

Remote sensing in soil erosion assessment for land resources management

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Remote sensing (RS) and geographical information system (GIS) have emerged as the most reliable and effective tools for generating land resources information in a cost-effective and time-efficient manner. Advances in spatial, spectral and radiometric resolutions of the remote sensing sensors provide a wide opportunity to the user to characterize land resources at different scale. The Revised Universal Soil Loss Equation (RUSLE) is widely used for assessment of soil loss and using this equation, erosion assessment was carried out in Bareli watershed of Seoni, Madhya Pradesh.

Key words: Land management, Remote sensing, RUSLE model, Soil erosion

SOIL erosion is a natural geological phenomenon associated with the hydrologic cycle. It occurs when the impact of water or raindrops detaches and removes soil particles causing the soil to degrade. Soil erosion gets further aggravated due to anthropogenic factors causing loss of top fertile soil from agricultural lands and reduction in reservoir capacity as well as downstream water quality due to siltation. Soil erosion can never be stopped completely, but it can be reduced to some extent by adopting suitable soil conservation measures.

Several research studies have proved that remote sensing (RS) and geographic information system (GIS) technologies provide reliable and precise information about eroding areas, vegetation cover, soils, landform and lithological units with reasonable costs in large areas. Several models for predictive evaluation of soil erosion have been integrated into RS and GIS for spatial assessment of soil erosion. Universal Soil Loss Equation (USLE) and its revised version, RUSLE, both are being used worldwide for the estimation of surface erosion.

RUSLE factors estimation

The RUSLE approach is compatible with GIS environment and the factors used in the model can be precisely derived from the remote sensing data. Mathematically, the RUSLE incorporates five factors as given below:

$$A = R \times K \times LS \times C \times P \quad (1)$$

where, A is the computed spatial average of soil loss over a period selected for R, usually on yearly basis (t/ha/y); R is the rainfall erosivity factor (MJ mm ha/h/y); K is the soil erodibility factor (t/ha/MJ/mm); LS is the slope length steepness factor (dimensionless); C is the cover management factor (dimensionless, ranging between 0 and 1); and P is the erosion control (conservation support) practices factor (dimensionless, ranging between 0 and 1).

Rainfall erosivity (R) factor: The R-factor measures the impact of rainfall on erosion in MJ mm/ha/h/year and it is designed to represent the input that drives the sheet and rill erosion process through climatic factor. It is generally determined as a function of the volume, intensity and duration of the rainfall. Its

calculation, therefore, requires detailed data regarding the quantity and intensity of the rainfall.

Soil erodibility (K) factor: The soil erodibility factor (K-factor) represents both susceptibility of soil to erosion and the rate of runoff. The K-factor is estimated from soil physical and chemical properties.

Slope length (L) and slope steepness (S) factor: The LS-factor indicates the effect of topography on erosion, which is proportional to the length and steepness of the slope. The LS-factor map can be derived from the Digital Elevation Model (DEM) using the equation:

$$LS = (\text{Flow accumulation} \times \text{Grid size})/22.1)^{0.4} \times (\sin(\text{slope}) \times 0.01745)/0.09)^{1.4}$$

where, flow accumulation is a raster of accumulated flow to each cell and grid size is the length of a cell.

Cover (C) factor: The C-factor represents the effect of cropping and management practices on erosion rate. It is defined as the ratio of soil loss from land cropped under specific conditions to the corresponding loss from clean-tilled or continuous fallow. The value of C depends



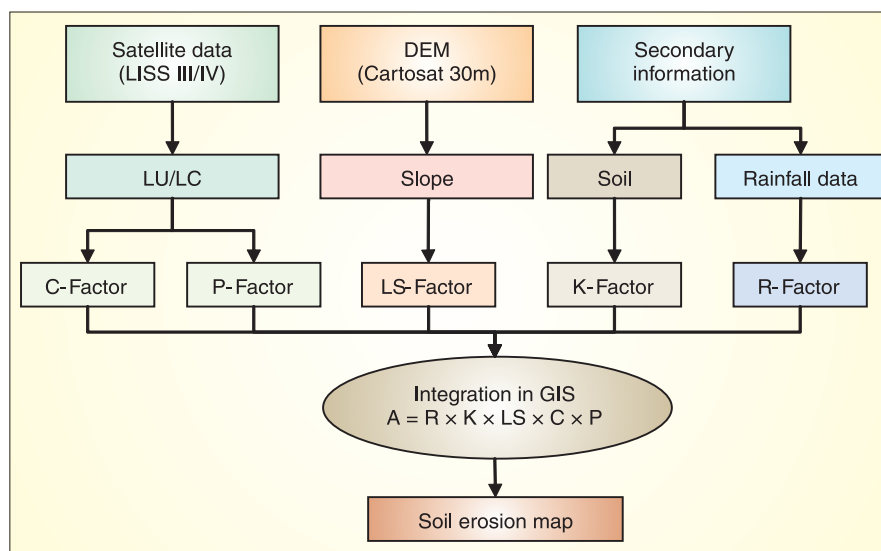
mainly on vegetation type, stage of growth and cover percentage. The C-factor remains the most important to check the risk of erosion. The land use cover and techniques of cultivation are the main human interventions that would accelerate or reduce erosion according to the situation.

Support practice (P) factor: The P-factor indicates the effect of contouring and tillage practices on soil erosion. The numerical value of P-factor is always between 0 and 1 according to the management of agricultural land. The P-factor value near to 0 indicates good conservation practice and the value near to 1 indicates poor conservation practice.

Case study in a watershed

A study was conducted in Bareli watershed located between 22°29'39" to 22°32'10" N latitudes and 79°46'44" to 79°49'50" E longitudes, covering an area of 1795 ha in Seoni district of Madhya Pradesh which is now experiencing frequent erratic rainfall, loss in vegetative cover resulting in increased soil erosion and reduced soil and crop productivity. The elevation of the area ranges from 520 to 620 m above mean sea level (MSL). The geology is basalt. Five major landforms, viz. plateau, escarpment, hills and ridges, isolated mound and pediments have been identified. The climate is mainly dry sub-tropical with mean annual temperature of 28.4°C and mean annual rainfall of 1,100 mm. The area qualifies for ustic soil moisture regime and hyperthermic soil temperature regime, respectively. The natural vegetation comprises of teak (*Tectona grandis*), babul (*Acacia spp.*), palas (*Butea frandosa*), charoli (*Buchanania lanzan*), jujube (*Ziziphus jujuba*) etc. The major crops are paddy (*Oryza sativa*), pigeon pea (*Cajanus cajan*) and maize (*Zea mays*) in kharif and wheat (*Triticum aestivum*), gram (*Cicer arietinum*) and in patches safflower (*Carthamus tinctorius*) in rabi under irrigation or stored moisture. Mango and guava are the main fruit crops of the area.

The factors of RUSLE model were estimated from climatic data



Conceptual framework of soil loss analysis by RUSLE model

(rainfall events), satellite image (IRS-P6 LISS-IV and LISS-III data), digital elevation model (Cartosat-1 DEM, 30 m resolution), soil map (1:10K) and land cover (1:10K). The methodology used in the present study is represented in figure.

Rainfall erosivity (R) factor: Rain fall data collected from the rain gauge stations established in an around the study area was brought in to ArcGIS, interpolated and a surface map was prepared. In this analysis, average annual rainfall was used for R factor computation. Rainfall erosivity (R) value ranged from 479 to 488 MJ mm/ha/h/y.

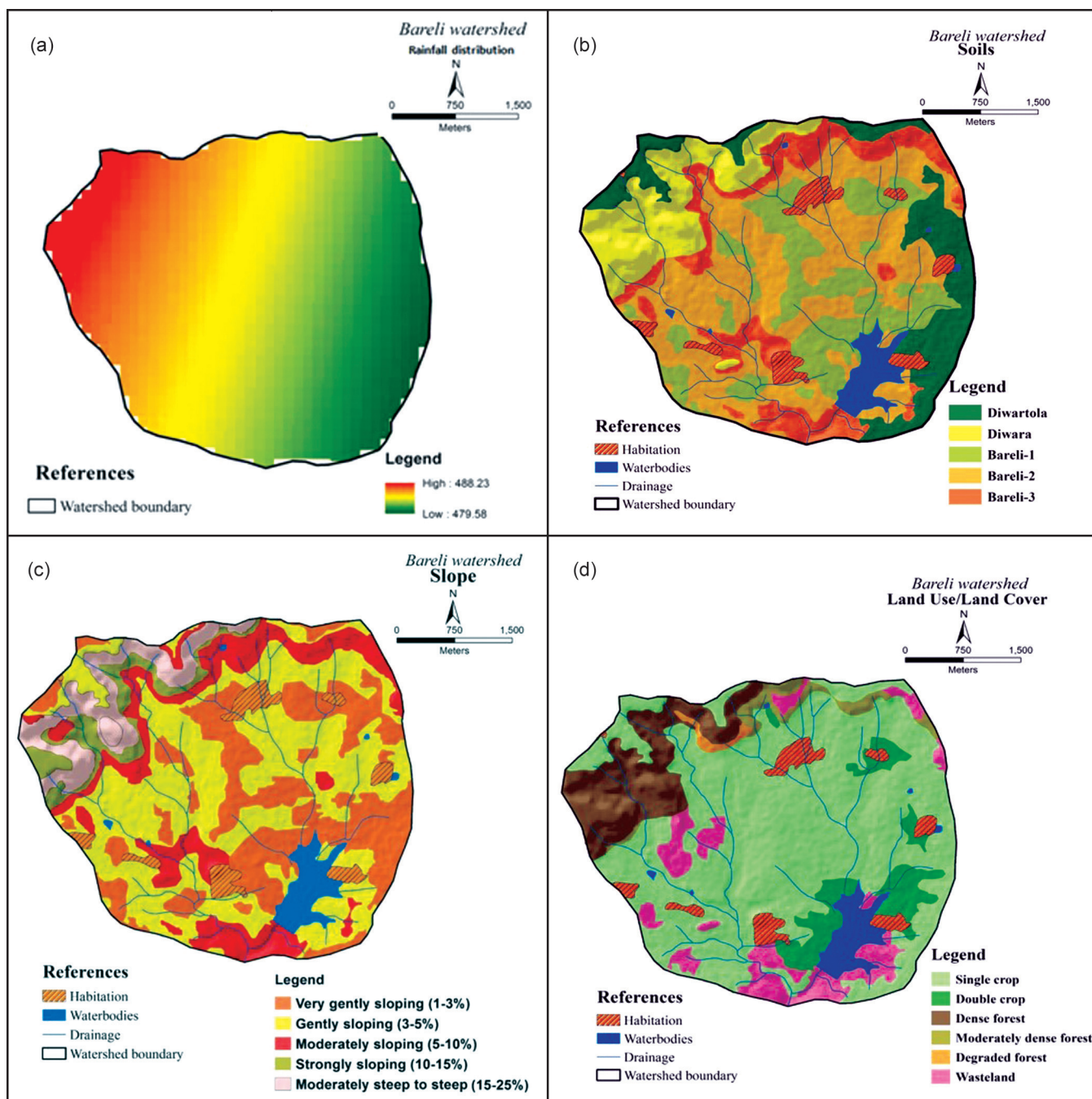
Soil erodibility (K) factor: Five soil series, namely, Diwartola, Diwara, Bareli-1, Bareli-2 and Bareli-3 were identified and mapped in the area during the soil survey. The soils of Diwartola are shallow, moderately well drained, very dark greyish brown (10YR 3/2M), clay in texture (62.1 to 63.3%) underlain by hard basalt with moderate erosion and qualify for Lithic Haplustepts at subgroup level. The soils of Diwara are shallow, well drained, very dark greyish brown (7.5YR 3/3M), clay in texture (52.6 to 54.6%) underlain by hard basalt with moderate erosion and qualify for Lithic Ustorthents at subgroup level. Soils of Bareli-1 are moderately deep, well drained, very dark grayish brown (10YR 3/2M), clay in texture (57.2 to 65.4%) underlain by hard basalt with severe erosion. Soils of Bareli-2 are shallow, well drained, very dark greyish brown (10YR 3/

2M), clay in texture (62.4%) underlain by hard basalt with moderate erosion and qualify for Lithic Ustorthents at subgroup level. Soils of Bareli-3 are moderately deep, well drained, dark greyish brown (7.5YR 3/3M), calcareous, clay soils (55.7 to 61.1%) underlain by hard basalt with severe erosion and qualify for Typic Ustorthents at subgroup level. The K factor values for each soil types were estimated based on its physical and chemical properties and found to be ranging between 0.24 to 0.31 t/ha/MJ/mm.

Length and slope factor (LS): Using Cartosat-1 DEM, five slope classes, viz. very gently sloping (1-3%), gently sloping (3-5%), moderately sloping (5-10%), strongly sloping (10-15%) and moderately steeply sloping (15-25%) lands were delineated. The computed values of LS factor ranged from 0 (gentle slopes at lower and middle part) to 57.0 (steeper slopes at upper reaches).

Land use/land cover (C) factor: The visual interpretation of IRS FCC (False colour composite) led to the identification and delineation of five land use/land cover categories such as single crop, double crop, forest, wasteland and habitation. The estimated values of C factor ranged from 0 to 1 in the watershed.

Support practice (P) factor: The P factor is the ratio of soil loss from a plot with a specific conservation practice to the corresponding loss from a plot with up and down



a) Rainfall distribution, b) soils, c) slope, d) land use/land cover

cultivation under identical conditions. A conservation practice (P) factor value of 1.0 was assigned to forest land. Based on field management practices, a P factor map was generated.

Soil erosion assessment

To estimate annual soil loss on a pixel-by pixel basis and the spatial distribution of the soil erosion in the watershed, GIS analysis was carried out in ArcGIS (Table 1). Nearly 38.5% of total geographical area (TGA) was under very low risk erosion with an average annual soil

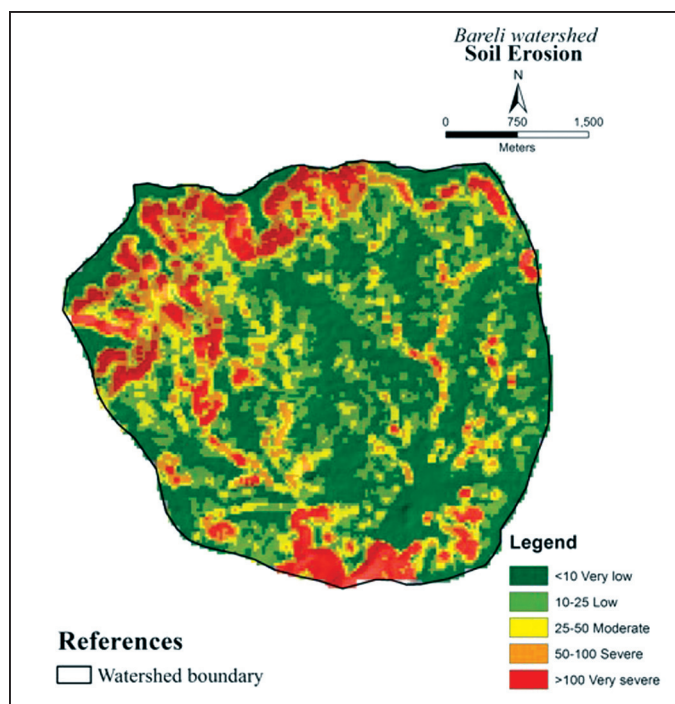
loss of <10 t/ha/yr as it constitutes nearly level (0-1%) to very gentle slopes (1-3%) followed by low soil erosion risk constituting 25.3% with a soil loss of 10-25 t/ha/yr comprising gently sloping (3-5%) lands. The moderate, severe and very severe soil erosion risk classes constitute 14.3, 11.2 and 10.7%, respectively, which needs immediate attention for developing strategies for soil and water conservation measures.

Land resources management

Based on potential and limitations of land resources, suitable soil and

water conservation measures including agri-horticulture, agro-forestry, silvipasture and intensive cultivation have been suggested.

The plateau areas having shallow and severely eroded soils (Diwartola) are mostly under rainfed cropping without any soil and water conservation measures. To improve the productivity on these cultivated land units, agri-horticulture with gooseberry, guava, custard apple and drum stick may be tried under integrated nutrient management along with soil and water conservation measures like contour



Soil erosion map of Bareli watershed

bunding, gully plugging and water harvesting structures. The hills and ridges with escarpments and isolated mounds associated with moderately sloping (5-10%) to moderately steep to steep (15-25%) slopes with shallow and moderately to severely eroded soils (Diwara) are mainly under forest and wasteland. These

Bareli-3) are mainly under *khari* sorghum and in patches irrigated wheat and gram are grown during *rabi*. Proper field bunding, gully plugging and contour bunding is needed to conserve soil and water. Agri-horticulture involving gooseberry, guava, custard apple and drum stick and silvi-pasture systems

lands to be put under afforestation with fast growing multipurpose trees. Staggered contour trenches need to be taken up to reduce the runoff and soil loss and improve the soil moisture.

Very gently to gently sloping piedmont surfaces with shallow to moderately deep soils and moderate

erosion (Bareli-1, Bareli-2 and

Table 1. Estimated rate of soil erosion in Bareli watershed

Average annual soil loss (t/ha/yr)	Soil erosion risk classes	Area (ha)	% of TGA
<10	Very low	699.1	38.5
10-25	Low	459.4	25.3
25-50	Moderate	259.8	14.3
50-100	Severe	203.8	11.2
>100	Very severe	193.5	10.7

with multi-purpose trees with integrated nutrient management needs be taken up in these land units to improve the productivity and livelihood of stakeholders.

SUMMARY

Soil erosion assessment and monitoring is important for sustainable management of land resources. Remote sensing and GIS provide near real-time data of the land resources and helps in quick assessment of land resources for taking appropriate measures for its optimum management.

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Soil erosion assessment and conservation planning

Total potential runoff volume for the period 2011 to 2015 was estimated using SCS CN method in Dhanora block, Seoni district, Madhya Pradesh. The average total potential runoff volume generated from the block is about $202.017 \times 10^6 \text{ m}^3$ and average depth of runoff is 367 mm. On watershed basis, the average volume of runoff varies from $2009.83 \times 10^3 \text{ m}^3$ (Sub watershed-VI) to $60560.3 \times 10^3 \text{ m}^3$ (Sub watershed-II) and depth of runoff varies from 333 mm (Sub watershed-I) to 524 mm (Sub watershed-VIII).

The drainage treatment for different watersheds of Sujala project, Karnataka has also been carried out in Harve 2 microwatershed of Chamarajnagar district.

Source: DARE-ICAR Annual Report 2018-19

Potential of NIR spectroscopy to evaluate soil quality in Vertisols of central India

Application of Visible (VIS)-near infrared (NIR) spectroscopy as a rapid, reliable diagnostic tool was assessed for characterization of soil physical (sand, silt, clay, bulk density) and chemical properties (N, P, K, pH and EC) of black soils (Vertisols) of central India. The soil quality index (SQI) was computed using both spectrally derived indicator values and laboratory derived measurement following the methods of scoring, weighting factor and principal component analysis (PCA). The results indicated a significant and positive correlation between laboratory derived SQI and spectral derived SQI for the studied Vertisols of central India. Observed SQI ranges from 0.66 to 0.99 while Spectral SQI (SSQI) ranges from 0.68 to 0.98.

Source: DARE-ICAR Annual Report 2018-19