



Delineation of erosion risk areas in Andhra Pradesh and Telangana states of India

Prasant Kumar Mishra¹, Debashis Mandal^{1,3}, S.K.N. Math¹ and Vishwa Nath Sharda²

¹ICAR-Indian Institute of Soil and Water Conservation, Dehradun; ²Agricultural Scientists Recruitment Board, New Delhi.

³E-mail: dmandalcswcrti@gmail.com

ARTICLE INFO

Article history:

Received : July, 2017

Revised : February, 2018

Accepted : May, 2018

Key words:

Erosion risk,
Potential erosion,
Soil conservation planning,
Soil loss tolerance limit,
Soil sustainability

ABSTRACT

Although several studies have assessed land degradation status in India, relatively few have evaluated the actual erosion risk areas. Moreover, no systematic procedure or methodology exists to analyze and integrate the available data base for delineation and prioritization of erosion risk areas for effective planning and execution of soil conservation programs and ensure environmental security. In this paper, a methodology has been developed as a case study to assess the soil erosion risks by integrating spatial data on potential erosion rates and soil loss tolerance limits (SLTL) for conservation planning in Andhra Pradesh and Telangana, predominantly a semi-arid tropical region in India. The analysis showed that about 19% of total geographical area (TGA) of the state requires conservation measures though about 67% area suffers from potential erosion rates varying from 5 to more than 40 t ha⁻¹ yr⁻¹. It was observed that about 81% of TGA in the state does not require any specific soil conservation measure as the prevailing erosion rates are well within the SLTL. The suggested technique can be successfully employed for delineation and prioritization of erosion risk areas in any region or country for identifying best management practices to contain the erosion losses and efficiently plan the land resources to allocate funds on priority.

1. INTRODUCTION

Some of the problems associated with the soil erosion include loss of fertile top soil for agriculture, siltation of streams and lakes, eutrophication of surface water bodies and loss of aquatic biodiversity (Onyando *et al.*, 2005). Management practices to minimize these problems can be effectively carried out if the magnitude and spatial distribution of soil erosion are known. Delineation of soil erosion risk areas is a challenging task, especially in the developing countries due to non-availability of relevant data and analytical tools for such an assessment. As a result, it becomes difficult to establish appropriate soil conservation measures on the risk prone areas to arrest soil loss and ensure sustainable management of soil resources (Upadhyay 1991; Arhonditsis *et al.*, 2002). The data available on

land degradation, potential soil erosion rates and permissible soil loss are either qualitative in nature or insufficient for efficient planning of conservation programs at state or regional level. Realistic assessment of erosion risk areas, thus constitutes the first step for raising awareness among governmental and non-governmental institutions. Besides, the residents and other stakeholders in a given region have to adopt appropriate strategies for sustainable and efficient use of natural resources for the current and future generations.

Soil erosion by water is a major problem in semi-arid parts of Andhra Pradesh and Telangana causing loss of top soil and terrain deformation in about 45% area. The severity of erosion in the entire state is due to undulating topography, high intensity rainfall and high erodibility of soils. Various papers involve

methods of evaluating soil erosion risk based on prevailing soil erosion rate or sediment yield index (Sreenivas and Venkataratnam 2005; Rahman *et al.*, 2009; Bewket and Teferi 2009) which does not take into account the degree of resilience or recovery at a given location. However, field experience and scientific evidences propose that the soil has an inherent ability to tolerate or permit a certain amount of erosion loss depending upon its location specific attributes and still maintain its long-term productivity and sustainability (Mandal *et al.*, 2009 and 2010) The permissible soil erosion rate or the soil loss tolerance limit (T-value) is a function of a balance between soil forming and soil depleting forces. USDA-NRCS (1999) proposed a typical range of T-values in integer steps varying from 2.5 to 12.5 t ha⁻¹ for different types of soils. Hence, permissible soil loss or T-value should also be taken into account in conjunction with prevailing rate of erosion while assessing the soil erosion risks in a given area. A soil erosion risk map can be a starting point of any regional intervention policy for soil erosion control and conservation. Such a database can be better generated and analyzed in a geographical information system (GIS) environment to delineate and prioritize the soil erosion risk areas at state or regional level. The soil erosion risk areas have not been delineated and prioritized earlier by adopting a systematic approach that integrates the prevailing erosion rates and the SLTL employing spatial technologies such as GIS technique for treating the erosion affected areas at state, regional or country level.

To provide an effective result for soil erosion risk assessment a methodology has been developed as a case study to assess the soil erosion risks in the states of Andhra Pradesh and Telangana, India by integrating spatial data on potential erosion rates and SLTL in GIS environment. It can be successfully applied to assess and prioritize soil erosion risks in any region or country and identify the best management practices to bring the erosion losses within the permissible limits. The objective of this study was to provide a soil erosion risk map for efficient planning and execution of conservation programs in Andhra Pradesh and Telangana.

2. MATERIALS AND METHODS

Study Area

The study area is located between 12°37' to 19°54'N latitudes and 76°46' to 84°46'E longitudes and

covers an area of 2,75,068 km² which constitutes about 8.4% of the TGA of the country comprising of Andhra Pradesh and Telangana states of India. The area has wide differences in climate, geology, landforms and vegetation, which are reflected in a large variety of soils. Depending upon this variability, the state is divided into three broad physiographic regions, namely South Deccan plateau, Eastern Ghats and Coastal Plains alongwith Deltaic areas. The climate varies from semi-arid to arid excepting coastal region of the state with rainfall mostly concentrating during the south-west monsoon (June to September). The summer temperature varies from 20 to 40°C, while in winter it falls between 13 and 32°C. The south-west monsoon plays a major role in changing the climatic condition of the state and it comprises two-third of total rainfall, while north-east monsoon contributes only one-third of the total rainfall in the state. The soils in the study area belong to 6 orders, 12 suborders, 18 great groups, 47 sub-groups and 132 soil families. Inceptisols are dominant soils covering about 36% of total area followed by Alfisols (30%), Entisols (11%), Vertisols (8%), Aridisols (3%) and Mollisols (2%) (NBSS&LUP, 1996). In the present study, 238 soil mapping units covering the entire geographical area of the state were considered to assess the soil erosion risk areas for efficient planning and implementation of conservation programmes. The most serious problem in the region is water erosion resulting in loss of topsoil. Soil depth varied between <25 to >150 cm. Soils under Southern Deccan plateau and eastern Ghat had relatively shallow soil depth than the soils under Western Ghat, and Coastal and Delta plains.

Estimation of Potential Erosion Rates and Soil Loss Tolerance Limits (SLTL)

Many process based models have been employed in the past for estimating soil erosion in different regions of the world (Li *et al.*, 2009; Rehman *et al.*, 2003; Khaleel *et al.*, 1979; Ewing and Michell, 1986; Hirschi and Bradfield, 1988; Nearing *et al.*, 1989; Beasley *et al.*, 1980; Knisel, 1980). However, the most commonly adopted empirical model is the universal soil loss equation (USLE) (Wischmeier and Smith, 1978) owing to its simplicity. Several studies have been conducted in India (Ali and Sharda, 2005; Sharda and Ali, 2008; Narain *et al.*, 1994) and other countries (Van Rompaey *et al.*, 2002; Tiwari *et al.*, 2000; Larson *et al.*, 1997) to evaluate the performance of the USLE in predicting

soil loss under different situations. Average annual soil loss ($\text{t ha}^{-1}\text{yr}^{-1}$) due to sheet and rill erosion from an area was predicted by the eq. 1.

$$A = RKLSCP \quad \dots(1)$$

Where, A- average annual soil loss ($\text{t ha}^{-1}\text{yr}^{-1}$), R- rainfall erosivity index number, K- soil erodibility factor, L- the slope length factor, S- the slope steepness factor, C- crop cover and management factor and P- conservation practice factor.

Information on rainfall, soil, land use, crops and conservation practices were collected from soil survey data sheet of ICAR-NBSS&LUP, Regional Centre, Bangalore and other different sources of the Andhra Pradesh and Telangana states.

In the present study, potential soil erosion rates for Andhra Pradesh and Telangana states were estimated by collecting data on various parameters of USLE at 10×10 km grid spacing. The parameters of the USLE were estimated for a particular grid area (10×10 km) using the average conditions. The rainfall factor, R, was determined from point rainfall values at grid points using an empirical prediction equation and the iso-erodent map of India (Ram Babu *et al.*, 1978). The soil erodibility factor, K, was estimated using data on soil physical and chemical properties of dominant soil association units at the grid location following Wischmeier and Smith (1978). For topographic factor, LS, slope steepness and length of slope were calculated using digital contour map. Slope length was taken as the distance from the point of origin of the runoff to the point where the slope steepness decreases sufficiently to cause deposition or to the point where runoff enters a well defined channel (Kurothe *et al.*, 1997; Yadav and Sachdeva, 2008). The crop cover and management factor, C, for each grid point was selected either on the basis of main crop grown in the grid area or existing natural land use. In case of two or more land uses with substantial area, a weighted average value was calculated. Soil conservation practice factor, P, was assigned to each grid point depending on the conservation practice used in that grid area. Average annual soil loss at each grid point was computed using corresponding factors and the corresponding erosion rates were then coupled with ARC-GIS (Version 9.3) software to prepare composite potential soil erosion rate map of the state employing extrapolation technique. Depending upon the

intensity of erosion, the potential erosion rates were organized into 6 classes, viz., very low ($<5 \text{ t ha}^{-1}\text{yr}^{-1}$), low ($5-10 \text{ t ha}^{-1}\text{yr}^{-1}$), moderate ($10-15 \text{ t ha}^{-1}\text{yr}^{-1}$), moderately severe ($15-20 \text{ t ha}^{-1}\text{yr}^{-1}$), severe ($20-40 \text{ t ha}^{-1}\text{yr}^{-1}$) and very severe ($>40 \text{ t ha}^{-1}\text{yr}^{-1}$) for delineation of erosion risk areas in the state.

A general guide developed at the Iowa State University Statistical Laboratory (NRCS, 1999) was used to arrive at the SLTL or T-values for each soil unit (Mandal *et al.*, 2009 and 2010) based on the soil group of each soil mapping unit and the soil depth. Soil group was determined based on a weighted additive model in which potential indicators were assigned weights as per their relative importance. These indicators, as derived from the sensitivity analysis of the Water Erosion Prediction Project (Nearing *et al.*, 1990), include infiltration rate, bulk density, organic carbon, water stable aggregates and fertility parameters. The required information on soil texture, organic carbon content and soil fertility status was collected and compiled from soil survey reports of ICAR-NBSS&LUP. The value of basic infiltration rate and bulk density was derived by using appropriate pedotransfer function (SSWATER). Soil erodibility factor (K) was computed based upon texture and organic matter content following Kirkby and Morgan (1980). After collecting relevant information on various parameters, SLTL values were computed for each grid of 10×10 km size corresponding to the potential erosion rate values. Accordingly, the T-value map was developed for the state by employing ARC-GIS (version 9.3) software. The T-value map developed by Mandal *et al.* (2009) and potential soil erosion map developed by Reddy *et al.* (2005) were used in this study to develop most critical areas for soil conservation planning on priority.

Assessment of Erosion Risks

The digital maps or spatial layers of potential erosion rates and T-values were integrated at 10×10 km grid level to assess erosion risks in a geospatial format (ARC-GIS 9.3). The digital intersection of the potential erosion rates and the SLTL provides the information about the spatial variability of the potential erosion risks areas where potential soil erosion exceeds soil loss tolerance values. The erosion risks were computed by employing the following equation:

Erosion Risk (ER) = [Mean value of potential erosion rate (E) – Soil loss tolerance limit (T)]

or

$$ER = E - T \quad \dots(2)$$

Those areas were delineated as risky where the difference between site specific potential erosion rates is more than the T-values. The areas where the difference between E and T-values is less than zero require no soil conservation treatment. By following this procedure or methodology, a thematic map for the erosion risks in Andhra Pradesh and Telangana was developed in GIS environment.

3. RESULTS AND DISCUSSION

Extent of Soil Erosion

The soil erosion map of Andhra Pradesh and Telangana (Fig. 1) depicts six classes of soil erosion

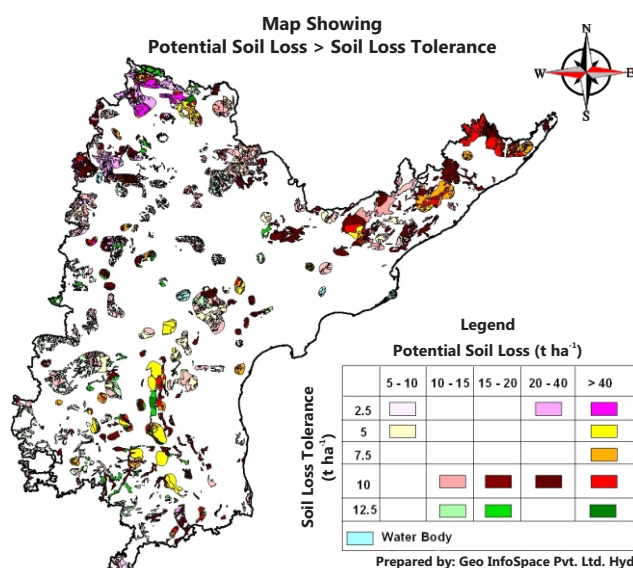


Fig. 1. Spatial distribution of critical areas with soil loss more than tolerance limits in Andhra Pradesh and Telangana

Table: 1

Area under different potential erosion rates and tolerance limits in Andhra Pradesh and Telangana

Area (M ha) under different erosion categories	Erosion categories (t ha ⁻¹ yr ⁻¹)						Others
	<5 (very low)	5 to 10 (low)	10 to 15 (moderate)	15 to 20 (moderately severe)	20 to 40 (severe)	>40 (very severe)	
	8.87 (32.26)	7.42 (26.96)	3.62 (13.16)	2.07 (7.54)	3.43 (12.50)	1.79 (6.53)	0.29 (1.04)
Area (M ha) under different T value	T-value (t ha ⁻¹ yr ⁻¹)						Rock/unreported
	2.5	5.0	7.5	10.0	12.5	Rock/unreported	
	1.18 (4.30)	4.14 (15.05)	9.17 (33.35)	9.91 (36.03)	2.27 (8.25)	0.83 (3.02)	

Note: Values in the parentheses are % TGA

rates ranging from less than 5 to more than 40 t ha⁻¹yr⁻¹. The major portion (32%) of the state falls in <5 t ha⁻¹yr⁻¹ soil loss category (Table 1), which is mainly covering command area (irrigated area) and rainfed leveled land. These are mostly the flat land areas in Deccan plateau of Andhra Pradesh and Telangana spread over east and west Godavari and Krishna districts of Godavari river zone and southern Telangana zone with loamy textured soils. Low erosion (5-10 t ha⁻¹yr⁻¹) occurs in about 7.41 M ha (27%) in almost all the districts of Andhra Pradesh and Telangana. Moderate (10-15 t ha⁻¹yr⁻¹) and moderately severe (15-20 t ha⁻¹yr⁻¹) erosion in about 3.62 M ha (13%) and 2.07 M ha (7%) in Anantapur, Chittoor, Kurnool, Warangal, Nalgonda and Karimnagar districts, respectively. Moderate to moderately severe erosion in these areas is primarily due to poor soil cover and fine textured soils. Erosion permitting crops such as sorghum, pearl millet, finger millet, cotton and maize are the dominant crops to cover soil during monsoon season in this region. Severe erosion (20-40 t ha⁻¹yr⁻¹) covers 12.5% area in the districts of Adilabad, Kadapa, Chittoor, Anantapur, Prakasam, Khammam, Nizamabad, Rangareddy and Vizianagaram. The low soil organic matter, steep slopes and rainfall pattern (period and high intensity) are major contributing factors for the severe erosion in these areas. Only 6.5% of the TGA is subjected to very severe (>40 t ha⁻¹yr⁻¹) erosion concentrated in hill and coastal areas (Kadapa, Adilabad, Srikakulam, Vishakhapatnam, Vizianagaram, East Godavari and Khammam). This may be attributed to high rainfall intensity and undulating topography in these areas. Nalawatmath *et al.* (2006) observed very low (< 5 t ha⁻¹yr⁻¹) and low (<5-10 t ha⁻¹yr⁻¹) erosion in similar physiographic regions of Karnataka.

From the above soil loss estimates, it is suggested that 19% area of the state (having >20 t ha⁻¹yr⁻¹ soil loss)

Extent of Soil Erosion Risks

priority classes were identified based on the targeted erosion rate or T-value at a given location in each state. Priority area with a target value of $2.5 \text{ t ha}^{-1}\text{yr}^{-1}$ is considered as most critical, requiring immediate attention for proper soil conservation planning. Critical areas prone to soil erosion risk were identified based on assigned target values or T-values of the area. Erosion risk was determined by computing a ratio between measured soil loss and soil loss tolerance (Basic, 1992). Priority area with target value of $2.5 \text{ t ha}^{-1}\text{yr}^{-1}$ is considered as most critical which require immediate attention in respect to soil conservation planning. Based on the present analysis, out of the total priority area of 5.31 M ha, about 0.54 M ha (11%) land area was found to be very critical with target value of only $2.5 \text{ t ha}^{-1}\text{yr}^{-1}$ (Table 2). The remaining priority area had 0.46 M ha (7.41%), 0.32 M ha (21.80%), 3.12 M ha (29.33%), and 0.87 M ha (30.45%) with target values of 5.0, 7.5, 10.0 and $12.5 \text{ t ha}^{-1}\text{yr}^{-1}$, respectively. Among the various risk classes, about 0.09 m ha area is most critical due to target value of $2.5 \text{ t ha}^{-1}\text{yr}^{-1}$ and prevailing erosion of $>40 \text{ t ha}^{-1}\text{yr}^{-1}$. Based on the analysis, it is concluded that about 19.30% of TGA of the state requires different degrees of erosion management. The areas where the prevailing erosion rate is more than the permissible limits require to be addressed on priority through appropriate conservation measures for bringing the erosion rate within the permissible rates.

The analysis also revealed that about 7.67% area had highest priority and is subjected to high erosion risk. The spatial distribution of critical areas under different T-classes is presented in Fig. 1. Considering the potential erosion rates alone, 80.7% of TGA of the country covered under 5 erosion categories with potential erosion rates varying from $5 \text{ t ha}^{-1} \text{ yr}^{-1}$ to $>40 \text{ t ha}^{-1} \text{ yr}^{-1}$ requires different types of erosion management practices. Similar approach was reported by Saroinsong *et al.* (2007) in generating erosion hazard

Soil Loss Tolerance (t ha ⁻¹ yr ⁻¹)	Potential Soil Loss (Area)							
	0-5	5-10	10-15	15-20	20-40	> 40	Others	Total
2.5	0	0.14	0	0	0.30	0.09	0	0.54
5	0	0.28	0	0	0	0.17	0.003	0.46
7.5	0	0	0	0	0	0.31	0.007	0.32
10	0	0.96	0.56	0.18	0.98	0.37	0.05	0.31
12.5	0	0.38		0.14	0.28	0.05	0.007	0.87
							Grand Total	5.31

map at watershed scale by comparing estimated soil loss with tolerable soil loss and identified the erosion hazard area where intolerable soil loss was predicted. It thus fully justifies the need for adopting an integrated approach for delineation and prioritization of erosion risk areas rather than considering only the potential erosion rates. Basic (1992) also suggested that erosion risk could be used as a reliable indicator of sustainability for highly erosive soils.

4. CONCLUSIONS

Soil erosion risk assessment is essential for the proper planning and management of future soil erosion disasters. A methodology has been developed by integrating potential soil erosion rates with SLTL for delineation of erosion risk prone areas in Andhra Pradesh and Telangana states of India. The analysis indicated that out of the total priority area of 5.31 M ha, about 0.54 M ha (11%) land area was very critical with target value of only 2.5 t ha⁻¹yr⁻¹ in the entire state. About 80.7% of TGA in the states does not face any erosion risk as the potential erosion rates are within the tolerance limits.

The results of the study can be used as basic data to assist conservation management and land-use planning, and the method used in this study is valid for generalized planning and assessment purposes to identify areas most vulnerable to soil erosion. Thus, the findings from the study would immensely help the land use planners and policy makers to identify and execute the site specific best management practices to treat the most vulnerable erosion prone areas on top priority and to bring the erosion rates within the permissible limits.

ACKNOWLEDGEMENTS

The authors express their gratitude to all the scientists of ICAR-IISWC (formerly CSWCRTI) who have directly or indirectly contributed to ensure timely completion of the study. Financial support provided by the Institute to undertake this study is thankfully acknowledged.

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