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Identification of vulnerable areas to soil erosion risk in India using GIS methods

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Abstract

This paper attempts to provide information for policy makers and soil conservation planners in the form of district-wise soil erosion risk (SER) maps prepared for the state of Telengana, India. The SER values for each district were computed by extracting the information on grid-wise soil erosion and soil loss tolerance limit values existing on the country-scale in a GIS environment. The objectives of the study were to (i) identify the areas of the state with high erosion risk, and (ii) identify areas with urgent needs of conservation measures. The results reveal that around 69 % of the state has negligible risk of soil erosion above the tolerance limits, and does not call for immediate soil conservation measures. The remaining area (2.17 M ha) requires conservation planning. Four districts, viz. Adilabad, Warangal, Khammam and Karimnagar are the most risk prone with more than one-fourth of their total geographical areas showing net positive SER values. In order to obtain a clearer picture and categorize the districts based on their extent of vulnerability, the Weighted Erosion Risk values were computed. Adilabad, Warangal and Khammam were identified as the worst-affected districts in terms of soil erosion and therefore need immediate attention for natural resource conservation.

1 Introduction

Soil is a finite and non-renewable natural resource. It takes between 200 and 1000 yr for 2.5 cm of topsoil to form under cropland conditions (Piementel et al., 1995). Fertile soils have always been the mainstay of prosperous civilizations, and great civilizations have fallen in the past because they failed to prevent the degradation of soils on which they survived (Diamond, 2005).The inherent productivity of many lands has been dramatically reduced as a result of soil erosion, accumulation of salinity and nutrient depletion (Scholes and Scholes, 2013).

Global assessments of present-day land degradation indicate that the percentage of total land area that is highly degraded has increased from 15 % in 1991 to 25 % by

2011 (FAO, 2011; UNCCD Secretariat, 2013). Another 36 % of the global land area is slightly or moderately degraded but in stable condition, while only 10 % is improving (FAO, 2011). With the exception of hyper-arid and cold regions, it has been estimated that worldwide, about 56 million km^2, i.e. about 43 % of ice-free land is vulnerable to various degrees of water erosion (Reich et al., 2001). In India, about 120.72 M ha area is affected byvarious forms of land degradation, of which 82.57 M ha is accounted for-solely by water-induced soil erosion in excess of 10 $Mg\,ha^{-1}\,yr^{-1}$ (Maji, 2007).

Among the different Indian states, nearly 40 % (10.93 M ha) of the total geographical area of erstwhile Andhra Pradesh was affected by water erosion (> 10 $Mg\,ha^{-1}\,yr^{-1}$), placing it third among the Indian states in this regard (Maji et al., 2010). Further, the district-wise soil loss ranges from less than five to greater than 40 $Mg\,ha\,yr^{-1}$ (Reddy et al., 2005). Andhra Pradesh has recently (2 June 2014) been bifurcated into two states, viz. Andhra Pradesh and Telengana, comprising thirteen and ten districts, respectively. Therefore, as per the report (Reddy et al., 2005), the ten districts of present day Telengana (effectively nine as Hyderabad is essentially an urban district), contributed 42 % to the water erosion-affected area (soil loss > 5 $Mg\,ha^{-1}\,yr^{-1}$) of the undivided state. This implies that about 66 % of the geographical area of the newly formed state has a soil loss of more than 5 $Mg\,ha^{-1}\,yr^{-1}$.

The above situation may look alarming for the soil conservation planners of the state, but, the statistics only provide information on the amount of soil lost under the present set of conditions without taking into account the inherent resilient capacity of the soil to resist to erosive forces. This capacity has been quantified through the adjusted soil loss tolerance limits (SLTL), or adjusted "*T*" values (Mandal et al., 2006), which is a dynamic, discrete and site-specific value estimated with the help of easily recorded minimum datasets. This approach led to the mapping of adjusted "*T*" values for different agro-ecological regions and physiographic zones of India (Bhattacharyya et al., 2008; Lakaria et al., 2008, 2010; Jha et al., 2009).

The erosion and SLTL maps of any region or state can be combined together using a GIS platform to generate the soil erosion risk (SER) map by following a simple protocol (Mandal and Sharda, 2013). Such a map is expected to be the most simplified one for the purpose of conservation planning. Some studies have been carried out on the systematic and scale-specific assessment of soil erosion risks (Deumlich et al., 2006; Volk et al., 2010) to serve as tools for decision making by policy makers. Most development plans in India are usually made for and implemented at district level as the functional unit. Therefore, in order to reach out to the functionaries of each state, we need to provide them district-wise information which will aid in prioritizing the soil conservation activities. This paper attempts to provide, for the first time in the country, such information in the form of district-wise SLTL and SER maps prepared in a GIS environment for the state of Telengana. The objectives of this paper are to: (i) identify the areas of the state with high erosion risk, and (ii) identify areas with urgent needs of conservation measures.

2 Materials and methods

2.1 Study area

The study was conducted on Telangana (Fig. 1), the twenty-ninth and thetwelfth largest state of India, comprising ten districts, and with a total geographical area (TGA) of 11.48 M ha. Telangana is situated on the Deccan Plateau, in the central stretch of the eastern seaboard of the Indian Peninsula. The state is situated between 15°50′ and 19°45′ N and between 77°25′ and 81°45′ E. It is bordered by the states of Odisha and Chhattisgarh in the north, by Maharashtra and Karnatakain the west, and by Andhra Pradesh in the east and south.The state is drained by two major rivers, viz. Godavari and Krishna, and by minor rivers such as the Bhima, the Manjira and the Musi.

The study area is covered by igneous (pink and gray granites and basalt) and metamorphic (granite gneiss) depositions (Satyavathi and Reddy, 2004). The major soil orders (Fig. 2) occurring in these landforms are Inceptisols, Vertisols, Entisols, Alfisols and Mollisols (Reddy et al., 1996).

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Telangana is a semi-arid area and has a predominantly hot and dry climate. It has been placed under agro-climatic region 10, agro-eco region (AER) 7 and agro-eco sub-region 7.2 (Gajbhiye and Mandal, 2005). On the basis of agro-climatic zonation, Telengana can be broadly divided into the northern Telengana zone (NTZ) and the southern Telengana (STZ). While the NTZ receives 810 to 1135 mm rainfall which climatically falls under semi-arid (moist) tropical, STZ receives 560 to 970 mm rainfall and is classified as semi-arid (dry) tropical (Satyavathi and Reddy, 2004).

According to the Statistical data of Andhra Pradesh (Govt. of AP, 2012), the state has a combined forest cover of about 2.74 million hectares (M ha), which is about 45 % of the forest area of erstwhile Andhra Pradesh. The net sown area of the state is 40 % of the TGA, with a cropping intensity of 124 %. The net irrigated area (NIA) of the state is 1.88 M ha, which is 44.5 % of the net cropped area and only 39 % of undivided Andhra Pradesh. Most of the irrigation is provided by wells, with the area irrigated being nearly 72 % of the NIA.

2.2 Soil loss Tolerance Limits (SLTL) map

The methodology followed for the development of SLTL values has been described earlier (Mandal et al., 2006; Lakaria et al., 2008). The soil mapping units (pertaining to Telengana) selected for the development of the soil map of undivided Andhra Pradesh (Reddy et al., 1996), were used for preparation of the SLTL map. A two-way matrix presenting soil depths against soil state/groups was used as a guide in assigning the "*T*" values for each soil mapping unit. The soil state/group for each mapping unit was obtained by employing a weighted additive model, wherein five indicators selected from the sensitivity analysis of the Water Erosion Productivity Project (Nearing et al., 1990) were assigned scores and weighted as per their relative importance. Since the primary function of the soil with respect to erodibility is to permit infiltration (Karlen and Stott, 1994), the highest weight of 0.35 was assigned to this soil function. Bulk density was assumed to be complementing the primary function (i.e. *infiltration)* and was assigned a weight of 0.10. The next most important function, resistance to physical degradation

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(soil erodibility factor, K) was assigned a weight of 0.25, while 0.15 were assigned to each of the functions concerned with resistance to biochemical degradation (soil organic carbon) and the sustainability of plant growth (soil pH, which is a general indicator of soil fertility status in the absence of other data). In this approach the ability of soil to sustain plant growth was assumed to be of less importance than the process contributing to infiltration or erodibility.

Data on soil texture, organic carbon and fertility parameters for each mapping unit were compiled from various publications of NBSSLUP (NBSSLUP, 2002; Reddy et al., 1996). Basic infiltration rate and bulk density were derived by appropriate pedotransfer function using SSWATER, and soil erodibility factor, K was computed based on texture and soil organic matter content (Kirkby and Morgan, 1990). The indicator values were transformed into dimensionless scores ranging from 0 to 1 through fuzzy modeling (Wymore, 1993) using a scoring algorithm. With this approach, attribute values were converted to common membership grades (0–1), according to class limits specified by analysts based on experience or conventionally imposed definitions (McBratney and Odeh, 1997). If $\mathrm{MF}(x_i)$ represents individual membership function (MF) values for ith soil property x, then the basic model can be described as:

$$\mathrm{MF}(x_i) = \left[1/\left(1 + \{(x_i - b)/d\}^2\right)\right] \tag{1}$$

As there are various soil characteristics to be rated, the membership function values of individual soil characteristics under consideration were then combined using a convex combination function to produce a joint membership function (JMF) for all attributes, Y as follows:

$$\mathrm{JMF}(Y) = \sum_{i=1}^{n} \lambda_i \mathrm{MF}(x_i) \tag{2}$$

where, λ_i = weighting factor for the ith soil property x_i; $\mathrm{MF}(x_i)$ = membership function for the ith soil property x.

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An asymmetric model is used where only the lower and upper boundaries of a class have practical importance. This function consists of two variants:

1. Asymmetrical left (more is better)

$$\mathrm{MF}(x_i) = \left[1/\left(1 + \{(x_i - b_1 - d_1)/d_1\}^2\right)\right] \text{ if } x_i < (b_1 + d_1) \quad (3)$$

2. Asymmetrical right (less is better)

$$\mathrm{MF}(x_i) = \left[1/\left(1 + \{(x_i - b_{2+}d_2)/d_2\}^2\right)\right] \text{ if } x_i > (b_2 - d_2) \quad (4)$$

The Model parameters include lower crossover point, central concept (b) and upper crossover point and width of transition zone (d). The lower and upper crossover points represent the situation where a land attribute is at a marginal level for a given purpose, while "b" is for an ideal level (Burrough et al., 1992; Sys, 1985). For example, for infiltration an ideal value was set at $5\,\mathrm{cm\,h^{-1}}$ following the critical level concept developed by Lal (1996), while crossover point (marginal) was set between 1 and $2\,\mathrm{cm\,h^{-1}}$. Similarly the value of K (erodibility), presented in an ordinal form consisted of five classes (Table 1) and has an asymmetric right function (model 4), that is less is better, because as the K value increases resistance to erosion decreases. The associated score of 1 represents the highest potential function for that system, i.e. the indicator is non-limiting to particular soil functions and processes.

It was assumed that the general relationships between a given indicator and the soil functions were relatively constant. The relationship is expressed in the shape of an indicator's scoring curve (Karlen and Stott, 1994; Andrews et al., 2002). Thus use was made of an increasing logistic curve, more is better as for infiltration, organic carbon and fertility and a lower asymptotic curve, less is better as for bulk density (Grossman et al., 2001). A "less is better function" was also used for soil erodibility (Harris et al., 1996).

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Ratings obtained for different soil functions when converted to 0 to 1 scale were multiplied by their respective weights. The aggregate of all the weighted parameters was then used to quantify the state of soil (Q) for each soil mapping unit:

$$Q = q_{\mathrm{we}} w_{\mathrm{we}} + q_{\mathrm{wt}} w_{\mathrm{wt}} + q_{\mathrm{rpd}} w_{\mathrm{rpd}} + q_{\mathrm{rbd}} w_{\mathrm{rbd}} + q_{\mathrm{spg}} w_{\mathrm{spg}} \quad (5)$$

Where "q" is the individual ratings for different soil function such as q_{we} represented by the infiltration rate; q_{wt} the water transportation; q_{rpd} the rate of physical degradation; q_{rbd} the rate of biological degradation; q_{spg} the ability of soil to sustain plant growth and w the weight assigned to each function.

Soils were grouped in to three groups: I ($Q < 0.33$), II ($Q = 0.33$–0.66) or III ($Q > 0.66$) based on the aggregated score (Q) as obtained in Eq. (5). Therefore, soils under group III perform all functions at optimal levels and thus may erode at higher rates than those under groups I or II. A general guide developed at the Iowa State University Statistical Laboratory (USDA-NRCS, 1999) was used to arrive at the erosion tolerance (T) limits (Table 2) based on the soil group of the unit and soil depth.

The "T" values were computed for each 10 km × 10 km grid point earmarked by NBSSLUP for the preparation of maps related to soil (Reddy et al., 1996) and potential soil erosion rates (Reddy et al., 2005) of undivided Andhra Pradesh. The values of "T" and potential soil erosion rates (PSER) pertaining to the grid points located in the ten districts of Telengana were extracted from those earlier maps and new SLTL and PSER maps were carved out for the state on an Arc-GIS (version 9.3) platform.

2.3 Soil Erosion Risk (SER) map

The spatial layers of SLTL and PSER maps were integrated using the Arc-GIS (version 9.3) software at 10 km × 10 km grid levels to generate the SER statistics and map of Telengana state. The intersection of SLTL and PSER provides information on the actual risk associated with soil erosion. More specifically, the SER was computed for each point as follows:

$$\text{SER} = \text{Median value of the PSER} - \text{“}T\text{” value} \quad (6)$$

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The potential rates of erosion (Reddy et al., 2005) were classified into various ranges, viz., < 5, 5–10, 10–15, 15–20, 20–40 and > 40 $Mg\,ha^{-1}\,yr^{-1}$ representing slight, moderate, strong, severe, very severe and extremely severe erosion. For our purpose, we first reduced the classes to four as: (a) < 5 $Mg\,ha^{-1}\,yr^{-1}$ with a mid-value of 2.5 $Mg\,ha^{-1}\,yr^{-1}$, (b) 5–10 $Mg\,ha^{-1}\,yr^{-1}$ with a mid-value of 7.5 $Mg\,ha^{-1}\,yr^{-1}$, (c) 10–20 $Mg\,ha^{-1}\,yr^{-1}$ with a mid-value of 15.0 $Mg\,ha^{-1}\,yr^{-1}$, and (e) 20–40 $Mg\,ha^{-1}\,yr^{-1}$ with a mid-value of 30 $Mg\,ha^{-1}\,yr^{-1}$. The class > 40 $Mg\,ha^{-1}\,yr^{-1}$ was combined with the 20–30 $Mg\,ha^{-1}\,yr^{-1}$ class because the area under the former class was the lowest (12 %) in the state. As the potential soil erosion rates were defined as class ranges with no exact value, the mid-value of each class was considered for the ease of subtraction between PSER and "*T*" values corresponding to each point in the map. The SER values thus obtained for an individual grid point was placed under one of the five categories created for conservation planning and prioritization purpose: < 0, 0–5, 5–10, 10–20 and 20–30 $Mg\,ha^{-1}\,yr^{-1}$. The SER map was generated for the state as a final product for conservation planners and other development agencies.

2.4 Weighted Soil Erosion Risk (WSER)

Since the extent and severity of erosion risk in each district has large variations, it is difficult to identify the most affected district in the state. To overcome this problem and prioritize the districts, a simplified weighted erosion risk (WSER) index for each district was computed, which simultaneously combines information on two parameters: (a) percent geographical area of a district affected by soil erosion risk, (b) and their severity of soil erosion risk.

Since severity of erosion risk is expressed in a class with a pre-defined range, the median of each class-range was chosen: (a) to represent the class, and (b) as a weight to signify the severity of erosion risk in affected area. Therefore, weighted erosion risk is expected to assign high priority to districts with greater proportion of its geographical

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area under high erosion risk class.

$$\mathrm{WSER}_j = \sum_{i=1}^{n} A_{ji} \cdot W_i$$

j = the number of district in the state i.e. 9 and, $i = (1, 2, \ldots, n)$ is the number of erosion risk classes i.e. 4.

Where, WSER_j = weighted soil erosion risk for ith district. A_{ji} = area under ith class in jth district. W_i = weight assigned for ith class.

Further, for the ease of interpretation and classification, values of WSER were converted into WSER index using the given formulae

$$\mathrm{WSERI}_j = \frac{\mathrm{WER}_j - \mathrm{WER}_{\mathrm{Min}}}{\mathrm{WER}_{\mathrm{Max}} - \mathrm{WER}_{\mathrm{Min}}}$$

Where, WSERI_j = Weighted soil erosion risk for jth district. $\mathrm{WER}_{\mathrm{Min}}$ = Minimum value of WER among all the districts. $\mathrm{WER}_{\mathrm{Max}}$ = Maximum value of WER among all the districts.

Based on the WSER index values, districts were classified into three classes representing priority class-I, II and III using percentile analysis. A percentile is a value below which a certain proportion of the observations lie. It is a measure that tells us what percent of the total frequency scored (our case WER index scores) at or below a certain point. We estimated two such data points using the percentile function of Microsoft excel, viz. 33 and 66 percentile, represented by the estimated values of 0.290 and 0.607, respectively. Therefore, all the districts based on their WER index scores, were divided into three equal groups or priority classes (PCs): (i) PC-I, representing districts having WER value less than 0.290, (ii) PC-II, with the districts having WER index value between 0.290 to 0.607, and (iii) PC-III where the WER Index score was more than 0.607.

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3 Results and discussion

3.1 Potential rates of soil erosion

The district-wise areas subjected to different classes of annual potential soil loss are shown in Table 3. A major part of the TGA of the state (37 %) has moderate rates of erosion (5–10 $\mathrm{Mg\,ha^{-1}\,yr^{-1}}$), while about 20 % is prone to erosion rates in excess of 10 $\mathrm{t\,ha^{-1}}$. In respect of the latter, Adilabad leads the table with more than one-third of its area being strongly eroded. Extremely severe erosion rates (> 20 $\mathrm{Mg\,ha^{-1}\,yr^{-1}}$) occur in about 0.25 Mha of the state, with roughly 83 % credited to the three districts of Warangal, Khammam and Adilabad alone. A comparison among the different districts of Telengana with respect to the percent area under different erosion classes has also been made in Table 3. While Adilabad, Karimnagar, Khammam, Nizamabad and Warangal have more than 20 % of their total areas affected by > 10 $\mathrm{Mg\,ha^{-1}\,yr^{-1}}$, the class 5–10 $\mathrm{Mg\,ha^{-1}\,yr^{-1}}$ needs to be focused. In this respect, 56, 46 and 44 % of Rangareddy, Khammam and Medak, respectively may be targeted for soil and water conservation measures.This is necessary to prevent further escalation of erosion rates and increase chances of recovery.

3.2 Soil loss tolerance limits (*T*)

The SLTL map of Telengana district has been shown in Fig. 3. Soils prone to high rates of erosion may not require immediate conservation measures if they have high "*T*" values. On the other hand, soils with slight or moderate rates of erosion but with low "*T*" values call for urgent conservation strategies (Lakaria et al., 2008). Although more than 20 % of the TGA of Telengana is prone to erosion rates > 10 $\mathrm{Mg\,ha^{-1}\,yr^{-1}}$, 48 % of the area of the state can tolerate soil loss up to 10 $\mathrm{Mg\,ha^{-1}\,yr^{-1}}$. Figure 4 depicts the percent distribution of different "*T*" classes across the districts of the state. Only nine % of the state has "*T*" values below 5 $\mathrm{Mg\,ha^{-1}\,yr^{-1}}$. About 17.8, 16.0, 13.1 and 10.5 % of the soils of Khammam, Warangal, Adilabad and Nizamabad, respectively can tolerate erosion rate exceeding 5 Mg ha^{-1} yr^{-1}. An area of 0.19 M ha in the state has a "*T*" value of only 2.5 Mg ha^{-1} yr^{-1}, of which 79 % occurs in the two districts of Adilabad and Nizamabad.

3.3 Soil Erosion Risk (SER)

The process of decision making becomes easier when both the above conditions (erosion and tolerance) are combined into a single parameter, the soil erosion risk (Mandal and Sharda, 2013). An area with a positive value of SER demands measures for soil conservation. The soil erosion risk map generated for Telengana, by deducting the "*T*" values from soil erosion rates has been shown in Fig. 5. The results shown in the Table 4 revealed that around 69 % of the state has low SER, and does not call for immediate soil conservation measures. The remaining area (2.17 M ha) requires conservation planning albeit through prioritization. Four districts, viz. Adilabad, Warangal, Khammam and Karimnagar are the most risk prone with more than one-fourth of their total geographical areas showing net positive SER values. Among the four, Adilabad was assigned the highest priority as about 40 % of its area is prone to erosion risk. This could be attributed to the highest (among all districts of Telengana) average annual rainfall (1157 mm), highest area under shallow soils (36 %), undulating topography (range −239 to 543 m above mean sea level) and one of the lowest cropping intensities in the state (114 %). On the other extreme is Medak, which is the least erosion prone district with only 6 % of its area showing positive SER values. This is probably due to the highest net sown area in the state (46.7 %), higher cropping intensity (135 %), lower rainfall (873 mm) and relatively flatter general topography (range −469 to 620 m above mean sea level) leading to greater area under medium to deep soils (only 8 % of the cultivated soils are shallow, data not sown).

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3.4 Weighted Soil Erosion Risk (WSER)

The index also placed Adilabad district on topmost priority as it is the most severely affected district of the state (Table 5). In spite of having the highest share of area (7 %) under the category 20–30 Mg ha^{-1} yr^{-1}, Warangal district appears second in the list owing to the relatively lower area under the risk categories 0–10 (15 %) and 10–20 Mg ha^{-1} yr^{-1} (0 %). Medak, with the least WER value is least affected district of the state.

The WSER index can therefore be considered as an important threat to agricultural production in a particular district. For example, the top three districts in terms of WSER index viz., Adilabad, Warangal and Khammam together account for 24, 27 and 32 % of the cereals, pulses and oilseeds production of Telengana, respectively (DES, Andhra Pradesh, 2010). This calls for prioritized soil conservation measures in the districts to ensure minimum loss in crop production. Logically the order of priority in conservation planning would be the areas with a risk exceeding 20 (0.23 M ha), followed by 10 (0.16 M ha) and 5 (1.78 M ha) Mg ha^{-1} yr^{-1}. However areas with high erosion risk may be put to alternate land use as they mostly occur in hilly areas and those with highly undulating topography, and a huge cost would be involved in applying conservation measures. Therefore, we feel that the highest priority should be accorded to those areas where the risk is between 5 and 10 Mg ha^{1} yr^{-1}, because if such areas are left untreated for long it may lead to irreversible loss of agricultural land. Among the districts, Adilabad has the highest area (0.46 M ha) with SER 5–10 Mg ha^{-1} yr^{-1}, followed by Khammam (0.27 M ha).

4 Conclusion

The study led us to conclude that soil erosion risk values, derived from the presently occurring soil loss under different agro-ecological conditions and the inherent capacity of the soil to tolerate erosion is a more useful indicator for policy makers and plan-

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ners to prioritize soil and water conservation activities. The exercise conducted for the youngest state of India allowed us to categorize the districts of the state into different risk classes on the basis of the weighted erosion risk index for management prioritization. Adilabad, Warangal and Khammam are the districts identified to be worst-hit by soil erosion and therefore need immediate attention for natural resource conservation.

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Table 1. Range of soil properties and their scaling (0–1).

Ranking	Soil attributes									
	Infiltration ($cm\,h^{-1}$)		Bulk density ($Mg\,m^{-3}$)		Erodibility Factor *K*		Total organic carbon (%)		pH	
	Range	Score	Range	Score	Range	Score	Range	Score	Range	Score
1	0.5–1.0	0.2	< 1.40	1.0	< 0.10	1.0	< 0.50	0.2	< 5.0 > 9.0	0.2
2	1.0–2.0	0.3	1.40–1.47	0.8	0.10– 0.29	0.8	0.50–0.75	0.3	5.0–5.5 8.5–9.0	0.3
3	2.0–3.5	0.5	1.48–1.55	0.5	0.30–0.49	0.5	0.75–1.00	0.5	5.5–6.0 8.0–8.5	0.5
4	3.5–5.0	0.8	1.56–1.63	0.3	0.50– 0.69	0.3	1.00–1.50	0.8	6.0–6.5 7.5–8.0	0.8
5	> 5.0	1.0	> 1.63	0.2	> 0.70	0.2	> 1.50	1.0	6.5–7.5	1.0

Table 2. Assignment of T value to soil mapping units based on soil depth and aggregated score.

Soil depth (cm)	Group I ($Q < 0.33$)*	Group II ($Q = 0.33$–0.66)	Group III ($Q > 0.66$)
	Annual permissible soil loss limit ($Mg\,ha^{-1}$)		
< 25	2.5	2.5	7.5
25–50	2.5	5.0	7.5
50–100	5.0	7.5	10.0
100–150	7.5	10.0	10.0
> 150	10.0	12.5	12.5

* Q is soil state (the total aggregated score).

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Table 3. Potential rates of soil erosion in different districts of Telangana.

District	Geographical area (ha)	Area (ha) affected by erosion rates ($Mg\,ha^{-1}\,yr^{-1}$)			% District area affected by particular erosion rate		
		< 5	5–10	> 10	< 5	5–10	> 10
Adilabad	1 614 212	295 921 (7.5)	662 515 (15.5)	561 289 (23.6)	18.3	41.0	34.8
Karimnagar	1 174 298	499 705 (12.6)	298 633 (7.0)	287 042 (12.0)	42.6	25.4	24.4
Khammam	1 666 634	403 890 (10.2)	769 889 (18.1)	361 325 (15.2)	24.2	46.6	21.7
Mahabubnagar	1 841 402	858 728 (21.7)	434 708 (10.2)	330 810 (13.9)	46.6	23.6	18.0
Medak	969 898	349 279 (8.8)	434 222 (10.2)	65 802 (2.8)	36.0	44.8	6.8
Nalgonda	1 391 423	532 045 (13.4)	546 086 (12.8)	246 320 (10.3)	38.2	39.3	17.7
Nizamabad	788 730	259 029 (6.6)	318 027 (7.5)	166 118 (7.0)	32.8	40.3	21.1
Rangareddy	737 398	183 269 (4.6)	414 530 (9.7)	81 812 (3.4)	24.9	56.2	11.1
Warangal	1 274 911	573 315 (14.5)	385 046 (9.0)	281 876 (11.8)	45.0	30.2	22.1
State	11 480 218	3 955 181	4 263 656	2 382 394	34.4	37.1	20.8

Values in parenthesis are percent of state area affected by that particular erosion class.

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Table 4. Aerial ('000 ha) extent of soil erosion risk classes in different districts of Telangana.

District	Soil erosion risk (R) values ($Mg\,ha^{-1}\,yr^{-1}$)				
	< 0	0–5	5–10	10–20	20–30
Adilabad	876.4	81.8	459.5	74.2	27.4
Karimnagar	773.0	46.1	244.4	0	21.8
Khammam	1068.1	111.2	272.5	19.4	63.8
Mahabubnagar	1293.5	63.8	245.9	0	21.0
Medak	783.6	21.6	35.3	9.0	0
Nalgonda	1077.9	35.9	210.6	0	0
Nizamabad	561.2	34.3	91.2	56.4	0
Rangareddy	592.3	52.4	34.6	0	0
Warangal	876.9	81.3	188.6	0	93.3
State	7903.1 (68.8)	528.5 (4.6)	1782.7 (15.5)	158.9 (1.4)	227.4 (2.0)

Figures in parenthesis are percent of state area under a particular "R" class.

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Table 5. District-wise % geographical area under different Soil erosion risk ranges ($Mg\,ha^{-1}\,yr^{-1}$) and priority classes.

District	0–5	5–10	10–20	20–30	Weighted Soil Erosion Risk (WSER)	WSER Index	Priority class
Adilabad	5	28	5	2	337.6	1.000	PC-I
Warangal	6	15	0	7	309.9	0.905	PC-I
Khammam	7	16	1	4	252.4	0.707	PC-I
Karimnagar	4	21	0	2	212.3	0.569	PC-II
Nizamabad	4	12	7	0	204.8	0.543	PC-II
Mahabubnagar	3	13	0	1	137.4	0.312	PC-II
Nalgonda	3	15	0	0	120.0	0.252	PC-III
Rangareddy	7	5	0	0	53.0	0.022	PC-III
Medak	2	4	1	0	46.7	0.000	PC-III
Weights	2.5	7.5	15	25	–	–	–

Note: districts having the value of WER Index less than 0.290, 0.290 to 0.607 and more than 0.607 were grouped under priority class (PC)-I, PC-II and PC-III, respectively.

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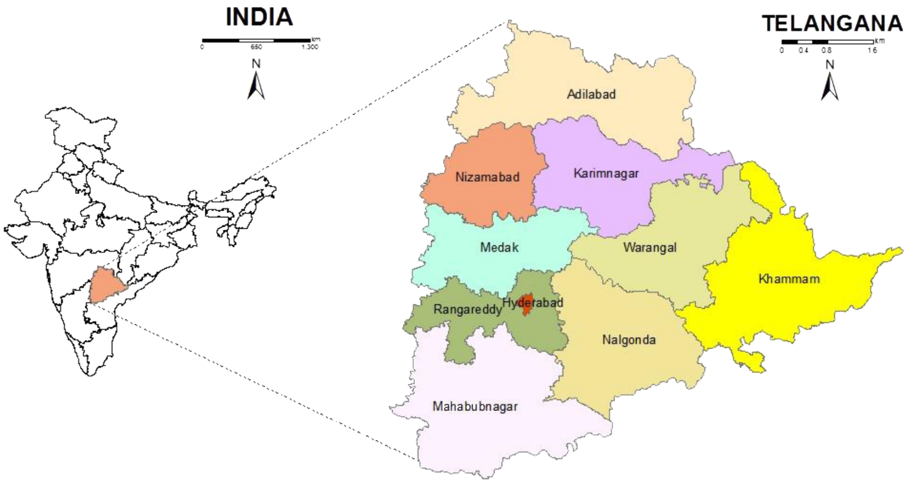

Figure 1. Outline of the study area.

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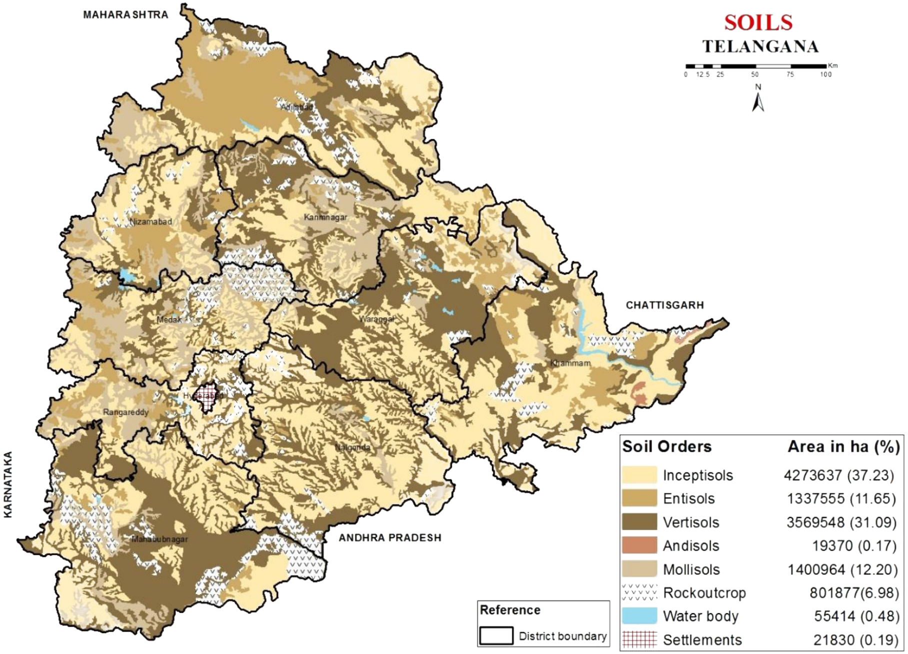

Figure 2. Major soil orders of Telengana.

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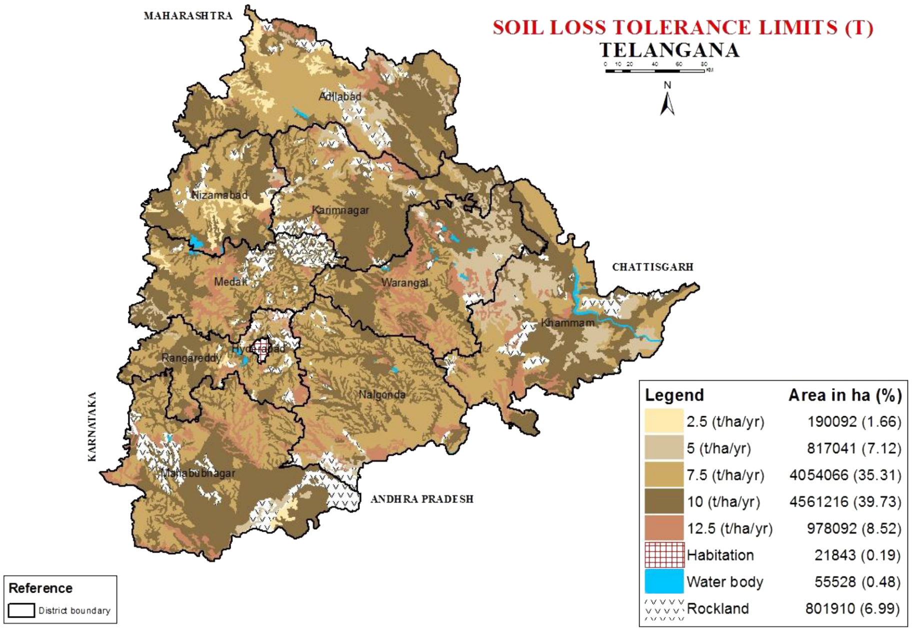

Figure 3. Soil loss tolerance map of Telengana.

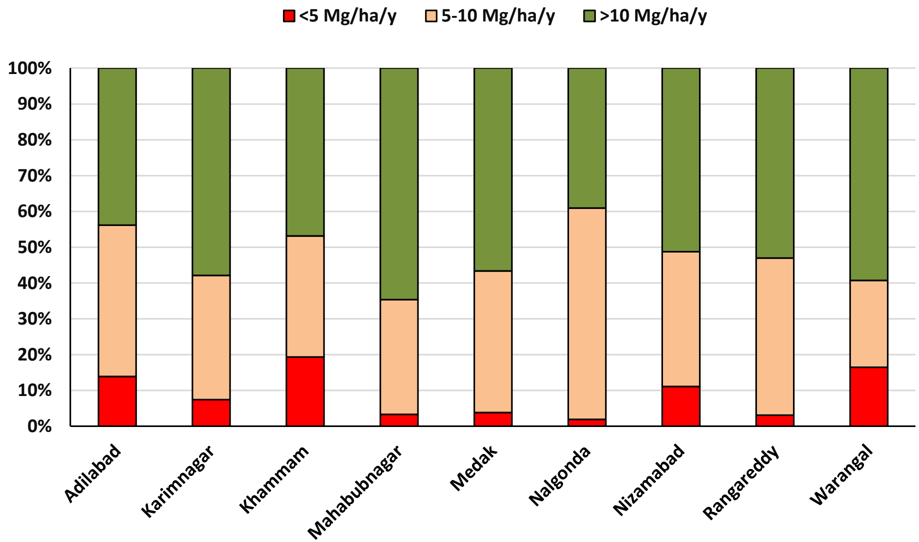

Figure 4. Percentage area distribution of different districts of Telengana under different "T" value classes.

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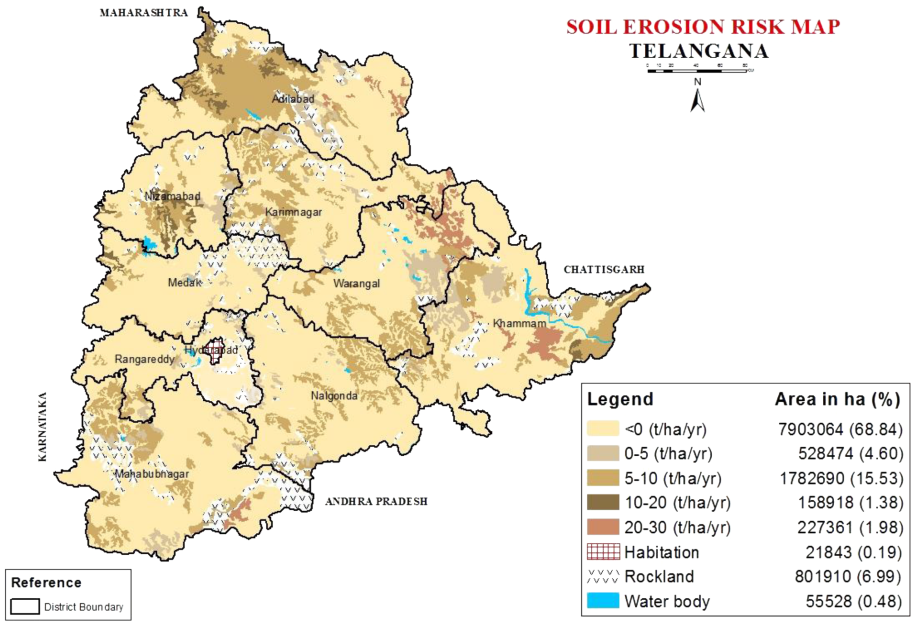

Figure 5. Soil erosion risk map of Telengana.

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