

Plant Species Selection for Controlling Rill and Gully Erosion : An Empirical Analysis

PRAVAT KUMAR SHIT* AND RAMKRISHNA MAITI

*Department of Geography & Environment Management, Vidyasagar University
 Medinipur 721102, West Bengal, India
 E-mail : pravatgeo2007@gmail.com
 Correspondence

Abstract

Rill-gully erosion is an important soil degradation process in lateritic rolling environments. Every year about 1.04 lakh ha area is affected by rill-gullies in West Bengal. The present paper deals with the characteristics of stem and root systems of eight plant species in lateritic environment. The study aims to investigate the plant traits, for identifying their suitability for controlling erosion in semi-arid lateritic environment, in western part of West Bengal. Both above and below ground plant characteristics are taken into account for determining the potential of grass roots and stem to prevent incision by concentrated flow erosion, the potential to resist bending by water flow, and sediment obstruction potential. Six indicators were selected to assess the scores for the three criteria, analysing both above-ground biomass (i.e. SD, M, and SOP) and below-ground biomass (i.e. RD, RLD, and RAR). The scores of the indicators are represented on amoeba diagrams. Among the eight experimental plant species, *Eragrostis cynosuroides* plant species are found to be more suitable than others for controlling rill-gully erosion.

Key words : Rill-gully erosion, Methodological framework, Stem, Root, Suitable plants.

Soil erosion is a serious environmental problem in sub-humid environment where dry bare lateritic soil is vulnerable to erosion during intensive rainstorms. Rill and gully erosion and sediment control in construction sites is a critical issue in the lateritic badland topography of western part of West Bengal ; because every year about 1.04 lakh ha area is affected by rill-gullies (1). Eco-technological approaches are important and also effective to prevent the initiation of rills and stabilize gullies. Many studies investigating the effects of plant in reducing soil erosion rates attribute to the effects of the above ground biomass (2). Root and root remnants physically bind soil particles and in this way form mechanism for soil and water movement (3). Ghidry and Alberts (4) showed that interrill soil erosion is controlled by root mass and root length. The potential of typical grass roots enhances the resistance of topsoil that results in reduction in concentrated flow erosion rates (2, 5—9). According to recent studies, the runoff erosion rates decrease exponentially with increasing area occupied by roots (2, 9, 10—13). Coppin and Richards (14) investigated that the vegetation can act as a protective barrier between the soil and the natural elements which stimulate erosion or mass movement. Some studies

aim to analyze the potential of roots to provide anchorage, absorb water and nutrients from the soil, stems to support the above the ground biomass and also capture eroding soil, and leaves to intercept precipitation and initiate evapotranspiration leading to decreased soil moisture levels. Especially in a lateritic sub-humid environmental context, the above ground biomass can temporarily disappear due to overgrazing or drying. Roots play an important role in controlling soil erosion rates. The present study focuses on quantifying the soil reinforcement by plant traits for eight typical lateritic plant species, using the stem and root properties with simple multi-criteria analysis to rank species according to their suitability for rill-gully erosion and stabilization.

Methods

Study Area and Selected Plants

Eight typical lateritic environmental plant species were collected for the measurement of stem and root properties from an ephemeral gully basin area (22°24.697'N, 87°17.798'E to 20°24.798'N, 87°17.895'E) located about 1 km southeast of the town of Medinipur in West Bengal (Fig. 1). The climate is semi-

Table 1. Stem and root properties used in analyzing erosion resisting indicators.

Species name	M _D (g)	Root properties						Stem properties				
		L _R (cm)	R _L (cm)	A (cm ²)	A _b (cm ²)	A _s (cm ²)	d _s (cm)	n _s	A _r (cm ²)	n _{1cm}	L _b (cm)	L _{tot} (cm)
<i>Andropogon aciculate</i>	3.044	11.2	14	20.531	0.64	1	0.078	10	20.25	12	4	66
<i>Panicum maxima</i>	1.254	8.2	10	2.9046	0.81	1	0.162	5	16.0	5	4	53
<i>Saccharum munja</i>	0.598	10	12	0.742	0.563	1	0.094	6	11.52	6	7	83
<i>Evolvulus nummularia</i>	0.794	3.64	6	1.4854	0.563	1	0.028	20	189.1	20	2	17
<i>Eragrostis cynosuroides</i>	1.42	13.8	17	0.9035	0.722	1	0.181	4	10.56	4	6	86
<i>Euphoria purpuria</i>	0.63	18.2	21	0.1187	0.141	1	0.141	1	156.25	1	2.5	43
<i>Lantana camara</i>	0.308	20.6	25	0.0463	0.20	1	0.20	1	30.25	1	2.2	40
<i>Hedyotis corymbosa</i>	0.148	13.2	17	0.0302	0.17	1	0.17	1	20.25	1	2	58

Where, n_s is number of stems in the horizontal area, A_b (m²) is the area occupied by the stem of a grass stand, A_s (m²) is horizontal area of the section, d_s is mean diameter ; A_r is the total surface occupied by above the ground biomass.

Stem density (M, in/m²), used for the quantifying the resistance of plants to water flow (both for shrub and grass), is calculated as follows (16).

$$M = \frac{n_s}{A_r} \dots (5)$$

Sediment obstruction potential (SOP, mm¹) is the indicator of ability to trap sediment.

$$SOP_{grass} = \frac{L_b * n_{1cm} * d_s}{L_{tot}} \dots\dots\dots (6)$$

Where, n_{1cm} is the number of stems along 1cm unit length, L_b (m) is the length occupied by the stems projected to a horizontal line perpendicular to the dominant flow direction at the plant base, L_{tot} (m) is total length determined by the vertical projection of above the ground biomass, in a direction perpendicular to the dominant flow direction and d_s (m) is mean stem diameter.

Methodological Framework

In this analysis suitability of plants for controlling initiation and extension rill-gully erosion initia-

Table 2. Transformation of absolute values into weighted (W) or score values (S).

Weighted or Score value	Bellow ground biomass (root properties)			Above ground biomass (stem properties)		
	RD (kg/m ³)	RLD (km/m ³)	RAR	SD (m ² /m ²)	M (m ²)	SOP (m/m)
0	0-0.004	0-0.02	0-0.03	0-0.02	0-0.12	0-0.0180
1	0.004-0.008	0.02-0.04	0.03-0.06	0.02-0.04	0.12-0.24	0.018-0.03
2	0.008-0.012	0.04-0.06	0.06-0.09	0.04-0.06	0.24-0.36	0.03-0.042
3	0.012-0.016	0.06-0.08	0.09-0.12	0.06-0.08	0.36-0.48	0.042-0.054
4	> 0.016	> 0.08	> 0.12	> 0.08	> 0.48	> 0.054
Rank value (effectiveness)	3	2	1	3	1	2

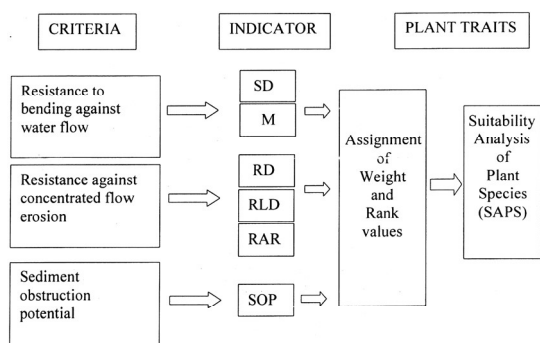


Figure 2. Multi-criteria approach for selecting plant species to control rill-gully erosion.

tion and extension was performed on the basis of a multi-criteria analysis (Fig. 2) using stem and root plant properties.

Suitability Analysis of Plant Species (SAPS)

To compare species, the numerical data were linked to each indicator for calculating weighted value ranging from 0 to 4. Rank values range from 1 to 3 according to their importance to protect the soil erosion during the concentrated flow. The amoeba diagrams were constructed for visual interpretation of the suitability of a plant species for rill and gully erosion control.

Suitability analysis of plant species to control rill-gully erosion (SAPS) were analyzed following equation (7)

Table 3. Plant traits of selected grass species and SAPS value.

Name of the plant species	Resistance against concentration flow erosion			Resistance to bending		Sediment obstruction potential Mean SOP (m/m)	SAPS value
	Mean RD (kg/m ³)	Mean RLD (km/m ³)	Mean RAR	Mean SD (m ² / m ²)	Mean M (m ²)		
<i>Andropogon aciculate</i>	0.020293	0.074667	0.024926	0.047486	0.49382	0.056727273	3.548026041
<i>Panicum maxima</i>	0.01254	0.082	0.101223	0.082028	0.3125	0.061132075	3.170925507
<i>Saccharum munja</i>	0.003987	0.066667	0.048861	0.038392	0.52083	0.047566265	2.932770496
<i>Evolvulus nummularia</i>	0.005293	0.024267	0.032699	0.002305	0.10576	0.065882353	0.624170824
<i>Eragrostis cynosuroides</i>	0.01136	0.0848	0.136179	0.088507	0.37878	0.050511628	3.792797224
<i>Euphorbia purpuria</i>	0.00315	0.091	0.059635	0.000044	0.0064	0.008197674	0.787635
<i>Lantana camara</i>	0.001472	0.077	0.064975	0.000653	0.033057	0.011	0.59195
<i>Hedyotis corymbosa</i>	0.00074	0.066	0.032241	0.000599	0.04938	0.005862069	0.428241

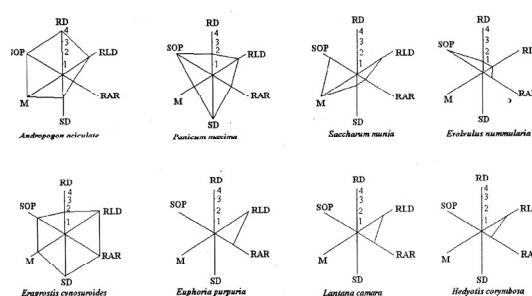


Figure 3. Amoeba diagrams representing erosion control potential of selected plant species.

$$SAPS = (AV_{SD} * R * S) + (AV_M * R * S) + (AV_{RD} * R * S) + (AV_{RLD} * R * S) + (AV_{RAR} * R * S) \dots (7)$$

Where, SAPS = the score value of suitability analysis of plant species, R = rank value, W = weighted value, AV = Absolute value.

Results and Discussion

Scores for the Above-Ground and Below-Ground Indicators

Mass of dry living roots is high for *Andropogon aciculate* which attributed to the higher (3.044 g) total root length. Total length of root is also higher for *Lantana camara* and *Euphorbia purpuria* (Tables 1 and 2). *Andropogon aciculate* and *Panicum maxima* are effective in controlling soil erosion due to higher root density (RD). Total length of the roots per unit volume of root-permeated soil is maximum for *Eupho-*

Table 4. Suitability of plant species of rill-gully control, depending on the three main criteria (H = high, M = medium, L = low).

Name of the plant species	Vegetation type	Resistance to bending against water flow	Resistance against concentrated flow erosion	Sediment obstruction potential	Overall suitability
<i>Andropogon aciculate</i>	grass	H	M	H	good
<i>Panicum maxima</i>	grass	M	H	H	good
<i>Saccharum munja</i>	grass	H	L	L	medium
<i>Evolvulus nummularia</i>	herb	L	L	H	low
<i>Eragrostis cynosuroides</i>	grass	H	H	H	Very good
<i>Euphoria purpuria</i>	shrub	L	M	L	low
<i>Lantana camara</i>	shrub	L	M	L	low
<i>Hedyotis corymbosa</i>	shrub	L	L	L	Very low

ria purpuria. Maximum portion of soil cross sectional area is occupied by the root of *Eragrostis cynosuroides* and thus it may be considered as the important species to restrict erosion. Considering all the indicators of concentrated flow erosion resisting potential (RD, RLD and RAR), *Panicum maxima* and *Eragrostis cynosuroides* seem to be most effective. This can be attributed to the high density of fine roots in the top soil for these plants. Sediment obstruction potential and resistance to bending are analyzed from stem properties. Stem density is high for *Panicum maxima*, *Eragrostis cynosuroides* *Evolvulus nummularia* and *Andropogon aciculate*. Considering the root and stem properties *Eragrostis cynosuroides* seems to be the best scoring (3.793) species among all in rill-gully field. *Andropogon aciculate*, *Panicum maxima* and *Saccharum munja* have average SAPS score of 3.548, 3.171 and 2.9327 respectively (Tables 3 and 4).

Amoeba Diagrams Analysis

The amoeba diagrams corresponding to each studied species are presented in Figure 3. Generally, from the species growing on lateritic soil along the rill-gully channel, the grass *Eragrostis cynosuroides* is most suitable for controlling rill and gully erosion. *Andropogon aciculate*, *Panicum maxima* and *Saccharum munja* grasses are effective to prevent erosion by concentrated flow, but are not able to improve slope stability as these are easily bent. On the steep the grass *Lantana camara* and *Euphoria purpuria* performs well, but cannot be used to prevent shallow mass movements, because no root is present in deeper soil layers. The *Eragrostis*

cynosuroides, *Andropogon aciculate* and *Panicum maxima* has a high potential to resist erosion and bending by water flow.

Suitability Analysis

The suitability of each species for three mentioned criteria is summarized (Table 4) from the values of concerned indicators. *Eragrostis cynosuroides* is most suitable to control erosion than other species (3.79) as it has maximum potential to resist to bending, concentrated flow erosion and sediment movement (Table 4 ; Fig. 3). The medium scoring of 3.54 and 3.17 experienced by *Andropogon aciculate* and *Panicum maxima* respectively and can also be used as effective protector of erosion.

Conclusion

Species selection is important for ensuring the success of any eco-technological solution for rill-gully erosion. Selection of species among naturally grown ranges seems to be important for better management. The species, having dense root and stem growth can protect soil from intensive erosion. After analyzing root and stem properties, *Eragrostis cynosuroides*, grass species is suitable to control erosion lateritic badland topography. The seasonal drying and intensive grazing may remove the above ground growth in dry season mainly. The early rain, having most effective erosion potential, can be managed by the intensive root system. The selected species, *Eragrostis cynosuroides* can effectively protect erosion by intensive root system throughout the year and by extensive stem growth during rainy season.

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