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PREDICTING SOIL EROSION BY WATER AND ITS MANAGEMENT IN THE LATERITIC AREAS OF WESTERN RAMPURHAT I BLOCK (BIRBHUM, WEST BENGAL)

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ABSTRACT

Environmental geography and environmental geomorphology severally emphasize that unless loss of soil is checked, it would amount to a great loss for mankind. Present investigation was conducted to assess the present status of soil loss and sediment yield in the selected adjoining lateritic areas (Cainozoic upland of laterites) of Rampurhat I block, Birbhum district (West Bengal) and Shikaripara block, Dumka district (Jharkhand). The field study revealed that different forms of water erosion are operated there in varying magnitude. In particular rainsplash erosion, sheet and inter-rill erosion (overland flow), rill and gully erosion are considered here as major forms of water erosion. The soil series of Bhatina, Raspur, Jhinjharpur and Maldiha are shallow, light-textured and gravelly with very low moisture retention capacity, low pH and low amount of clay and organic matter. These soils (remained under barren waste land with sparse bushy vegetation) are susceptible to moderate-severe rain-splash, rill and gully erosion, and should be kept under thick vegetative cover and afforestation. To understand and prevent the soil erosion at first we should make some precise quantitative estimation of soil loss. In order that, taking small catchments and slope facets as ideal geomorphic unit, the present study is centrally focused on the charteristics of lateritic soil, the empirical quantification of soil loss and implementation of low-cost soil conservation measures.

Keywords: Laterites; rain-splash detachment; rill erosion; inter-rill erosion; USLE and soil conservation

1.0 INTRODUCTION

Laterisation process itself is a form of soil degradation and soil erosion by water is very much associated with the lateritic soils of West Bengal and Jharkhand. Large tracts of waste land are remained without thick forest cover and at places hard indurated laterites are exposed in the border region of Rampurhat I block, Birbhum district (West Bengal) and Shikaripara block, Dumka district (Jharkhand). Doing extensive field survey of 65.84 km^2 area of study, we have found that it is worthwhile to indentify and estimate the different forms of soil erosion because a separate conservation practice is required to check each form of water erosion. It is observed that low water-holding capacity, low clay content, low percentage of organic matter, weak sub-soils structure, deforestation, grazing, peak volume of overland flow, high erosivity of monsoonal rainfall, surface crusting etc. favours rain-splash erosion, sheet erosion (inter-rill erosion), rill erosion and gully erosion.

This research article emphasizes upon firstly, the crucial features of lateritic soil which influence high erodibility of soil; secondly, on prediction of soil loss and thirdly, on suggestive low-cost conservation practices of degraded lateritic waste land and forest tracts.

2.0 OBJECTIVES

The ultimate goal is the fruitful application of pedo-geomorphic principles and quantitative techniques in the analysis of soil erosion and conservation. So to achieve this goal, the chief objectives are considered as follows:

1. Find out the important features of lateritic soil which influence soil erodibility,
2. Identify and locate the dominant forms of water erosion,
3. Quantify those forms of erosion through mathematical models,
4. Mapping the spatial variation of soil erosion, and
5. Suggest some eco-friendly low-cost conservation practices to control soil loss.

3.0 MATERIALS AND METHODS

Quantitative and process-from approaches are taken into consideration to fulfill the above objectives of this pedo-geomorphic study. Frequent field observations, recording and interpretation are three fundamental pillars of soil erosion study. This study has both an applied aspect and environmental concern. The sub-basins and slope facets are taken as the geomorphic unit of investigation (spatial scale) and steady time scale is taken into consideration. In the pre-field session district resource map of Birbhum district (Geological Survey of India, 2001), district planning map (NATMO, 2001), topographical sheet of Survey of India (72 P/12/NE, 1979), IRS 1-D LISS III image (2001), SRTM data (2006), numerous literatures, reports, bulletins and books are collected and consulted regularly. We have taken much help of technical bulletins of National Bureau of Soil Survey (NBSS) and Land Use Planning of India. The field survey is completed with the help of Garmin G.P.S. and Abney Level. The soil samples and related geomorphic data are collected from field work. The baseline map of the study area is prepared using MapInfo 9.0 software. Raw image processing, geo-referencing, sub setting of area of interest, image enhancement, and output of thematic raster and vector overlays are done in ERDAS 9.1 and ArcGis 9.2 softwares.

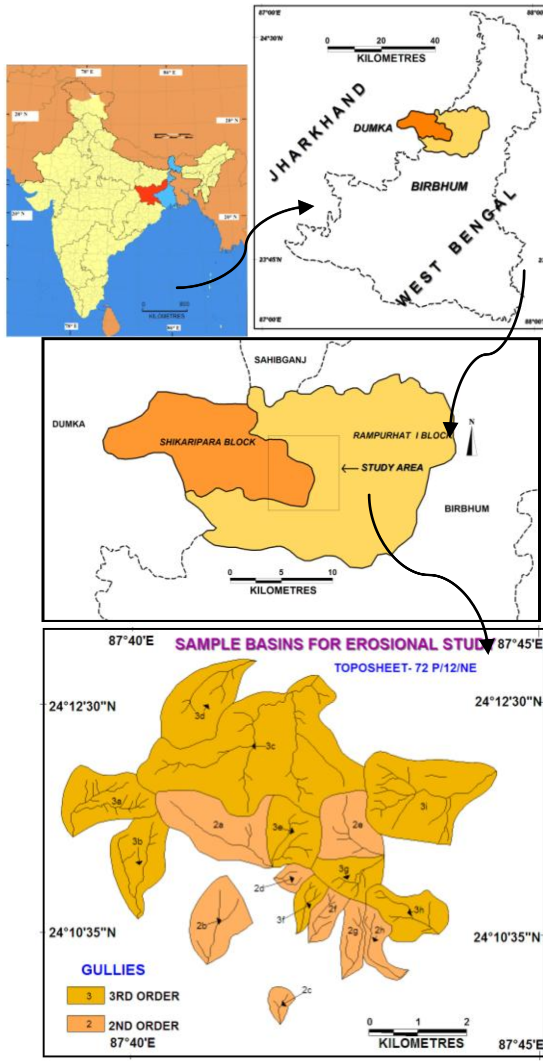

Figure 1.Location map of the study area

4.0 RESULTS AND DISCUSSIONS

4.1 Location of the Study Area: The selected region of erosional study (geographical area of 65.84 km^2) is situated in the adjoining area of western Rampurhat I block of Birbhum district, West Bengal and eastern Shikaripara block of Dumka district, Jharkhand. This geomorphic region is associated with the eastern plateau fringe of Rajmahal Basalt trap. It is the lateritic interfluve portion of Brahmani (north) and Dwarka (south) rivers. The study area is situated at 5 km west of Rampurhat railway station, near Baramasia bus-stop. The latitudinal extension ranges from 24^{0}10' to 24^{0}13'N, and longitudinal extension ranges from 87^{0}39' to 87^{0}45'E (fig 1 and 2). The maximum and minimum altitudes are 89 metre and 36 metre from mean sea level respectively.

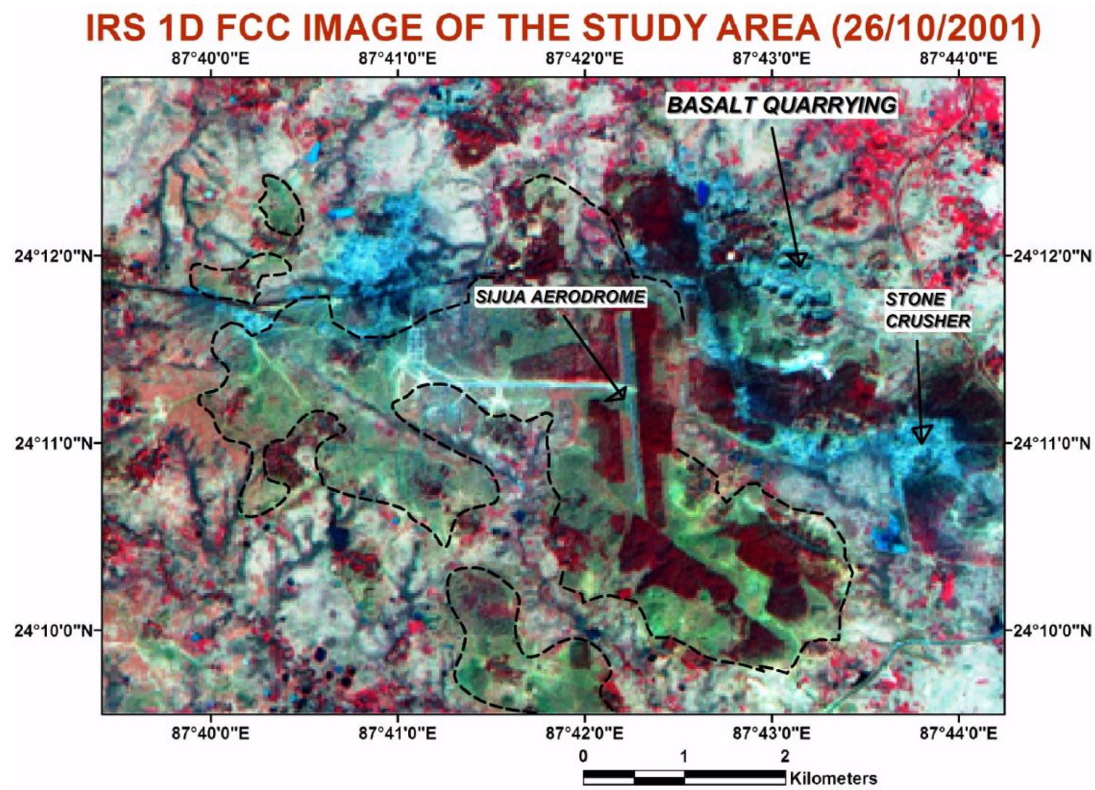

Figure 2.Greenish patches (Standard FCC image) are the degraded lateritic land of the study area (2001)

4.2 Important Characteristics of Lateritic Soil: The major soil of the area under study is red gravelly lateritic soil (Entisols) depositionally developed over weathered granite-gneiss and Rajmahal basalt under the sub-tropical and sub-humid climatic conditions. The inherent characteristics of soils are needed to be known for the soil erosion study, because erodibility of soils is depended on physical characteristics of those soils. The erodibility of a soil is its vulnerability or susceptibility to erosion that is the reciprocal of its resistance to erosion. A soil with a high erodibility will suffer more erosion than a soil with low erodibility if both are exposed to the same rainfall. The chief characteristics of lateritic soil of the study area are as follows:

1. We have found that mainly (1) Bhatina-Raspur-Jhinjharpur and (2) Bhatina-Jhinjharpur-Raspur soil series associations are recognized in the study area (NBSS, 2005).
2. Three groups of soil texture are found here: (1) clay loam (highly erodible), (2) sandy clay loam (moderate) and (3) sandy loam (low).
3. Low quantity of clay particles (<30%) and organic matter (<1.3%) are the main culprits of high soil erodibility of this area, because the clay particles combine with organic matter to form soil aggregates or clods and it is the stability of these which determines the resistance of the soil.
4. According to Pascoe (1973) laterites of Birbhum district is marked as low level laterite which was broken off from the high level laterites of Rajmahal hills (Eastern parts) and then carried to the eastern lower

level by the action of streams, rain wash, surface runoff and then re-deposited in this area. In this wet and dry type of monsoonal climate and due to ground water fluctuations those materials become cemented again through segregative action of hydrated oxides (development of red duricrust at top layer).

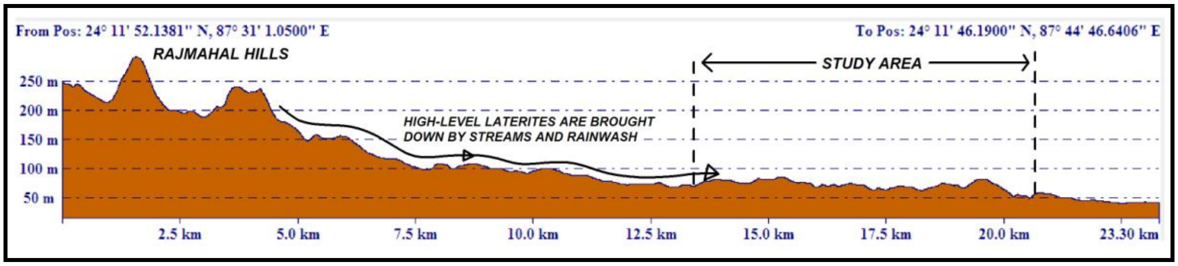

Figure 3.Probable Occurrence of low-level laterites of the study area (based on SRTM data)

5. The low-level laterites is further eroded or lowering of the surrounding unlateritized areas (or areas where the laterite is unindurated), hard lateritic portion is left standing above the adjacent country. In effect, the relief becomes inverted here (soup-plate laterites, remained as domal dissected uplands).
6. These soils are medium-shallow and gravelly with low moisture retention capacity and high coarse sand percentage (>50%). Productivity potential is low to medium and Organic Carbon is very low in these soils.
7. In monsoonal rainfall (June-September) these soils are become sticky and low permeable in top layer which favours surface and subsurface wash. These soils having weak structure (inter-particle cohesion is weak and presence of voids is high) and low clay fraction (<20%) of top soil are very susceptible to rain-splash, sheet wash, rill and gully erosion.
8. In laterite profile, the distinct zones of red-brownish to yellow topsoil, Duricrust, mottle clay, white clay, grit with cores and weathered laterite of honey-comb structure are found (fig 4). The horizons of kaolinitic clay are very much susceptible to tunnel erosion (soil pipe flow), which enhances the headward extension of gully and roof collapsing.

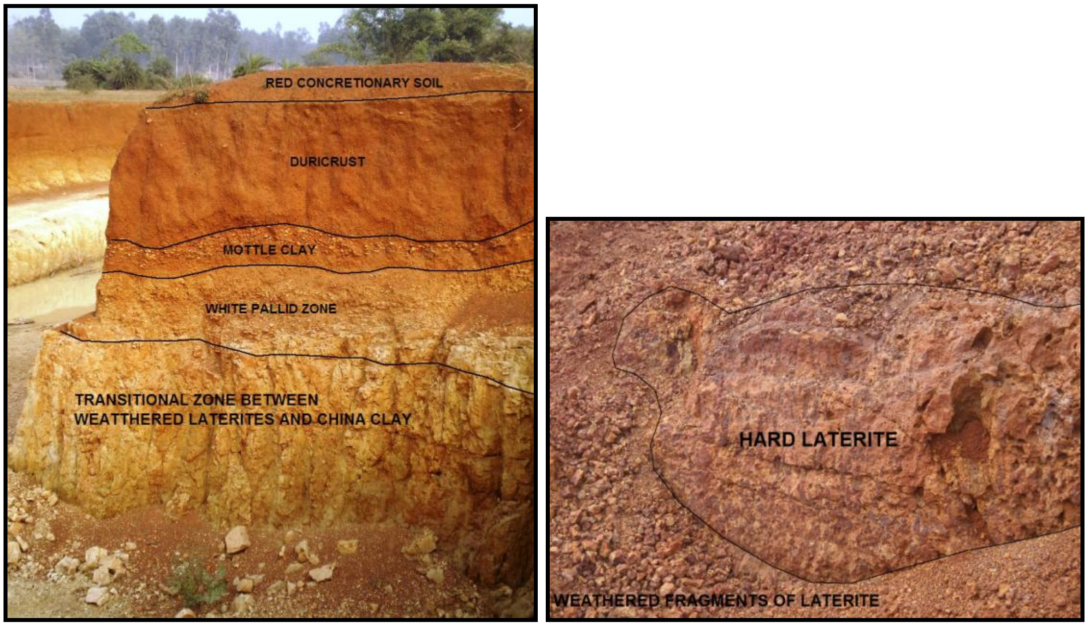

Figure 4.Profile of lateritic soil (left) and hard laterites (right) at the north-west of Bhatina village, Rampurhat I block

4.3 Rain-Splash Detachment: The erosive capacity of a falling mass of water depends on the energy of the falling drop determines the force of the blow that must be absorbed at each point of impact, while the horizontal area of the drop determines the amount of soil that must sustain that blow. When the raindrops strike the surface of the soil and it break down the clods and aggregates. The soil particles are torn loose from their moorings in the soil mass. When the surface soil is pounded by raindrops the infiltration rate decreases rapidly as the proportion of large drops increase, the concentration of soil in the runoff water increases and the infiltration rate decreases.

The consolidation effect is best seen in the formation of a surface crust, usually only a few milimetre thick, which results from the clogging of the pores by soil compaction. The most important effect of a surface crust is to reduce infiltration capacity of lateritic soil and thereby promote greater surface runoff (Morgan, 1986). It has been reported that heavy monsoon rainfall intensity is around 23.51-25.51 mm/hour in this area (Water Resource and its Quality in West Bengal, A State of Environmental Report, WBPCB, 2009). Based on Hudson's studies of tropical rainfall and graph, it is found that median drop diameter of monsoon rainfall is almost 2.2 mm with terminal velocity of almost 6 metre/second.

Among numerous index of raindrop erosion, the rain-splash detachment equation of Ellison (1945) is incorporated here:

$$\mathbf{E = K. V^{4.33} . d^{1.07} . I^{0.63}}$$ where,

E= soil detachment (gm or kg);

K= constant for soil types (erodibility factor of soil);

V= typical terminal velocity of monsoonal raindrops (m/s);

d= typical raindrop diameter (mm) and

I= typical rainfall intensity (mm/hr).

Table 1.Estimation of potential rain-splash detachment at sample sites (after Ellison, 1945)

Sample site	Latitude (N)	Longitude (E)	sand %	silt %	clay %	K^1	E (kg)
1	24°10'40"	87°42'40"	49.8	27.6	22.6	0.28	11.72
2	24°11'6"	87°42'40"	65.3	24.6	10.1	0.31	12.98
3	24°10'57"	87°42'49"	64	22.4	13.6	0.22	9.21
4	24°11'23"	87°42'40"	50.1	27.3	22.6	0.22	9.21
5	24°11'24"	87°42'6"	52.6	28.3	19.1	0.26	10.89
6	24°11'51"	87°42'41"	70.2	19.1	10.7	0.19	7.95
7	24°11'46"	87°42'16"	48.3	22.6	29.1	0.20	8.37
8	24°10'43"	87°42'21"	49.1	28.3	22.6	0.27	11.31

Note: $^1K=1.2917[2.1x10^{-4} M^{1.14} (12-a)+3.25(b-2)+2.5(c-3)]/100$ where M= %silt (100 - %clay); a= %organic matter; b= the soil structure code and c= the profile permeability code (provided in table 3)

4.4 Rill and Inter-rill Erosion: Sometimes the sheet flow gets concentrated in thin thread like channels forming grooves called rills. Year after year, rills slowly increase not only the numbers but also in their shape and size. Free water acquires both rotational and translation energy as it concentrates to form channelized flow. The rotational energy detaches soil by scouring. The energy of translation enables the flowing water to transport the detached material downhill. Since these energies are concentrated and applied to restricted areas of the ground surface, the flowing water carves grooves into the surface soil. In their initial stages and near the crest of slopes, these grooves are known as rills.

As soon as it starts, runoff promptly develops minute rills and that portion of runoff that flows between rills is called sheet or inter-rill erosion. This type of erosion is mostly due to shallow flow. Some particles are carried away in runoff flowing in a thin sheet and some concentrate in small rills. Splash and inter-rill erosion make up about 70% of total soil erosion and occur simultaneously although splash erosion dominates during the initial process. Inter-rill erosion is a function of particle detachment, rainfall intensity (mainly monsoonal periods) and field slope (fig 5).

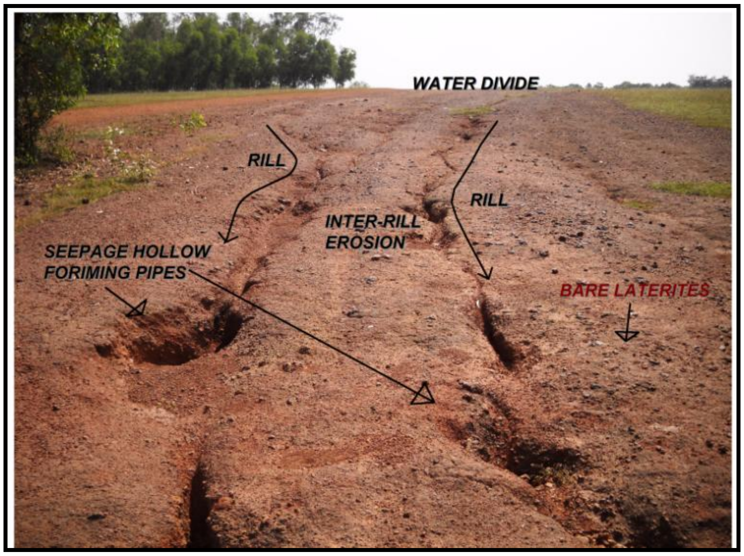

Figure 5.Rill and inter-rill erosion (presence of seepage hollows) on bare laterites at 1 km west of Bhatina village

To measure the rill and inter-rill erosion we have taken web-based 'Hillslope Erosion Model' which has been developed by United States Department of Agriculture - Agricultural Research Service (USDA-ARS) research scientists. The web-based software was designed and developed by scientists at the USDA-ARS Southwest Watershed Research Center in Tucson, Arizona, USA. Given hillslope segment lengths, slopes, % canopy cover, % surface ground cover, runoff volume, and a soil erodibility value, the model will simulate erosion process along the hillslope and will return runoff volume, sediment yield, inter-rill detachment, rill detachment, rill deposition, and the mean concentration of sediment in the flow for each hillslope segment. This model incorporates the physically-based model (kinematic wave equations) which includes the laws of conservation of mass and energy. The further information about the Hillslope erosion model is provided at web link: "http://eisnr.tucson.ars.ag.gov/hillslopeerosionmodel/".

Table 2.Prediction of annual rill and inter-rill erosion using Hillslope Erosion Model (USDA-ARS)

slope segment number	cumulative segment length (m)	slope	canopy cover	ground cover	inter-rill detachment[2]	rill detachment	rill depression	runoff volume[1]	total sediment yield[3]
		%	%	%	(Kg/m^2)	(Kg/m^2)	(Kg/m^2)	(m^3/m)	(Kg/m)
Slope Profile 1									
1	37	2.96	19	10	10.165	0	0.704	18.892	350.061
2	60	2.77	14	11	9.986	0	2.482	30.636	522.652
3	77	6.30	12	16	8.06	11.917	0	39.316	862.256
Slope Profile 2									
i	20	5.00	16	9	18.094	4.076	0	10.212	443.394
ii	49	4.44	19	17	12.418	0	1.078	25.019	772.241
iii	125	3.20	13	21	10.716	0	3.73	63.825	1,303.18
Slope Profile 3									
A	38	3.70	19	12	3.77	0.084	0	19.403	146.455
B	57	5.60	11	13	3.763	1.515	0	29.104	246.745

Note: [1]Mean annual runoff of year-2010- **510.6 mm**; [2]soil erodibility- **1.38** (profile 1), **2.31** (profile 2), and **0.56** (profile 3); [3]Sediment Yield at the bottom of the hillslope- **111.981 T/ha** (profile 1), **104.254 T/ha** (profile 2) and **43.289 T/ha** (profile 3).

4.5 Gross or Total Erosion: R. P. C. Morgan (1986) said that soil erosion (as a whole) is a two-phase process consisting of the detachment of individual particles from the soil mass and their transport by erosive agents such as running water and wind. When sufficient energy is no longer available to transport a third phase, deposition, occurs. Gross erosion or total erosion includes rain-splash detachment, rill erosion, inter-rill erosion and gully erosion. One thing is more important is that low-level laterites of West Bengal are very much prone to extreme form of channel erosion which is gullies. Morgan (1986) said that the main cause of gully formation is too much water, a condition which may be brought about by either climatic change or alterations in land use. If the velocity or tractive force of the runoff exceeds a critical or threshold value, gullying will occur (Schumm, 1979).

From the consecutive field visits it has been found that tunnel erosion, less vegetation cover, micro-piracy of rills, cross-grading of inter-rill divides, soil slumping at gully heads and sidewalls, rill formation on sidewall of gullies, catchments shapes, peak overland flow of monsoon, weak sub-soil structure of mottle clay, animal grazing and surface crusting are the most important factors of excessive networking of rills and gullies.

The Universal Soil-Loss Equation (USLE) predicts the soil loss due to sheet, rill and gully erosion (gross erosion) under specified geo-climatic conditions. The equation is mentioned below:

$$\mathbf{A} = \mathbf{R} \times \mathbf{K} \times \mathbf{LS} \times \mathbf{C} \times \mathbf{P} \quad \text{where,}$$

A= soil loss per unit area (tons/ha/year),

R=the erosivity factor to account for the erosive power of rainfall, related to the amount and intensity of rainfall over the year (erosion index unit, NBSS, 2005);

K=the soil erodibility factor to account for the soil loss rate in tones/ha erosion index unit plot which is defined as a plot of 22.1 m long on a 9% slope under a continuous bare cultivated fallow, it ranges from less than 0.1 for the least erodible soils to approaching 1.0 in the worst possible case. It depends on soil texture, organic matter, permeability and structure (NBSS, 2005);

LS=the topographic factor to account for the length and steepness of the slope; the longer the slope, the greater is the volume of surface runoff, the steeper the slope, the greater is its velocity, LS=1.0 on a 9% slope, 22.1 metre long (NBSS, 2005);

C=the cover and management to account for the effects of vegetative cover and management techniques which reduce the rate of the soil loss, so in the worst case when none are applied, C=1.0 whereas in an ideal case when there is no loss, C would be zero (NBSS, 2005) and

P=the support pr conservation practices factor to account for the effects of soil conservation measures (NBSS, 2005).

Soil Survey Staff, Central Soil and Water Conservation Research and Training Institute, Dehardun and Department of Agriculture (Govt. of West Bengal) have prepared many quantitative expressions to measure those five factors. Here eight samples one km^2 grids of sample basins are selected (based on toposheet 72 P/12/NE) to employ soil loss equation. Eight soil samples of slope segments are collected from those girds (below 150 mm depth). The main used equations are as follows:

i. $\mathbf{EI_{30} = 79 + 0.363\ X}$, where X= annual rainfall in mm.

ii. $\mathbf{K=1.2917[2.1x10^{-4}\ M^{1.14}\ (12-a)+3.25(b-2)+2.5(c-3)]/100}$ where M= %silt (100 **-** %clay); a= %organic matter; b= the soil structure code and c= the profile permeability code (table 3)

iii. $\mathbf{LS= (l/22.13)^{m}\ (0.065+0.045\ S+0.0065\ S)}$ where l=Slope length (metre) and S= Slope gradient (%).

Table 3.Soil structure code and permeability code (after Wischmeier, Johnson and Cross, 1971)

Soil structure (b)		Soil Permeability (c)	
Very fine granular	1	very slow	6
Fine granular	2	slow	5
Coarse granular	3	slow to moderate	4
Blocky, platy or massive	4	moderate	3
		moderate to rapid	2
		rapid	1

Table 4.Estimation of predicted soil loss (tons/ha/year) from eight sample sites with reference of sample basins

Sample Site	Reference Basin	Soil Texture	Soil Structure code	Soil Permeability code	R	K	LS	C	P	A (t/ha/ year)	A (kg/ m^2/year)
1	2g	clay loam	4	3	600	0.28	0.29	0.50	1.0	24.36	2.43
2	3g	sandy loam	4	2	600	0.31	0.43	0.65	0.7	36.40	3.64
3	3f	sandy loam	4	2	600	0.22	0.43	0.50	1.0	28.38	2.83
4	2e	sandy clay loam	3	3	600	0.22	0.39	0.45	0.7	16.21	1.62
5	3e	sandy clay loam	4	2	600	0.26	0.48	0.55	1.0	41.18	4.11
6	3c	sandy loam	3	3	600	0.19	0.47	0.40	0.7	15.00	1.50
7	3c	clay loam	3	4	600	0.20	0.24	0.40	0.4	4.60	0.46
8	2f	clay loam	4	3	600	0.27	0.52	0.45	0.7	26.53	2.65

Source: Estimation is computed by author; NBSS (2005); R.P.C. Morgan (2005); Irrigation and Waterways Department, Govt. of West Bengal (2010).

4.6 Spatial Distribution of Soil Erosion: The comparative status of land use map (1979-2010) reveals that forest covers as well as eroded lateritic waste land cover is simultaneously increased. The reason behind that the afforestation program is going on, but side by side grazing is not controlled at all around the severe gullied areas and newly developed forest tracts. More loss of grass and tree cover (loss of moisture) enhances the indurations of laterites (duricrust) and infertile waste land. Based on toposheet, IRS LISS III image, Google Earth and field survey, a soil erosion map (fig 6) is prepared to highlight the present status of forest (3.95 km^2), degraded lateritic land(16.23 km^2), stone quarrying (2.9 km^2) and network of gullies. The area under >60 metre contour (from mean sea level), area around Sijua Aerodrome and adjoining open scrub-barren tract are very much erosion prone. Central and eastern parts of the study area have more lateritic waste land and large continuous gullies. Agricultural lands of Bhatina, Maluti and Masra villages are affected by gully extension and laterisation processes. According to Fournier index (1960), the potential suspended sediment yield of sample catchments varies from 2.92-3.09 ton/km^2/annum, which signifies the high erosion risk.

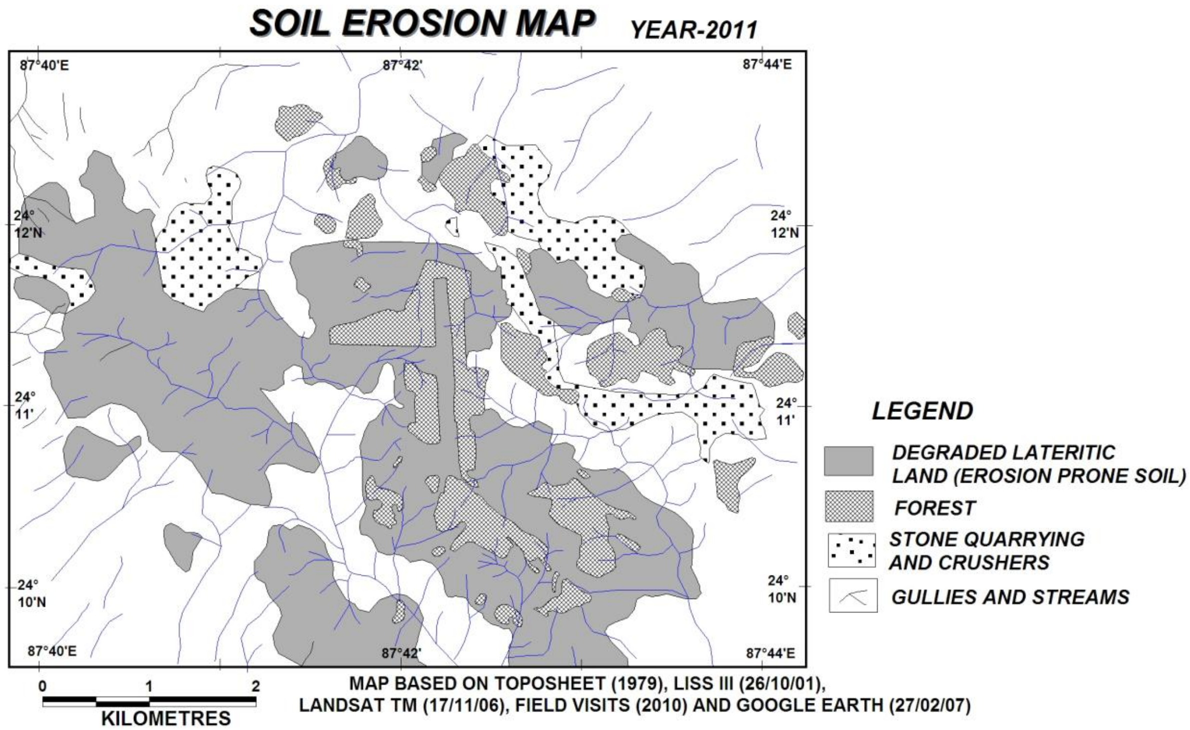

Figure 6.Soil Erosion map of the study area (2011)

4.7 Soil Conservation: From the above analysis it is clear that rain-splash, rill, inter-rill and gross erosion should get separate attention to take urgent steps in conservation practices. Based on monsoonal rainfall intensity and soil erodibility we have found that rainsplash detachment have great potentiality of soil loss in the range between 7.95 to 12.98 kg per square metre. So the ultimate aim of soil conservation is to obtain the maximum sustained level of production from given area of land whilst maintaining soil loss below a threshold level. Since erosion of lateritic soil is a natural process it cannot be prevented totally in this geo-climatic area, but it can be reduced to an acceptable rate. Also side by side we should formulate the low cost-high benefit decisions in the conservation measures, keeping in mind that uses of locally available equipments and local people participation are mandatory for long term success.

After understanding the magnitude of different forms of water erosion the strategies of erosion management must be based on following principles:

i. Covering the top-soil to protect it from raindrop,
ii. Increasing the infiltration capacity and organic matter of lateritic soil to reduce catchment runoff and soil transport,
iii. Improving the aggregate stability of the soil,
iv. Preventing water concentrating and moving down the slopes in a narrow path (rills and gullies) and
v. Slowing down the sediment laden water movement when it flows along the hillslope and channel slope.

Since the lateritic soil is very poor in fertility and water holding capacity, then both agronomic and mechanical methods of protection can be relevant in this area. In general way, soil management can be viewed as means of increasing the resistance to erosion, mechanical methods as an attempt to control the energy available for erosion and agronomic measures as a way of affording protection to the soil. In this area the following strategies and measures can be adopted to minimize soil loss.

4.7.1 Agricultural Measures-

The soil series of Bhatina, Raspur, Jhinjharpur and Maldiha are shallow, light-textured and gravelly with very low pH (<6.0) and organic content (<1.3%). Most of the lands are barren waste land with sparse bushy vegetation and this area is recommended as a frequent drought prone area of Eastren India. In terms of land capability (VIes, IVes, IIIes), irrigability (4st, 3st) and productivity potential (low-medium), the main recommendation of NBSS is the introduction of orchard plantation (mango, guava etc.).

Though the mean annual gain of rainfall is almost 1437 mm but ground water level fluctuates greatly in pre-monsoon and post-monsoon seasons (average levels of ground water table of April, 2006 and November, 2005 are 10 metre and 3 metre respectively). Again no rain-water harvesting program is still going on. Another flaw of canal irrigation is that most of agricultural lands of the study area are situated at western parts (highlands) of the Dawarka-Brahmani main canal. Therefore, in this harsh wet-dry sub-tropical climate, following cropping pattern (erosion resistance and drought protected) and land use can be adopted (table 5).

Table 5.Suggested cropping pattern and land uses (NBSS, 2007)

RAINFED AREA			**IRRIGATED AREA**			**OTHER USES**
Pre-monsoon	Monsoon	Winter	Pre-monsoon	Monsoon	Winter	
Fallow	Maize	Horse gram, Mustard	Maize/Sesame	Vegetables	Vegetables	Forests/Pasture/ orchard

4.7.2 Grazing Management-

Natural cultivation of healthy grass is the most cheap cost conservation practice in the lateritic waste land. But it would take sufficient time to grow uniformly upon hillslopes. From the ground observation it is found that domestic animals do not give chance to grow well the grass cover in monsoonal seasons. Again animal pugmarks on the moist soil are helpful for surface depression (groves) and runoff water concentration in steep slopes (fig 7). Then the following measures can be taken:

a. Maintaining adequate pasture cover by better stock management,
b. Be prepared to fence off and exclude stock from land vulnerable to gully erosion and
c. Locate watering points, stock yards, shade areas and gates away from gully prone areas.

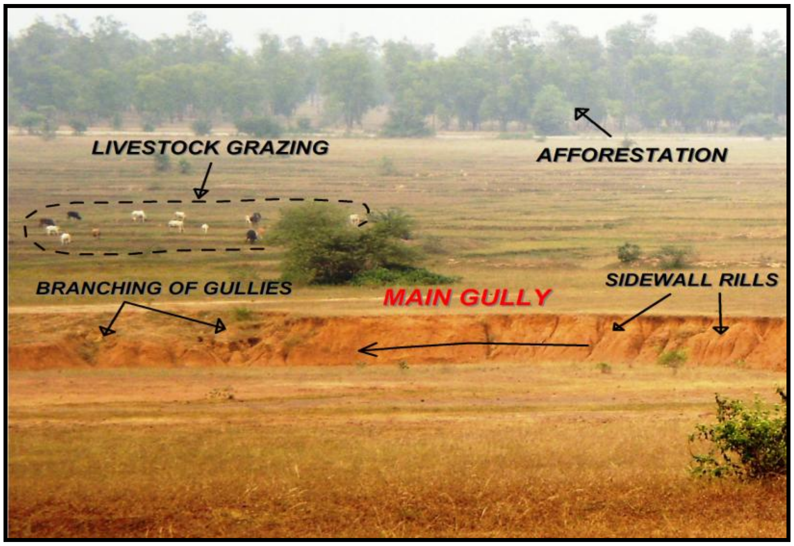

Figure 7.Livestock grazing at western gullied tract of Sijua aerodrome

4.7.3 Revegetation-

Vegetation provides protection against scouring and minimizes the erosion risk by reducing flow velocity. As the velocity falls, sediment is deposited forming an ideal environment for new vegetative growth. The area under > 60 metre (from mean sea level) and indurated laterites cover should be kept under grass and forest. The ground reality is that large scale basalt quarrying and 'morum' quarrying is the main culprit of degradation of forest tracts ('Sal' and 'Mahua') and soup-plate laterite formation. The catchments of 3a, 3b, 3c, 3i and 2f (fig 1) should be properly revegated because those catchments yields huge peak runoff volume (25.11 to 86.15 m^3/s) and high drainage texture (31.86 to 76.16 per km^2). The suitable location of plantation is the semi-permanent wet sites and break of slope that mean high confluence zones of streams (fig 8). The mix species of plants should include grasses, forbs and woody species, both bushes and tree in this area.

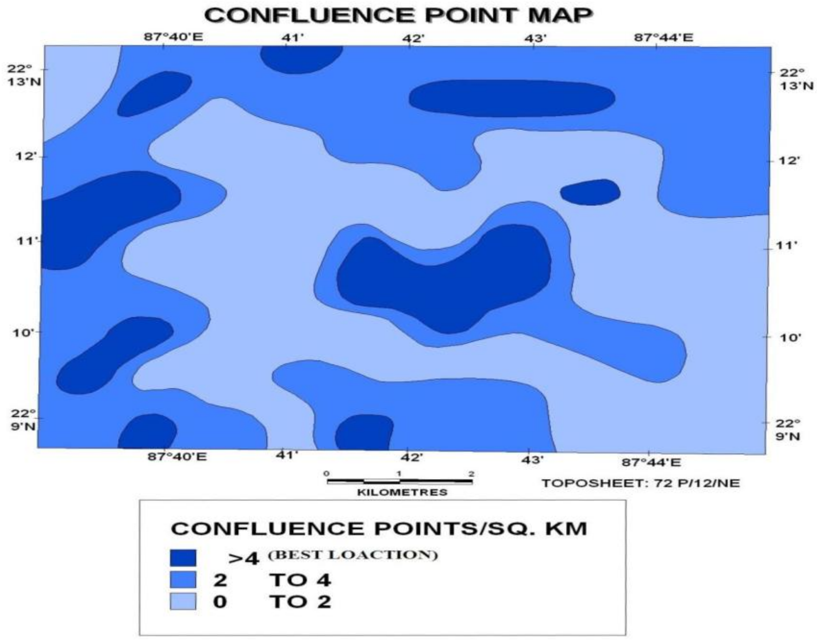

Figure 8.Confluence point (no. confluences of streams per km^2 grid) map

One way of planation of grass and tree is the plantation along the contour line of equal interval. It provides the benefits- protection against raindrop erosion, natural bunds, increase infiltration, increase organic matter, check tunnel erosion through the deep network of roots, reduce overland flow and sheet erosion, reduce indurations of laterites and check narrow concentration of surface flow (fig 9).

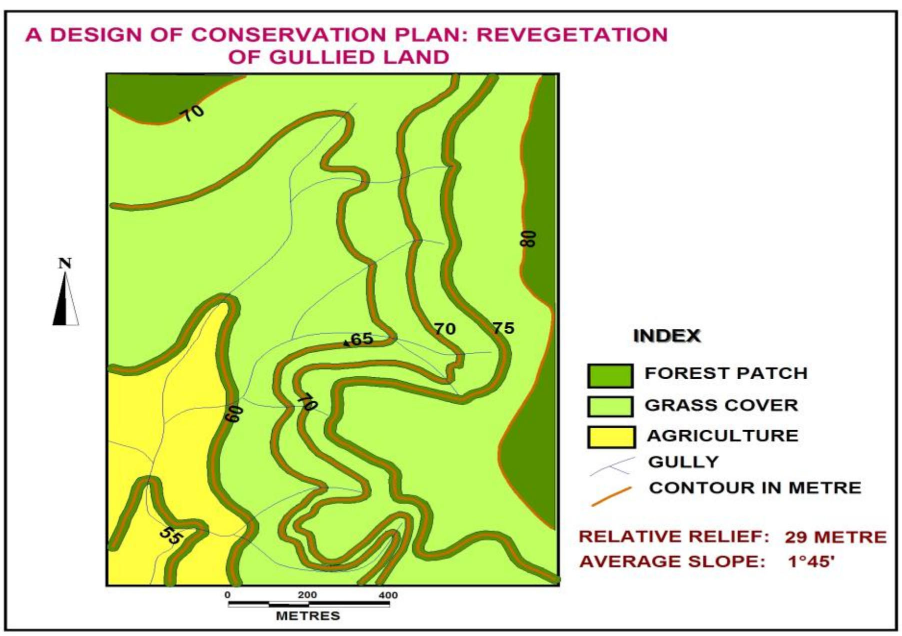

Figure 9.A design of conservation plan: revegetation of gullied land

4.7.4 Restoration of gullied lands-

To restore or stabilize the gully floors, sidewalls and valley sides, following possible measures should be applied:

a. In the mature U-shape gullies, the areas of sedimentation favour good growth of bushy vegetation,
b. The valley sides should be kept under alternative cover of grass, shrubs and trees with occasional bench terraces,
c. Branches of dead shrubs or trees can play a useful role in stabilizing a gully floor (fig 10) by restricting access by grazing animals and
d. A series of small weir-nets can be placed on the sidewalls to reduce branching of gullies and to trap the suspended sediment load coming from upslope.

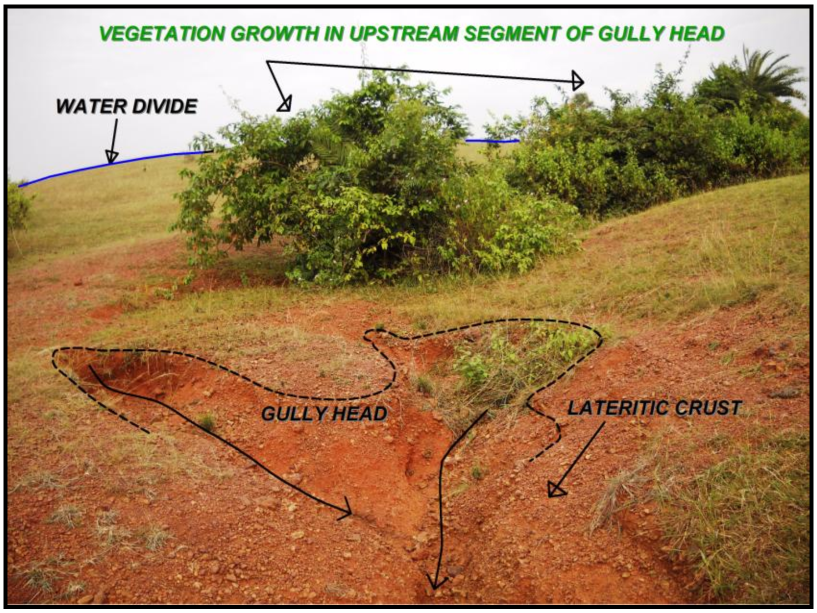

Figure 11.Vegetation growth in upstream segment of gully head (preventing overland flow) at Bhatina village

4.7.5 Controlling Expansion of Gully Heads-

The lateritic soil does not have good aggregate structured sub-soils, so stabilization structures play an important role in gully reclamation and gully erosion control. Small loose dams, usually 0.4 to 2.0 m in height, made from locally available materials such as wooden planks, brushwood or basalt rock, are built across gullies to trap sediment and thereby reduce channel depth and slope.

The spacing of the dams can be determined from the formula of Heede (1976):

SPACING= HE / k tanØ cosØ

where HE is the dam height and k is a constant, k=0.3 for tanØ<=0.2; k=0.5 for tanØ> 0.2. The dam height is measured from the crest of the spillway to the gully floor. As the average depth of gullies is 2 to 6 metre, then the height of the dam should be 0.5-1.5 metre. In addition, aprons of litter and loose basalt rock must be installed on the gully floor downstream of the dam to prevent flows from undercutting the structure (fig 12).

The suitable locations of loose rock-dams are gully heads and break in slope of gully floor (secondary knick point). If we can built small check dams in the oval and circular shape gully heads, we shall get benefits of water conservation, reduction of runoff velocity, trap sediment, increase moisture content etc. The confluence zones of greater than 4 (fig 8) can be considered as perfect location of dam construction. Still, these structures are used in association with plantation of grass, trees and shrubs.

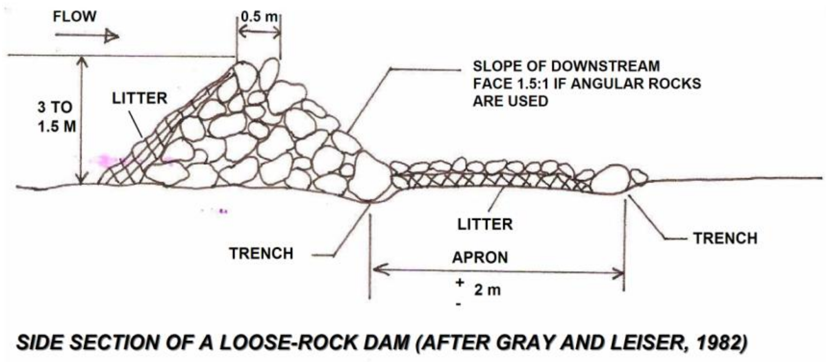

Figure 12.A suggested view of loose-rock dam of basalt, constructing along the gully floor

4.7.6 Fencing of Gully Floor-

Using bamboo, branch of trees and litter we can made single fence brush dam at an equal interval along the gully floor. Making 100 mm thick posts and wires we can build artificial low cost fence to trap sediment upstream (fig 12 and 13). Also 150 mm thick layer of litter or jute should be placed in the downstream and upstream face of the fence to diminish transport capacity of surface flow. One thing is important that posts should have good base to check peak runoff volume and kinetic energy of suspended sediment movement in rainy seasons.

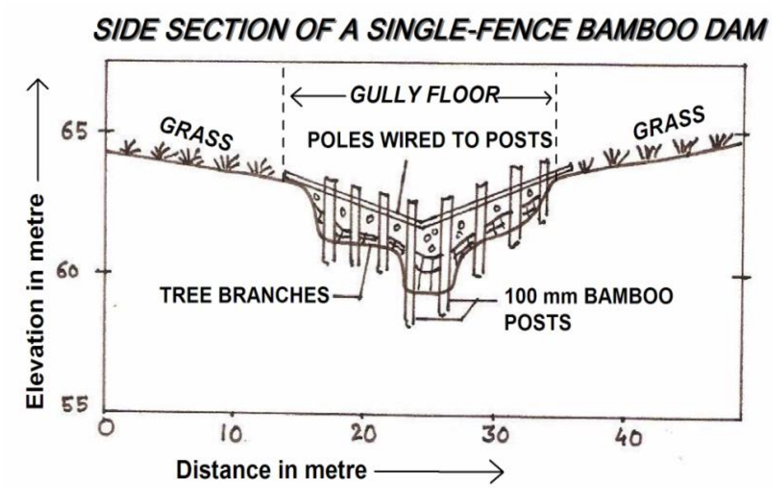

Figure 12.Side section of a single-fence Bamboo dam

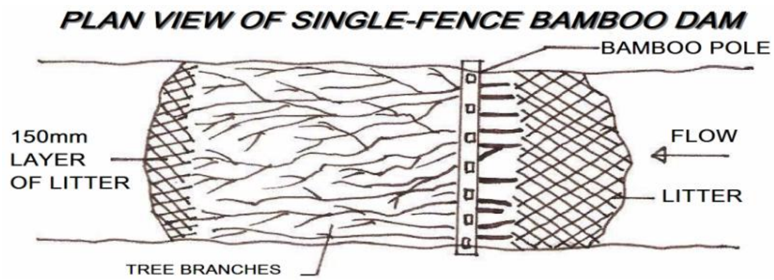

Figure 13.Plan view of single-fence Bamboo dam

4.8 CONCLUSION

The study area is covered with Rajmahal basalt, china clay and mostly laterite. Hard massive basalt is of Jurassic to Cretaceous age, soft and medium hard laterite is of Cainozoic age and china clay is of Late Pleistocene to Early Eocene age. The region is a small portion of inter-fluvial lateritic tracts (eastern fringe of Rajmahal Hills) between Brahmani and Dawarka rivers. The region experiences a hot-dry and sub-humid climate. This geo-climatic and hydrologic condition favours the formation of low-level laterites which is also currently took place in this region. The presence of iron-oxides, hard duricrust, rich kaolinitic clay and plant fossils at different depth are the glimpses of deep chemical weathering of multi-cyclic laterites of 'Rarh Plain' of West Bengal.

Since the morphometric and hydrological variables do not work in isolation but as closely inter-related phenomena. Some of the variables account for the major amount of explained variation of erosional landforms in this particular geo-climatic condition. These are Constant of Channel Maintenance, source points, Basin Relief, Ruggedness Number, Lemniscate Ratio, drainage texture, maximum valley-side slope and mean ground slope (based on Principal Component Analysis of thirteen variables of seventeen 3^{rd} and 2^{nd} order basins).

From this study we can say that there will be more success in soil conservation if we give separate attention in each type of soil erosion (categorization of erosion risk areas). In brief, soil erosion ranges from 0.46-3.64 kg/m^2/year in this region. Again when we consider developing regional economy, the measures of soil conservation should be based on low-cost equipments, sustainable structures and local people participation. Therefore, to control severe soil loss and to enhance the soil loss tolerance level, we can adopt those conservation practices particularly in this lateritic area.

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REFERENCES

1. Bagchi, K.N. and Mukherjee, K.N. (1983): Diagnostic Survey of West Bengal, Calcutta University, Calcutta
2. Billi, P. and Dramis, F. (2003). Geomorphological Investigation on Gully Erosion in the Rift Valley and the Northern Highlands of Ethiopia, Catena Vol. 50, Elsevier Science
3. Blanco, H. and Lal, R. (2008). Principles of Soil Conservation and Management, Springer, Dordrecht
4. Chatterjee, A.B., Gupta, Avijit and Mukhopadhyay, P.K. (1970). West Bengal (ed.), Firma K.L. Mukhopadhyay, Calcutta
5. Chesworth, Ward (2008). Encyclopedia of Soil Science (ed.), Springer, Dordrecht
6. Chorley, Richard J. (1969). Water, Earth and Man (ed.), Methuen, London
7. Chow, V. T. (1964). Handbook of Applied Hydrology (ed.), McGraw-Hill, New York
8. Cooke, R. U. and Doornkamp, J. C. (1987). Geomorphology in Environmental Management, Clarendon Press, Oxford
9. Dury, G. H. (1976). River and River Terraces (ed.), MacMillan, London
10. Gerrard, A. J. (1981). Soils and Landforms: An Integration of Geomorphology and Pedology, George Allen and Unwin, London
11. Ghosh, S. and Maji, T. (2011). Pedo-geomorphic analysis of Soil Loss in the Lateritic Region of Rampurhat I block of Birbhum district, West Bengal and Shikaripara block of Dumka district, Jharkhand, International Journal of Environmental Sciences, Volume 1, No. 7, Integrated Publishing Association
12. Hudson, Norman (1984). Soil Conservation, English Language Book Society, London
13. Jog, S. R. (1995). Indian Geomorphology, volume 1 (ed.), Rawat Publications, Jaipur
14. Knighton, David (1998). Fluvial Forms and Processes, Arnold publishers, London
15. Kumar, Anil and Pandey, R. N. (1989). Wasteland Management in India, Ashish Publishing House, New Delhi
16. McFarlane, M. J. (1976). Laterite and Landscape, Academic Press, London
17. Morgan, R. P. C. (1986). Soil Erosion and Conservation, Longman Scientific and Technical, Harlow
18. Morgan, R.P.C. and Rickson, R.J. (1995). Slope Stabilization and Erosion Control (ed.), E and FN SON publication, London
19. Panniza, Mario (1996). Environmental Geomorphology, Elsevier, Amsterdam
20. Sachetzal, R. and Anderson, S. (2005). Soils: Genesis and Geomorphology, Cambridge University Press, London
21. Sarkar, D., Nayak, D.C., Dutta, D. and Dhyani, B.L. (2005). Soil Erosion of West Bengal, National Bureau of Soil Survey and Land Use Planning, NBSS Publ. 117, Nagpur
22. Sarkar, D., Nayak, D.C., Dutta, D. and Gajbhiye, K.S. (2007). Optimizing Land Use of Birbhum District (West Bengal) Soil Resource Assessment, National Bureau of Soil Survey and Land Use Planning, NBSS Publ. 130, Nagpur
23. Singh, S., Sharma, H.S. and De, S.N (2004). Geomorphology and Environment (ed.), ACB Publications, Kolkata
24. Stallings, J. H. (1957). Soil Conservation, Prentice-Hall Publication, London
25. Wischmeir, W. H. and Smith, D.D. (1972). Predicting Rainfall-Erosion Losses from Cropland and East of the Rocky Mountains, USDA, Agriculture Handbook No. 282, Washington
26. Wischmeir, W. H. and Smith, D.D. (1978). Predicting Rainfall-Erosion Losses-A Guide to Conservation Planning, USDA, Agriculture Handbook No. 537, Washington
27. Zachar, D. (1982). Soil Erosion, Elsevier Scientific Publishing Company, Amsterdam