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# Erosion risk identification study using RUSLE model in G. Madugula Mandal, Visakhapatnam District, A.P., India

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**Abstract:**

*Soil erodability that correlated with barren or void vegetation cover land has an outlandish result in the lower part of the study area. This study aim to analysis the soil erosion risk of G Madugula Mandal, Visakhapatnam district. The study combines both remote sensing and GIS techniques to obtain severe erosion risk zones in the study area by taking into consideration of ancillary data such as Soil, DEM and LandSat satellite data. The method verified and cross checked by ground truth data. The results show that, Very Low and Low classes are scattered in all over the study area due to the randomization of the Land units and represent almost 76.14% of the study area. The Very Low class is occupying 50.67% of the study area in correspondence to valley fills or foot slopes, where the low slope gradient allows the accumulation of materials transported by water or* *gravity. The High class is mainly concentrated in the Kumbidisingi Panchiteat at Solamulu and in a small unit in Solabham Panchiteat Mallipadu village representing 17.36% of the study area. Therefore, appropriate soil conservation measure should be taking place in order to further prevent soil loss.*

**Key words:** Soil, RUSLE equation, Remote sensing, GIS, DEM

## Introduction

Soil erosion is a global environmental crisis in the world today that threatens natural environment and also the agriculture. Accelerated soil erosion has adverse economic and environmental impacts (Lal, 1988). It creates on-site and off-site effects on productivity due to decline in land/soil quality. The current rate of agricultural land degradation world-wide by soil erosion and other factors is leading to an irreparable loss in productivity on about 6 million hectare of fertile land a year. Asia has the highest soil erosion rate of 74 ton/acre/yr (El-Swaify, 1994) and Asian rivers contribute about 80% per cent of the total sediments delivered to the world oceans and amongst these Himalayan rivers are the major contributors articulated that the Himalayan and Tibetan regions although covers only about 5% of the earth's land surface, but supply around 25% of the dissolved load to the world oceans. The alarming facts figured out by Narayan and Babu (1983) that in India about 5334 Mt (16.4 ton/hectare) of soil is detached annually, about 29% is carried away by the rivers into the sea and 10% is deposited in reservoirs resulting in the considerable loss of the storage capacity. Das, (1985) has reported in India it is estimated that about 38 % out of a total reported geographical area, that is about 127 million hectare are subjected to serious soil erosion.

The integrated use of remote sensing and GIS could help to assess quantitative soil loss at various scales and also to identify areas that are at potential risk of soil erosion. (Saha et.al., 1991). Several studies showed the potential utility of GIS technique for quantitatively assessing soil erosion hazard based on various models (Saha et.al, 1991, shrestha, 1997). Bear on your mind the above discussion, the present study aims at characterizing the land resources through remote sensing and other ancillary data and to integrate these informations in GIS to compute quantitative soil loss using RUSLE model for sustainable development.

## Study area

The study area delinated from the Survey of India (SOI) topographical maps of the series 65 J/8, J/12, 65 K/5, and 65 K/9 published on a scale 1:50, 000 is located between the 17º 45' N to 18º 10' North latitudes and 82º 20' E to 82º 45' East longitudes and a part of the Eastern Ghats located in the Visakhapatnam district of Andhra Pradesh, India. The geographical area of the mandal is 720 Sq.Km which is bounded on the North-East by Paderu and Madugula mandals, on the west and south-west by Chintapalli mandal, on the south by Ravikamatam, on the North Pedabayulu mandal. G.Madugula is a broad picturesque and rich valley with an altitude of over 900m above the mean sea level. The entire G.Madugula is inhabited by schedule tribes with different sectors and is surrounded by hill streams. The location map of the study area is shown in Figure 1.

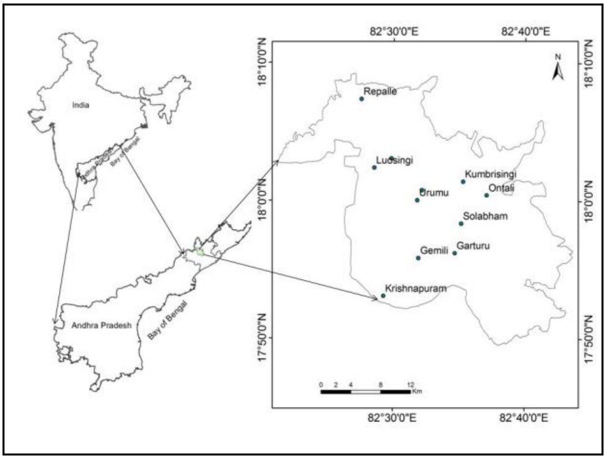


**Fig.1: Location map of the study area**

## Methodology

### Slope map

Terrain data was analyzed as a component in complex GIS modeling. Slope is expressed as the change in elevation over a certain distance. Slope function in "Image Interpreter" was used to generate a slope image. Slope is most often expressed as a percentage, but can also be calculated in degrees. Slope map was classified based on NRSA criteria given in the (Table 1)

**Table 1 Slope Classes**

| S. No | Gradient | Slope class |
|---|---|---|
| 1 | Steep slope | >31 |
| 2 | Moderately steeply sloping | $13^0$–$19^0$ |
| 3 | Moderately sloping | $6^0$–$13^0$ |
| 4 | Gently sloping | $3^0$–$6^0$ |
| 5 | Very gently sloping | $1^0$–$3^0$ |
| 6 | Nearly plain | <1 |

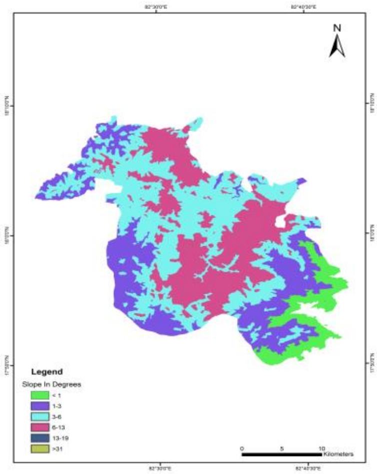


**Figure 1: Slope map of the study area**

## Revised Universal Soil Loss Equation (RUSLE) Calculation

The factors causing erosion such as climate, soil properties, vegetation cover and management practices are considered for estimating soil loss. The RUSLE equation is a multiplicative function of five factors controlling the rill and inter-rill erosion (Renard et al., 1997) and can be expressed as:

$$A = R*K*LS*C*P \qquad (1.1)$$

Where:
A is the mean annual soil loss expressed in ton\ha*yr
R is rainfall and runoff erosivity index (in MJ* mm\ha*yr)
K is soil erodibility factor (in ton*ha*h/ha*MJ*mm)
LS is slope Steepness and slope Length factor (dimensionless)
C is the cover factor (dimensionless)
P is the conservation practice factor (dimensionless).

## Erosivity Index - R factor

Long-term average R-values are often correlated with more readily available rainfall values like annual rainfall or the modified Fournier's index (Sadeghi et.al 2011). For the computation of R factor, data from single meteorological stations within the Mandal of 19 years of recording was used and Schreiber's method (Efe et.al., 2008) (as expressed in Equation1.2) was then applied for determining the precipitation change according to the elevation.

$$Ph = P_0 + 4.5 * h \text{ ( MJh}^{-1}\text{ year}^{-1}) \qquad (1.2)$$

Where Ph is the average annual precipitation (mm) and $P_o$ represents the amount of average annual rainfall (mm) at chosen meteorological station and h (measured in mega Joule per hector per year) is elevation of the place which the precipitation is be calculated. From the results of this calculation Ph values determined as 5849mm (as shown in Figure 2), a rainfall factor layer was then generated with ESRI ArcGIS over the whole study area by using a raster calculation. R-factor for different station may have different value but in the current study we have single station with 19 years of record so that we are forced to use this equation for single station which may or may not have effect in our conclusion.

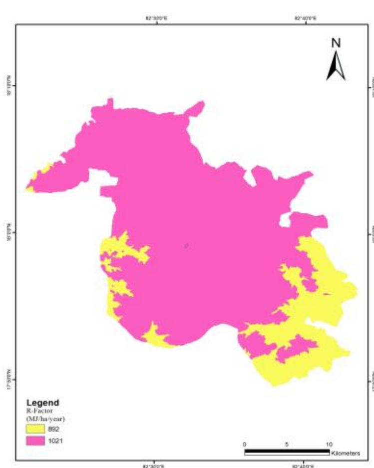


**Fig 2: R-Factor Map**

## Soil Erodibility - K factor

It has been found that the erodibility of a soil increases proportionally with the amount of fine sand and silt content (Giordani and Zanchi, 1995). In fact, finer textured soils, very rich in clay, are more resistant to particles detachment, because of their great cohesion, while coarser textured soils allow to a high infiltration of water, avoiding superficial runoff. Even the organic matter content is important for stating erodibility, as it contributes to increase particle aggregation (by the presence of chelating agents) and water infiltration. All the factors mentioned above are grouped in one equation (eq. 1.3), valid for soils with less than 70% of silt plus very fine sand (Wischmeier and Smith, 1978).

$$K = \frac{2.1 * 10^{-4}(12 - OM) * M^{1.14} + 3.25 * (s-2) + 2.5 * (p-3)}{100} \qquad (1.3)$$

Where:
OM is the percentage of organic matter;

M is the particle size parameter defined as:

$$M = (\%FineSand + \%Silt) * (100 - \%Clay) \qquad (1.4)$$

Where:
Fine Sand is considered the soil fraction between 0.1 and 0.05mm;
Silt, the fraction between 0.05 and 0.002mm;
Clay is the particles measuring less than 0.002mm (USDA classification cited in Renard et al., 1997).
“s” is the soil structure code.

The structure codes “s”, derived from Wischmeier and Smith monogram, 1978, are:

- very fine granular (<1mm)
- fine granular (1-2mm)
- medium coarse granular (2-5mm)
- blocky, platy or massive (5-10mm).

K-factor values were obtained from the lists of the major soil types after experimental research conducted by the General Directorate of Rural Affairs in Turkey (Table 1). K-factor values were obtained by adding the K-factor value as an attribute to the soil theme's table 1.

**Table 1: Soil Erodibility ( K-factor ) Values**

| Textural class | Organic matter content (%) | | |
|---|---|---|---|
| | **0.5** | **2.0** | **4.0** |
| Loamy sand | 0.12 | 0.10 | 0.08 |
| Clay loam | 0.28 | 0.25 | 0.21 |
| Clay | 0.25 | 0.23 | 0.19 |
| Sandy clay loam | 0.0277 | - | 0.0250 |

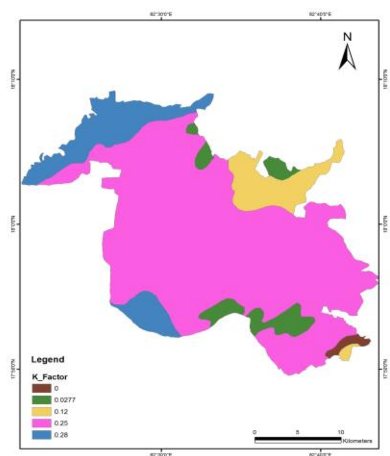


**Figure 3: K-Factor**

## Slope Steepness and Length - LS factor

The topographic factor is a very important parameter in water soil erosion, since the gravity force is playing a decisive role in surface runoff. LS factor takes in account together the steepness (S), which increase the velocity of runoff, and the length (L) of a slope, which contributes to enlarge the ground surface affected by runoff. This dimensionless factor has been calculated using two equations to estimate the topographic parameter; one for slopes up to 20% gradient and one for steeper slopes (Arnoldus, 1977).

$$LS = (FlowAccumulation \cdot CellSize/22.13)^{0.6} * (Sin(Slope0.01745)/0.09)^{1.3} \cdot 1.6 \quad (1.5)$$

This equation was developed on the raster calculator from the spatial analyst toolbar in ArcGGIS 9.3 to provide flow accumulation data.

**Table 2: Estimated values of LS factor under different slope classes**

| S. No | Slope class and gradient | Estimated LS value |
|---|---|---|
| 1 | Steep sloping | 9.6 |
| 2 | Moderately steeply sloping ($15^0$–$30^0$) | 6.8 |
| 3 | Moderately sloping ($5^0$–$10^0$) | 2.4 |
| 4 | Gently sloping ($3^0$–$8^0$) | 0.4 |
| 5 | Very gently sloping ($1^0$–$3^0$) | 0.2 |
| 6 | Nearly plain sloping | 0.08 |

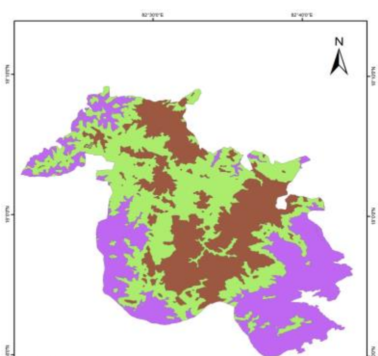


**Figure 4: LS-Factor map**

## Cover Management - C factor

Cover is usually referred to the vegetation, which has a strong influence on protecting soil from water erosion. In fact it can reduce erosive rain force being an obstacle for rain drops falling from the sky. Also, soil erodibility can be diminished by vegetation roots, which produce some chemical bonding matters able to compact soil particles, as well as they absorb water for their photosynthetic activities reducing the amount of runoff water. Spatial vegetative cover extracted from Landsat TM imagery was used to determine the spatial C-factor values that are based on experimental results from the literature.

**Table 3: Estimated values of C- factors under different land utilization types**

| *C*-factor | |
|---|---|
| Land cover | C value |
| Water body | 0.00 |
| Deciduous forest | 0.004 |
| Settlement | 0.00 |
| Degraded forest | 0.20 |
| Cultivated | 0.38 |
| Wasteland with scrub | 0.20 |
| Pasture land | 0.05 |
| Barren land | 0.44 |

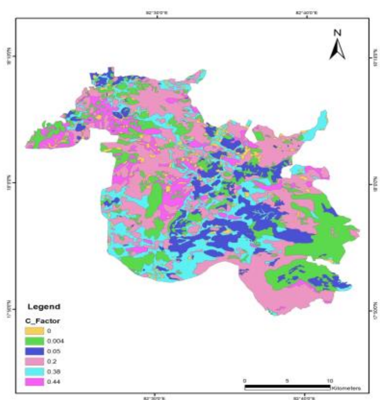


**Figure 5: C-Factor map**

## Support Practice - P factor

The ground truth checking conformed that higher conservation/support practice factor values are almost nil with forest and wasteland with scrub as these land utilization types does not have effective conservation measures. The cultivated lands as well have no conservation/support practice factor value as these areas are as should cover with field bunds. For all vegetation cover types no erosion control was found, therefore the P-factor was assigned the value 1.

**Table 4: Estimated values of P- factors under different land utilization types**

| Land utilization type | P value |
|---|---|
| Water body | 1 |
| Deciduous forest | 1 |
| Settlement | 1 |
| Degraded forest | 1 |
| Cultivated | 1 |
| Wasteland with scrub | 1 |
| Pasture land | 1 |
| Barren land | 1 |

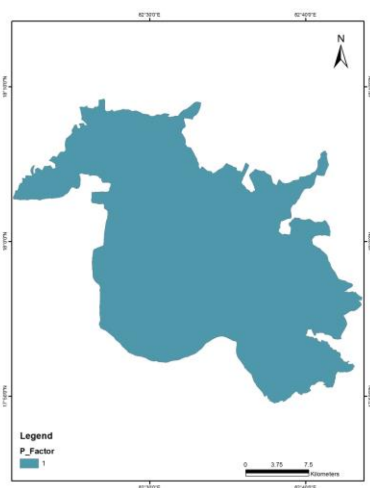


**Figure 6: P-Factor map**

## Result and Discussion

### Soil erosion risk map

Soil erosion risk map (Fig. 7) has been generated by applying the final RUSLE values on the land unit map which had been created in ArcGIS 9.3. In order to better understand the results, it is important to analyze them in relation with soil, morphological and topographical characteristics, paying attention even to the land cover.

The results show that, Very Low and Low classes are scattered in all over the study area due to the randomization of the Land Units and represent almost 76.14% of the study area. The Very Low class is occupying 50.67% of the study area in correspondence to valleyfills or footslopes, where the low slope gradient allows the accumulation of materials transported by water or gravity. These types of soils are deeper and have better permeability than in other places of the study area because of the flat morphology which enables conserving of soil sediments lost by erosion processes from neighboring hills. Low class is occupying 25.46% of the study area and has been found in the G. madugula Panchite, Peddalanka and Urumu village and Vanthala Panchite in Peddavalasa village. The increasing of soil loss amount is mainly due to slightly greater inclinations in comparison with the previous landforms. The Medium class in the study area is only in Kumbidisingi Panchiteat at Chintalagondi village and some pocket areas as 5.53% of the study area. In this case, the combination of the different factors computing soil loss rates gives an intermediate situation.

The High class is mainly concentrated in the Kumbidisingi Panchiteat at Solamulu and in a small unit in Solabham Panchite at Mallipadu village representing 17.36% of the study area. In both places slope length factor is increasing considerably and the absence of stone bunds along the contours allows a significant loss of soil, which is not sufficiently stopped by land cover (scrubs). The most dangerous situation (Very High class), has been found in correspondence to strongest slopes, absence of soil conservation practices and low vegetation cover to face the strong water erosion. Fortunately this class is occupying only 0.98% of the study area. The uncertainties regarding data sources may introduce larger uncertainties in soil erosion estimates. Great attention should be paid to the evaluation and preprocessing of data sources, such as data interpolation, conversion, and registration (LU et al, 2004).

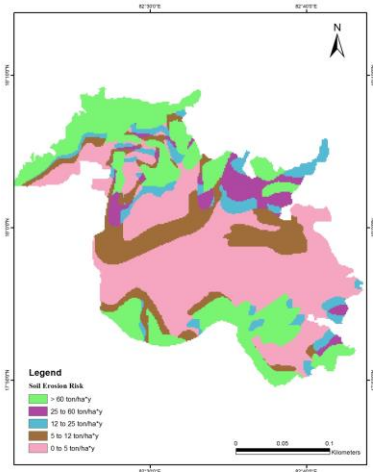


**Figure 7: Erosion Risk Map**

## Conclusion and recommendation

The result drive from the study has shown that the study area is highly vulnerable for soil loss and sediment depositions in the lower part of valley fill and foot hill. The lower risk zones are observed in most of the study where vegetation cover is void. High soil conservation work should be implemented in the study area by using appropriate conservation practices.

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