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Mapping of erosional soil loss in *Nanda-Khairi* watershed of Nagpur district of Maharashtra using remotely sensed data and GIS techniques

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Abstract : A study was taken up to map the erosional soil loss in *Nanda-Khairi* watershed of Nagpur district of Maharashtra using geocoded false colour composites (FCC) of IRS-1C (LISS-III) data of *kharif* and *rabi* seasons. The data related to soil, slope length and steepness, crop management and conservation measures were derived from satellite data, toposheet and ground truth survey and used as inputs in USLE Model for assessment of erosional soil loss. The soil erosion map prepared by the integration of USLE factors revealed five soil erosion classes. Nearly 62 per cent area of the watershed was under slight erosion with soil loss of <5 t/ha/yr. The moderately slight erosion (5-10 t/ha/yr) and moderate erosion (10-15 t/ha/yr) covered 28.1 and 0.4 per cent area of the watershed, respectively. The area under moderately severe (15-20 t/ha/yr) and very severely erosion (>40 t/ha/yr) classes covered 6.5 and 1.0 per cent area, respectively. Based on erosion class appropriate conservation measures have been suggested.

***Additional keywords:** Soil characteristics, soil erodibility, soil conservation*

Introduction

Information on spatial distribution of degraded/eroded lands and areas prone to degradation/ soil erosion is needed for formulation of conservation plan for development of an area. Mapping of such areas by conventional technique is time consuming and consistent set of ground measurements are needed. Satellite remote sensing provides scientific input for faster and precise mapping of natural resources (Saxena *et al* 2000; Bodhankar *et al.* 2002) and degraded/ eroded lands (Skidmore *et al.* 1997) and also facilitates for quick evaluation of vegetation status vital for erosion assessment. Several models have been developed to predict soil erosion but USLE model of Wischmeier and Smith (1978) is most frequently used in India (Saha *et al.* 1992; Sharma *et al.* 2003).

Through present paper, an attempt has been made to map the soil erosion in *Nanda-Khairi* watershed of Nagpur district, Maharashtra using remote sensing and GIS techniques and to suggest suitable soil conservation measures for management of resources.

Materials and methods

Study Area

The *Nanda-Khairi* watershed is located between 21° 01ˣ to 21° 05' N latitude and 78°54' to 78°59' E longitude in Hingna tahsil of Nagpur district, Maharashtra. The area has been evolved from the basaltic flows under paleoclimatic succession. The elevation ranges from 280 to 420 m above the msl and covers an area of 2980 ha. Physiographically, the area consists of plateau/summits, escarpment, upper and lower foot slopes, upper and lower alluvial plains. Nanda and Khairi nala drain the area. The climate is tropical subhumid (dry). The mean annual temperature is 26.9°C associated with mean annual rainfall 1050 mm. The area qualifies for '*Ustic*' soil moisture regime and '*Hyperthermic*' temperature regime. The natural vegetation comprises dry deciduous tree species, shrubs interspersed with grasses. Commonly occurring species of tree and grasses are Teak (*Tectona grandis*), babul (*Acacia spp.*), palas (*Butea frondosa*), charoli (*Buchanania latifolia*), ber (*Zizyphus jujuba*), and kans (*Saccharum spontaneum)* sorghum *(Sorghum bicolor*), soybean (*Glycine max*), cotton (*Gossypium spp.*) pigeonpea (*Cajanus cajan*), mung bean (*Vinga radiata*) and cowpea (*Vinga sinensis*) are major *kharif* crops whereas wheat (*Triticum aestivum*) and gram (*Cicer arietium*) are important *rabi* crops raised on residual moisture or under irrigation. Mandarin (*Citrus reticulata*) is main fruit crop in the watershed.

Methodology

Geocoded false colour composites (FCC) of IRS-1C (LISS-III) data of two seasons (*kharif* and *rabi*) were visually interpreted in conjunction with Survey of India (SOI) toposheet (1:50,000 scale) and subsequently ground-truth observations were collected to derive spatial information related to existing land use/land cover, physiography and soils. Soil samples (horizon-wise) collected from pedons of respective physiographic units were analyzed for relevant physical and chemical properties following standard procedures. Slope map was prepared using contour information available on SOI toposheet. The maps were digitized and processed under GIS environment using ILWIS 2.2 software. The maps of soil, slope and land use/land cover were reclassified into soil erodibility (K), slope length and steepness (LS) and crop management and conservation (CP) maps. These maps were integrated under GIS to compute the soil loss and to generate soil erosion map.

Results and discussion

Land use/ Land cover:

The present land use/land cover map prepared with the help of two seasons data indicate agricultural lands (single crop, double crop, and fallow land), notified forests (moderately dense, thin, and degraded) and wastelands (with and without scrub), habitation and streams/nala. (Fig.1a)

Slope:

Slope map of the area was prepared using contour information available on SOI toposheet (1:50,000 scale) and intensive ground truth. Five slope classes *viz.* nearly level (0-1%), very gently sloping (1-3%), gently sloping (3-5%), moderately sloping (5-10%) and moderately steep sloping (15-30%) were delineated. (Fig. 1b) Nearly 84 per cent area of the watershed is under very gently to gently sloping class whereas 11 per cent area is nearly level land. Moderately sloping and moderately steep sloping lands occupy 2.8 and 2.1 per cent area, respectively

Physiography-soils:

Based on visual interpretation of satellite data and ground truth survey, six major physiographic units i.e. plateau/summits, escarpment, upper foot slope, lower foot slope, upper alluvial plain and lower alluvial plain were identified and delineated. Soil map (Fig.1c) was prepared after establishing physiography- soils relationship (Table1) as physiography dictates soil profile development, soil moisture, erodibility *etc.*

Soil erosion assessment :

Universal Soil Loss Equation (USLE) model (A=RKLSCP) was used for estimation of soil loss in the watershed. The advantage of using this model is that the major input parameters like amount and intensity of rainfall, soil erodibility, land cover and terrain slope gradient which greatly influence the soil loss have been given due weightage.

Rainfall factor (R):

The total geographical area of the watershed is only 2980 ha which is quite small and hence it was assumed that there would not be much variation in the rainfall distribution pattern in the watershed. Ram Babu *et al.* (1978) estimated the erosion index of Nagpur area based on rainfall distribution pattern and reported annual rainfall erosion index value 483 for the area. The same index value has been used for the estimation of soil loss in the present study.

Soil erodibility factor (K):

The physiography-soil map was utilized to generate information on soil erodibility factor (K) and preparation of soil erodibility map. The soil erodibility factor was determined for each soil units using soil erodibility nomograph (Wischmeier *et al.* 1971). The soil erodibilty factor (K) for different soil series are presented in table 2. Soil units where two soil series occur in association, average soil erodibility index was computed after assigning 60 per cent weightage to the dominant soil and 40 per cent to the sub-dominant soil.

Table 1. Physiography-soil relationship

Physiography	Soil series Association	Soil Characteristics	Soil Taxonomy
Summits	Khairi-1 Rock outcrop	Shallow, somewhat excessively drained, dark reddish brown, (5YR 3/2), gravelly clay soils with moderate erosion; associated with rock outcrop.	Clayey-skeletal, mixed, hyperthermic Typic Haplustepts Rock ouh crop.
Escarpment	* Khairi-2	Very shallow, excessively drained, dark reddish brown (5YR 3/2),gravelly clay soils with very severe erosion.	Clayey-skeletal, mixed, hyperthermic Lithic Ustorthents
Upper foot slope	Khairi-3 Khairi-4	Very shallow, well drained, very dark greyish brown (10YR 3/2), gravelly clay soil with moderate erosion; associated with very shallow, well drained, very dark greyish brown (10YR 3/2), clay soil with moderate erosion.	Clayey-skeletal, mixed hyperthermic Typic Ustorthents Clayey, mixed, hyperthermic Typic Ustorthents
Lower foot slope	Khairi-4 Khairi-3	Very shallow, well drained, very dark greyish brown (10YR 3/2), clay soil with moderate erosion; associated with Very shallow, well drained, very dark greyish brown (10YR 3/2), gravelly clay with moderate erosion.	Clayey, mixed, hyperthermic Typic Ustorthents Clayey-skeletal, mixed, hyperthermic Typic Ustorthents
Upper alluvial Plain	Kirmati: Panjri	Moderately deep, moderately well drained, very dark greyish brown (10YR 3/2), very fine soils with moderate erosion; associated with deep, moderately well drained, very dark greyish brown (10YR 3/2), clay soils with moderate erosion.	Very-fine, smectitic, hyperthermic Leptic Haplusterts Fine, smectitic, hyperthermic Typic Haplusterts
Lower alluvial plain	Shivmarka : Panjri	Very deep, moderately well drained, dark brown (10YR 3/3), clay soils with slight erosion, associated with deep, moderately well drained, very dark greyish brown (10YR 3/2), clay soil with moderate erosion.	Fine, smectitic, hyperthermic Sodic Haplusterts Fine, smectitic, hyperthermic Typic Haplusterts

* Noncalcareous

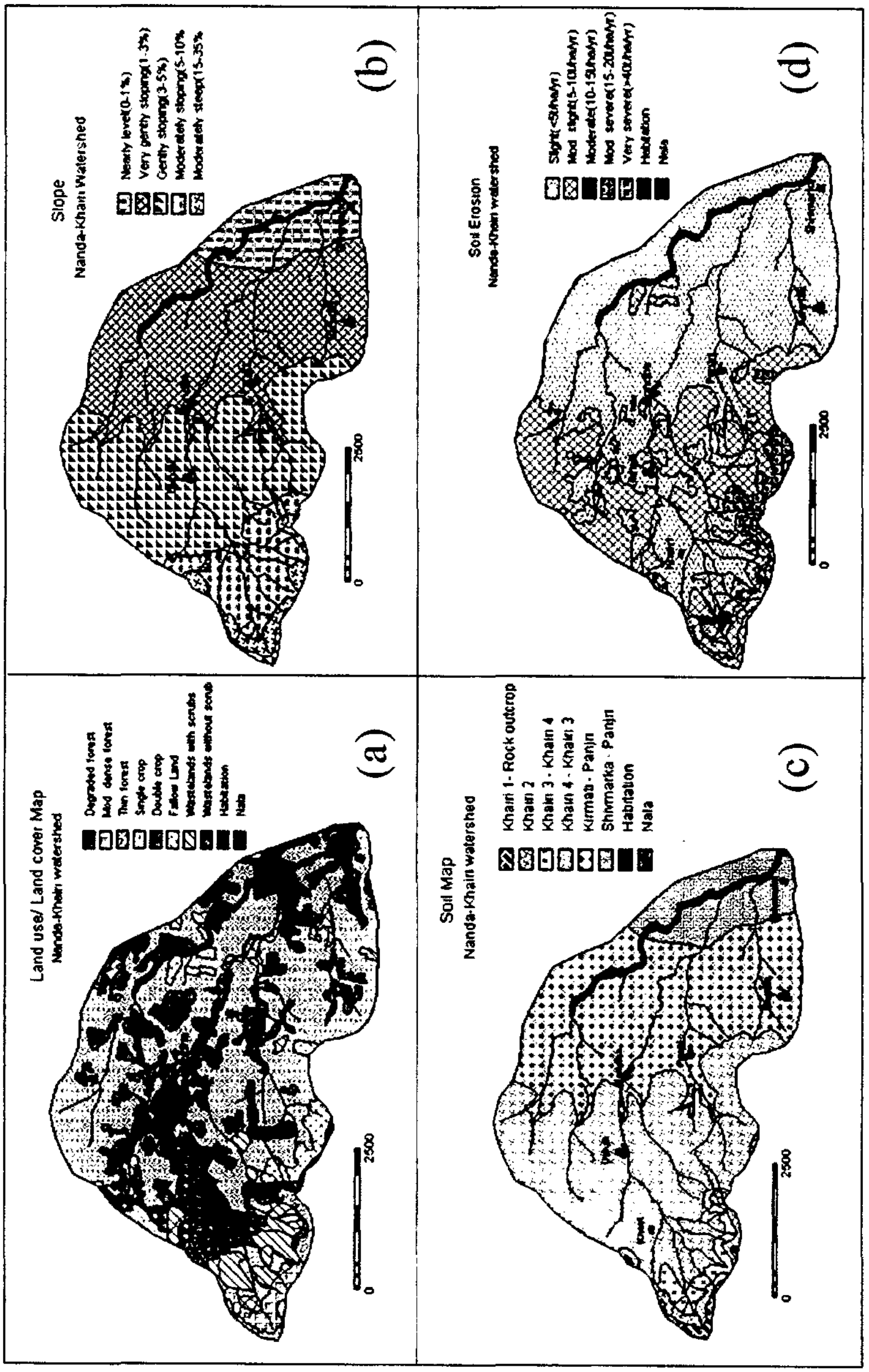

Fig. 1. Thematic maps of Nanda-Khairi watershed, Nagpur

Table 2. Estimated value of soil erodibility (K) factor for different soil series

Identified soil series	Silt (0.05-0.002 mm) (%)	Very Fine Sand (0.1-0.05mm) (%)	Sand (0.1-2mm) (%)	Organic matter (%)	Structure	Permeability	K value
Khairi-1	42.7	2.0	2.7	3.10	Blocky	Moderate	0.181
Khairi-2	44.3	1.7	8.5	2.22	Blocky	Moderate	0.219
Khairi-3	28.1	9.1	22.0	1.68	Blocky	Moderate	0.205
Khairi-4	22.8	4.6	24.7	0.98	Blocky	Moderate	0.156
Panjri	35.4	1.2	1.6	0.75	Blocky	Slight	0.206
Kirmati	33.4	0.9	5.7	0.55	Blocky	Slight	0.206
Shivmarka	37.3	0.8	7.0	0.81	Blocky	Slight	0.230

Table 3. Estimated value of LS factor for different slope classes

Physiography	Slope Class (%)	Estimated LS value
Summits/Plateau	Gently sloping (3-5%)	0.40
Escarpment	Steeply sloping (15-35%)	6.60
Upper foot slope	Moderately sloping (5-10%)	0.90
Lower foot slope	Gently sloping (3-5%)	0.40
Upper alluvial plain	Very gently sloping (1-3%)	0.20
Lower alluvial plain	Nearly level (0-1%)	0.11

Slope length and steepness factor (LS):

The LS factor for each physiographic units were determined based on degree and length of slope using nomograph developed by Wischmeier *et al.* (1978). The data (table 3) indicates that escarp slopes have the highest LS values because of steep slopes and lower alluvial plain had lowest LS value because of field bundings.

Crop cover and management factor (CP):

The 'C' and 'P' values used for different land utilization types were extracted from published literatures (Gurmel Singh *et al.* 1981; Karad *et al.* 1991; Kurothe *et al.* 2001). The CP values for different land utilization type in the watershed have been given in table 4. The dominant crop cover under the single crop is cotton, whereas in double cropland sorghum/soybean is taken during *kharif* followed by wheat/gram during *rabi* season. Hence the 'C' value for cotton and sorghum/soybean were considered for assessment of soil loss under single and double crop land respectively. Since no prominent conservation measures are followed in forest and wasteland areas and hence they were assigned 'P' value as 1. Under agricultural land the double crop land had very good bunding as compared to single crop and fallow land hence the 'P' value of 0.3 was assigned to double crop land and 0.5 to single crop and fallow land.

Table 4. Estimated value of CP factor for different land utilization types

Land utilization type	C value	P value	CP value
Moderately dense forest	0.01	1.0	0.01
Thin forest	0.10	1.0	0.10
Degraded forest	0.20	1.0	0.20
Single crop	0.35	0.5	0.17
Double crop	0.38	0.3	0.11
Fallow land	1.00	0.5	0.50
Wasteland with scrub	0.20	1.0	0.20
Wasteland without scrub	0.30	1.0	0.30
Habitation	0	0	0

Table 5. Distribution of area under different erosion classes in Nanda-Khairi watershed

Erosion class	Soil loss (t/ha/yr)	Area (ha)	% TGA
Slight	<5	1847.7	62.0
Moderately slight	5-10	839.9	28.1
Moderate	10-15	12.1	0.4
Moderately severe	15-20	193.6	6.5
Very severe	>40	28.5	1.0
Others (Habitation, Nala)	-	58.7	2.0
Total	-	2980.5	100

Soil erosion mapping:

After estimating the different USLE factors (R, K, LS and CP), the total soil loss (A) was estimated by multiplying all the factors. Based on estimated soil loss (t/ha/yr), the area was grouped under different erosion classes *viz.* slight (<5 t/ha/yr), moderately slight (5-10 t/ha/yr), moderate (10-15 t/ha/yr), moderately severe (15-20 t/ha/yr), severe (20-40 t/ha/yr) and very severe (>40 t/ha/yr). (Kurothe *et al.* 2001). The area under different soil erosion class is shown in table 4 and map in Fig.1d. Nearly 62 per cent area of the watershed in under slight erosion having soil loss less than 5t/ha/yr. These areas, as such, require no special treatment for soil conservation as the soil loss from these areas are near the tolerable limit of 4.5 t/ha/yr (Mannering, 1981). Moderately slight and moderate erosion cover about 28.5 per cent area. These areas require conservation practices such as proper field bunding and optimum vegetative cover to reduce the soil loss. The moderately severe and very severe erosion class comprises only 7.5 per cent area of the total watershed. These areas need special soil conservation measures to check soil degradation depending upon the soil-site characteristics and land utilization type.

Suggested soil and water conservation measures:

Natural regeneration of forest species in the moderately dense forest and afforestation in degraded forest and thin forest areas should be taken up to reduce the runoff and soil erosion from summits/plateau and escarpments. Based on soil characteristics, physiography, land use/land cover and soil erosion class, the drain-line treatments *viz.* gully plugging, check dams spillways and other suitable engineering structures should be taken up to conserve rain water and soil loss. The foot slope and alluvial plains which are mostly under cultivation, field treatments such as vegetative bunds, strip cropping, mulching and ploughing across the slope are suggested. Green manuring and FYM should be encouraged to increase the production of these soils. Climatically adapted fast growing tree species should be planted on wasteland with or without scrub lands to check the soil erosion.

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