand topographic thresholds the present work included 118 gully heads (3rd and 2nd order drainage basin) from the region and among these gully heads we selected slope segments of 146 valley-side and gully-head slopes, to establish drainage area and slope threshold (Figure 3). Sprinter 150 m of Leica Geosystem is used to measure the angle of slope segments and in few cases the slope angle is measured from ASTER DEM (digital elevation model).

Channel initiation by surface processes has been viewed as a threshold phenomenon related to size of contributing area (A) and its slope critical valley (S)[19,25–29,32,33]. The relation between S and A is used as a predictive model to locate the areas of instability within lateritic interfluves where gullies will form.

$$S = aA^{-b}, \tag{1}$$

where a is coefficient and b is exponent of relative area.

A slope versus drainage area relation is plotted on a semi-logarithmic graph for gullied and un-gullied valley reaches. A threshold line is drawn through the lower limit of scatter of the points[21] and this line represents, for a given area, a critical value for valley slope above which entrenchment of the laterite occurs. An empirically derived equation is developed based on S–A relationship, relating to the ratio of shear stress, applied by the flow and average shear stress of gully channel[34].

$$\text{Relative shear stress } (\tau) = A^{\text{b}}S/a. \tag{2}$$

We have applied Montgomery–Dietrich (M–D) envelope[20,26] as a tool to predict and compare the exact active processes to initiate gully heads. To denote the critical tractive or eroding force required for overland flow to initiate a channel, Du Boy's equation is applied here[18,35].

$$F = wd \sin\theta, \tag{3}$$

where F is the tractive or eroding force exerted on the slope by overland flow (gm cm^{-2}), w the specific weight of water, gm cm^{-3} (assumed constant), d the depth of flow in cm and θ is the gradient of ground slope.

We have applied the revised Morgan Morgan Finney model (RMMF) to estimate annual overland flow and its annual detachment rate and transport capacity[36–38]. The critical values of parameter are collected from table values of RMMF model[37]. The details of equations used are summarized as follows.

$$R_{\text{f}} = R(1 - \text{PI})1/\cos S, \tag{4}$$

$$R_{\text{c}} = 1000 \text{ MS BD EHD } (E_{\text{t}}/E_0)^{0.5}, \tag{5}$$

Table 1. Summary of parametric values of selected variables of gully erosion (i.e. major determinants of geomorphic thresholds) in study area

Slope length (L)		Slope gradient (S)		Drainage area (A)		Overland flow eroding force range (F)	Upstream overland flow range (Q)	Detachment of lateritic surface by overland flow (H)	Transport capacity by overland flow (G)
Range	Mean	Range	Mean	Range	Mean				
24.63 to 200.3 m	71.72 m	1.39 to 12.58°	4.6°	457.08 to 10513.9 m^2	4112.8 m^2	0.58 to 5.32 Nm^{-2}	560.58 to 693.45 mm	2.33 to 14.6 kg m^{-2} $year^{-1}$	8.8 to 72.3 kg m^{-2} $year^{-1}$

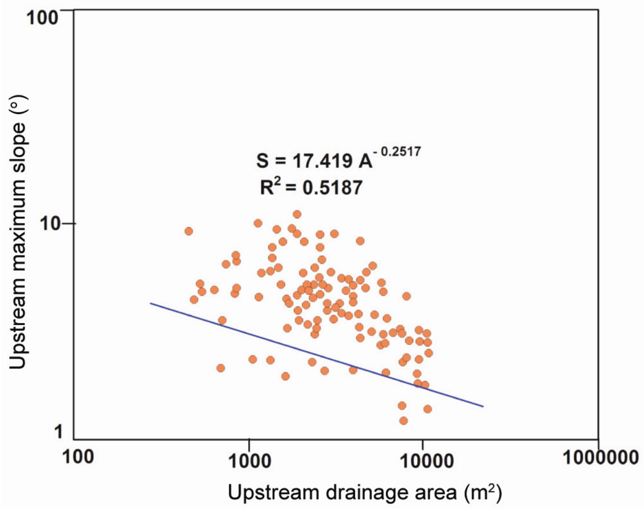

Figure 4. Establishing critical slope–area threshold relation ($S = 17.419A^{-0.2517}$) for the gullies of lateritic terrain on the basis of intrinsic thresholds S (in °) and A (in m^2).

$$R_0 = R/R_n, \quad (6)$$

$$Q = R_f \exp(-R_c/R_0)(L/10)^{0.1}, \quad (7)$$

where R_f is effective rainfall, R the mean annual rainfall, R_0 ratio of mean rainfall to rainy days, PI the permanent interception by vegetation cover on slope, S the slope, R_c the soil moisture storage capacity, MS the soil moisture content at field capacity, BD the bulk density of top soils, EHD the effective hydrological depth, Q the ratio of actual to potential evapotranspiration and L is the slope length, E_t/E_0 the ratio of actual to potential evapotranspiration, R_n is the number of rainy days in a year (Table 3).

In RMMF net flow erosion is derived from the minimum value between annual rate of soil particle detachment by overland flow (H) and annual transporting capacity of overland flow (G) (if $H < G$ then net annual erosion is H and vice versa).

$$H = ZQ^{1.5}\sin S(1 - \mathrm{GC})10^{-3}, \quad (8)$$

$$Z = 1/\mathrm{COH}, \quad (9)$$

$$G = CQ \sin S\ 10^{-3}, \quad (10)$$

where Z is soil erodibility constant, GC the ground cover, COH the soil cohesion and C the crop cover factor.

To judge and validate the calculated S–A relation (i.e. statistically fit or not), we have performed two statistical techniques, viz. (1) Student's t test of correlation coefficient (r), and (2) significance test of standard error of b (S_E)[39].

$$\text{Student's } t = r\sqrt{(N-2)}/\sqrt{(1-r^2)}, \quad (11)$$

where r is Pearson product moment correlation coefficient, N the total samples and $N - 2$ the degree of freedom.

$$S_E = b\sqrt{(1-r^2)}/N, \quad (12)$$

where the confidence limit of calculated S_E of b is ($b \pm 1.96S_E$).

The performance of the model is validated by the value of efficiency coefficient (EC)[40] and is applied successfully in the soil erosion research[38,41].

$$\mathrm{EC} = 1 - \Sigma(Q_{obs} - Q_{pred})^2/(Q_{obs} - Q'_{obs})^2. \quad (13)$$

In the above equation Q_{obs} is the measured value, Q_{pred} the calculated value and Q'_{obs} is the mean of measured value.

The upstream slopes above gully heads (Table 1) are negatively correlated ($r = -0.55$) with upstream drainage areas which are used as surrogate for the volume of runoff yield in the study area. A significant line is fitted through the lower-most scatter points for study sites which are incised to form gully heads. This empirical trend line ($S = 17.419A^{-0.2517}$, with R^2 of 0.52) provides an approximation to S–A threshold relationship for gully incision (Figure 4). Any site (un-trenched or trenched by gullies) lying above this critical line is more prone to gully erosion on this terrain of laterites. It is derived that the mean critical threshold slope for the initiation of gullies is 2.34°. The high value of a (i.e. 17.419) signifies the initiation of gullies by high volume of overland flow and small landslides in study sites. The negative value of b (i.e. –0.2517) and in general, $b > 0.2$ is considered, to identify the dominancy of overland flow erosion over sub-surface processes in the study area[25–28].

Development of numerous gullies on laterites reflects the geomorphic instability in the landform itself, when the critical hydro-geomorphic situation crosses the threshold limit, i.e. $SA^{0.2715} > T$ (T is the threshold value, i.e. 17.42 for this study site). It is estimated that critical drainage area for the slope of 2.34° is about 2908 sq. m to initiate gully. Here we have compared our result of S–A threshold relation with results of various studies conducted in different environments (Figure 5). It is found that our S–A critical line of threshold is placed below other lines, signifying a minimum geomorphic threshold to gully incision in this tropical sub-humid monsoon climate and other geographical conditions.

We have checked and validated the calculated S–A relation using eqs (11) and (12). The null hypothesis (H_0) is that there is no significant correlation between the two variables. For 116 degree of freedom ($N - 2$) the tabulated t value is 3.29 in 0.001 significance level (two-tailed), but our calculated t value (7.09) is much greater than tabulated t. This result reflects the rejection of H_0 and acceptance of alternative hypothesis which favours a significant and core inter-relation between S and A in the geomorphic system of gully erosion. The calculated confidence limit of S_E of b (0.271–0.232) does not enclose zero (i.e. zero gradient). It shows that the power regression ($S = 17.419A^{-0.2517}$) is certainly significant at 5% level. Therefore, this S–A threshold equation of channel initiation is valid statistically and can be applied in other erosion prone lateritic areas of Rarh Bengal.

Through inserting the values of drainage area (Q_{obs}) in the equation of $S = 17.419A^{-0.2517}$, the predicated slope values (Q_{pred}) of each gully are calculated. The mean slope of sample gullies (Q'_{obs}) is 4.6°. EC (eq. (13)) is estimated in case of slope prediction and its value is greater than 0.63 (greater than 0.5) which is generally interpreted that this model performs satisfactorily. Therefore, this model is validated in the study area. For the experiment, S–A model is applied in 82 gully heads of Masra–Jatla area (24°06′37″ to 24°08′15″N, 87°39′38″ to 87°41′14″E) and Bolpur–Santiniketan area (23°40′47″ to 23°41′46″N, 87°39′47″ to 87°40′36″E) of Birbhum district. In this badlands of laterites, we derived two distinct threshold equations of $S = 14.368A^{-0.236}$ (R^2 of 0.44) for Masra–Jatla area and $S = 112.48A^{-0.473}$ (R^2 of 0.85) for Bolpur–Santiniketan area respectively. In both cases, the dominancy of overland flow erosion is identified from significant b value (i.e. >0.2). In these two regions we have found that the value of EC varies from 0.54 to 0.77, depicting a good performance of S–A model.

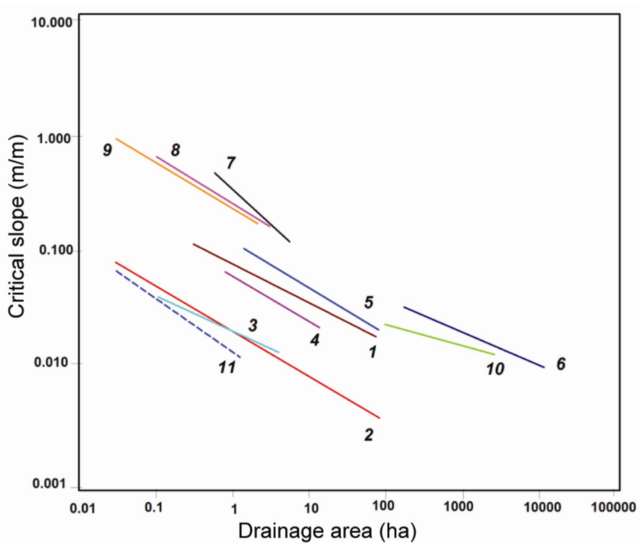

Figure 5. Comparing the calculated critical slope and drainage area threshold line (dotted line 11) with threshold lines (1 to 10) of other studies for understanding incipient gully development in a variety of environments (abroad India). Locations of study areas: (1), (2) Central Belgium; (3) Portugal; (4) France; (5) South Downs UK; (6), (7) Sierra Nevada USA; (8) California USA; (9) Oregon, USA, and (10) New South Wales Australia (modified from Patton and Schumm[19]; Montgomery and Dietrich[20]; Vandaele *et al.*[25]; Boardman; Poesen *et al.*[9]).

From b value (i.e. 0.2717) we have found the relative dominance of Hortonian overland flow[12] in the gully erosion. A theoretical division of the landscape into process regimes in terms of log S (X axis) and log A (Y axis) signifies different geomorphic thresholds to gully erosion and the resultant threshold line is popularized as Montgomery–Dietrich (M–D) envelope of A–S threshold. From M–D envelope, we have classified gully heads on the basis of erosion dominancy (Figure 6). In this study area, 52.51% and 27.96% of gullies are affected by overland flow erosion ($S = 1.23°$–$5.24°$ and $A = 2129.05$–10513.90 sq. m) and landslide erosion ($S = 5.20°$–$9.51°$ and $A = 457.08$–5702.5 sq. m) respectively (Table 2).

By adding appropriate values of S and A for each sample site in the slope-area threshold relation ($\tau = SA^{0.2517}/17.419$, neglecting negative sign of $b = 0.2517$, the slope of the trend line), we have estimated relative shear stress as gradational threshold which is a geomorphic indicator of energy state expression of the gully system. The result suggests a positive significant correlation ($r = 0.915$) between slope steepness (S) and relative shear stress (τ). In these experimental sites, with increasing value of S, the magnitude of τ steadily increases with a linear relation of $\tau = 0.32675 + 0.4352$ (R^2 of 0.838). This signifies that to develop gully head, the increasing slope provides more kinetic energy to flow which generates more shear stress on the lateritic surface (Figure 7).

Using eqs (4)–(7), we found that 118 catchments of gully heads yield an annual overland flow of 560.68–693.45 mm on laterites terrain which have the least growth of tropical deciduous vegetation cover and ample portion of bare crust soils (Table 3). The calculated mean overland flow of 619.51 mm is found to be sufficient to instigate rill and gully on critical slope angle and length. Du Boy's eq. (3) shows that the exerted eroding force of overland flow (measured mean depth of overland flow is 0.0025 m) ranges from 0.58 to 5.32 N m^{-2} above the gully heads. Here the slope–length ratio (S–L) is found to be an important geomorphic variable of fluvial erosion to denote relative dominancy of high slope with low length

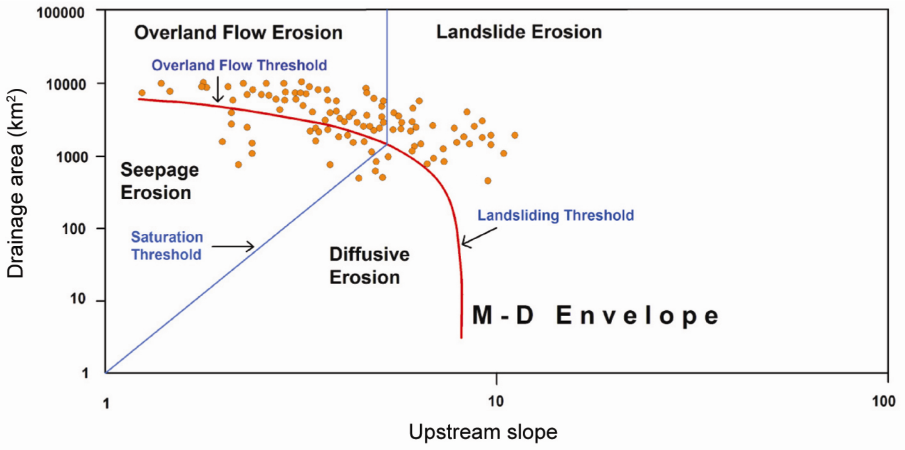

Figure 6. The diagram showing S (in °)–A (in m^2) scatter plot in M–D envelope (i.e. red curve) to depict erosion dominant gullies in the study area.

Table 2. Distribution of gully heads in respect of dominant erosion process using M–D envelope

Dominant gully erosion process	Percentage of gully heads	Slope range (°)	Area range (m^2)
Overland flow erosion	52.51	1.2–5.2	2129.1 to 10513.9
Seepage erosion	15.25	2.2–4.6	685.5 to 3843.7
Landslide erosion	27.96	5.2–9.5	457.1 to 5702.5
Diffusive erosion	4.28	4.4–5.3	483.2 to 879.9

Table 3. Important parameters with typical values used in RMMF model and other equations

Parameter	Parameter code	Typical value and range
Mean annual rainfall	R	1437 mm
Number of average rainy days	Rn	191 days
Soil moisture storage capacity	Rc	7.736
Permanent interception by vegetation cover on slope	PI	0 to 1
Crop cover management factor	C	1
Soil moisture content at field capacity (wt%)	MS	0.4
Bulk density of top lateritic soil (Mg m^{-3})	BD	1.73
Effective hydrological depth of soil (m)	EHD	0.05
Ratio of actual to potential evapotranspiration	E_t/E_o	0.05
Cohesion of surface soil	COH	3
Mean flow depth of overland flow (m)	d	0.0025
Specific weight of water (kN m^{-3})	w	9.807

Table 4. Validated and significant equations of gully erosion system in the study area

Relation between variables	a	b	Established equation	r	R^2
S–A (threshold relation)	17.419	–0.2517	$S = 17.419A^{-0.2517}$	–0.550	0.518
τ–S	0.4352	0.3267	$\tau = 0.3267S + 0.4352$	0.915	0.838
F–L	4.9511	–0.7219	$F = -0.41 \log L + 2.464$	–0.320	0.487
Q–SL	539.63	–0.0498	$Q = 539.63SL^{-0.0498}$	0.694	0.633
H–F	0.6242	3.8266	$H = 3.8266F + 0.6242$	0.980	0.975

S, Upstream slope gradient above gully head; A, Catchment area of gully head; τ, Relative shear stress; F, Eroding force by overland flow; L, Slope length above gully head; Q, Overland flow; SL, Slope–length ratio; H, Detachment by overland flow.

(i.e. high S–L value) in the gully erosion. There is significant negative correlation of –0.694 (significant relation, tested by Student's t) between S–L and annual overland flow. The deep gully heads with depth of 2.11–3.72 m have high S–L value of 0.21–0.45, which means that these deep gullies of laterites are formed due to high angle of slope with relatively low slope length and an average of 560 mm overland flow erosion. Basically, high

S–L with large catchment is the most vulnerable site of gully erosion. Here, overland flow is empirically related with S–L, developing a trend line of $Q = 539.63\ S\text{–}L^{-0.0498}$ (R^2 of 0.6537) (Figure 7). Slope length is found to be related with eroding force of overland flow (F), forming a critical trend line of $F = -0.7219 \log F + 4.9511$ (Figure 8).

Interestingly, when 28 un-trenched slope facets are plotted on the scatter diagram, the slopes are found to be of critical erosion potentiality, because these points are located high above the trend line. Thus, these slopes on laterites needed special attention to avoid initial rill and gully formation. These vulnerable slopes vary in length from 72.2 to 221.6 m and in angle from 5.1° to 13.57° (Figure 9). The only safety factor of these sites is that the lateritic terrain is covered widely by bushes, grasses, few tropical deciduous trees (mainly *Sal*) and *Acacia* plantation.

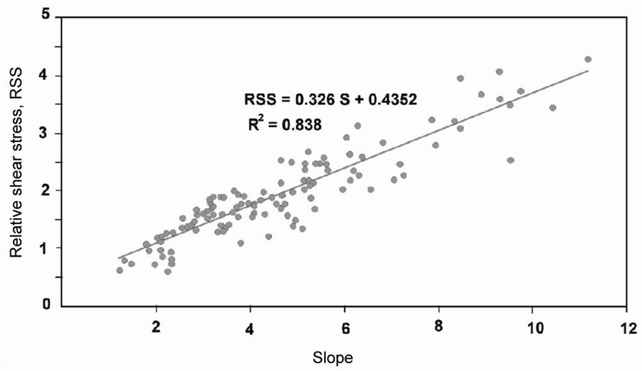

Figure 7. With increasing upstream slope of gully head, the potential relative shear stress (i.e. a ratio) of laterite slope facet is steadily increased, reflecting vulnerability of gully erosion by flow on steep slope.

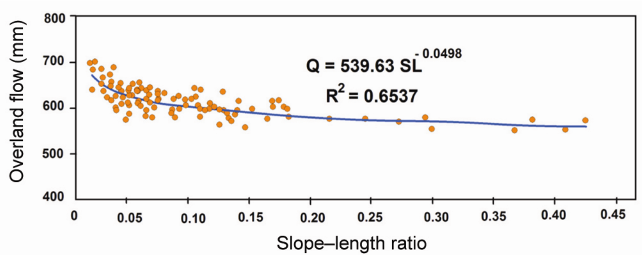

Figure 8. Overland flow (in mm) of each slope facet is decreased with increasing slope–length (S–L) ratio, above gully heads.

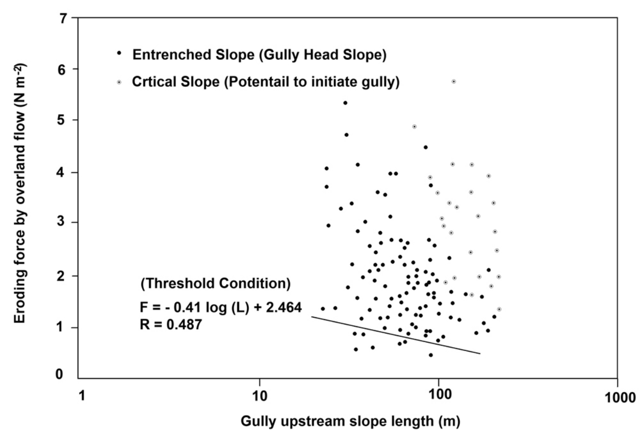

Figure 9. Identification of vulnerable untrenched slopes (in green coloured scatter) in the relation between critical slope (in °) of gully-head catchment and eroding force by overland flow (in N m^{-2}).

Detachment by rain splash and rill erosion above the gully heads are the major sources of sediment for gully catchment and transporting sediment downslope by runoff which is estimated by RMMF model. The analysis of RMMF model reveals that G is very high on this terrain, ranging from 8.8 to 72.3 kg m^{-2} year^{-1}, but the present H ranges from only 2.33 to 19.9 kg m^{-2} year^{-1}, i.e. the annual rate of flow erosion in the sample catchments. Here soil erosion exceeded the general permissible limit (11.20 t ha^{-1} year^{-1}). It is observed that with increasing F, the value of H also steadily increases in the slopes. This positive linear relation is depicted as $H = 3.8266\ F + 0.6242$ (R^2 of 0.9752), having significant correlation coefficient of 0.98 (tested by Student's t; Figure 10). Since the calculated confidence limit of S_E of b (0.645 to 0.602) is not zero, this relation is therefore statistically valid for the lateritic region. Catchments with high values of F annually yield high amount of sediment (>8 kg m^{-2} year^{-1}) due to overland flow erosion. We have developed five important empirical equations (i.e. statistically viable) of geomorphic system in the lateritic region to depict the role of thresholds in gully erosion (Table 4).

Determination of significant geomorphic intrinsic and extrinsic thresholds (viz. slope, drainage area and overland flow) is considered practically and statistically validated approach to study gully erosion processes by cause and effect analysis. Under the influence of extrinsic threshold (Q), the instability of gully erosion system is finally triggered by the intrinsic threshold (A and S) which already exists within the system. In the study sites, gullies are formed by deepening of rills and slumping of side slopes through the shearing effect of concentrated overland flow, increase in pore-water pressure and decrease in soil strength along seepage lines close to the streams. Gully development in the vicinity of concentrated flow is

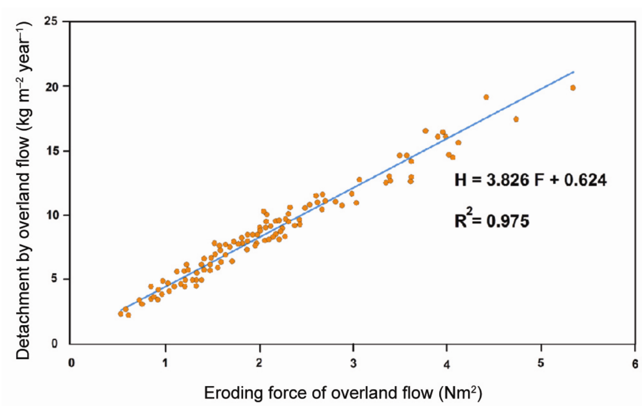

Figure 10. With increasing eroding force by overland flow (in Nm^{-2}) the annual detachment of soil particle by flow (in kg m^{-2} year^{-1}) is steadily increased above gully heads, emphasizing flow dominant erosion.

facilitated in the lateritic sediments with predominantly coarse-textured upper horizon (i.e. secondary duricrust of loose ferruginous nodules) abruptly overlying a compact, less permeable underlying mottle clay and kaolinite pallid zone (B horizon).

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ACKNOWLEDGEMENTS. The research was funded by the University Grants Commission, New Delhi (Major Project No.: UGC-MRP-MAJOR-GEOG-2013-37968). We thank Rahaman Ashique Ilahi, Suvendu Roy, Subhankar Bera and Subhamay Ghosh for their supports in the field study. We thank reviewers for providing critical comments and suggestions on this research work.

Received 7 June 2015; revised accepted 28 February 2017

doi: 10.18520/cs/v113/i03/478-485