CS(AR)-217

INTEGRATION OF REMOTE SENSING AND GIS TO ASSESS EROSION IN DHUANDHAR WATERSHED IN NARMADA BASIN

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE - 247 667
1995-96

CONTENTS

LIST OF FIGURES AND TABLES

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Universal Soil Loss Equation estimates mean soil erosion from a land surface. This erosion is caused due to rain splashes, sheet and rills. The catchment area under study is Dhuandhar, Banjar, Narmada basin. Area of the catchment is 54 sq. km. This catchment is drained by Dhuandhar and Patpara streams. Input to USLE are digital soil, land use maps and percent slopes. Values of several USLE factors are those given in literatures. The 'L' factor is that used in a case study for the catchment. The 'K' factor is based on soil texture data. Soil texture is found for two soil samples collected from field. A digital elevation map (DEM) is computed from a 1:50000 topographic map with 20 metres contour interval. Percent slope and mean annual soil erosion is computed in PC based GIS, ILWIS and ERDAS packages. Agricultural land and forests are protected from soil erosion due to good cover and management practices. Mean annual soil erosion is large from bare upland. Thus, upland may be afforested and many soil conservation measures may be adopted.

CHAPTER 1 INTRODUCTION

Soil is an important resource on the earth surface. Today largest population in the world is directly engaged in production of food and fibre. In earlier times, soil was assumed to be formed by weathering of rocks and has been termed regolith. Soil means an organized natural body. Soil is a product of evolution process. Plants and animals use soil as their habitat and become a part of it. Microbes decompose organic matter and form CO_2. Nitrogen in soil is transformed in inorganic nitrogen compounds. Organic matter is also translocated by running water and animals. Another important process is weathering of rocks. Rock minerals are transformed to secondary minerals and other compounds. Soluble minerals and compounds move to lower layers by water. In humid regions, water removes soluble minerals and compounds from soil. Soil is also added through dust, volcanic ash and eroded materials from uplands (Foth 1984).

Soil is eroded by wind and water. Erosion by water occurs through splashes, rills, sheets and gullies. Splash erosion occurs due to an impact of rain droplets on soil. Rain droplets strike soils and loosen up soil particles. Many rain droplets strike a unit area of soil in a given time. Sheet erosion is removal of a soil layer. Sheet erosion occurs in both, smooth soils and soils with depressions. Depressions are filled and flow from depressions occurs at their lower ends. Many small channels are formed in soils due to erosion. These small channels are called rills. Rills do not create difficulty in ordinary farm operations. Both, rill and sheet erosion occur together. Sheet erosion does not attract attention of an observer. Another erosion process is gully erosion. Many mechanisms form gullies. Concentrated flow in drainage ways erodes a lower horizon. Channel erosion occurs in finer and resistant soils in lower horizons. In such soils 'V' shaped gullies are developed. Sheet erosion will be dealt in greater details here. Gullies create impression of neglect of land. It draws immediate attention of an observer (Goldman 1990, Raghuwanshi and Bhatia 1987).

Average annual gross erosion: Universal Soil Loss Equation

Annual average soil erosion caused by rill and sheet erosion is estimated applying Universal Soil Loss Equation (USLE). The equation is developed by Weisheimeier and Smith (Raghuwanshi and Bhatia 1987). This is based on more than 10000 plot year data from 50 stations, results from rainfall simulation studies and field experience. This equation considers six factor representing rain erosivity, erodibility of soil and land and crop management practices (Eq. 1.1). Factors are described here. USLE can also be used to compute average monthly erosion and that due to storms. USLE does not compute deposition of soil with in a catchment. When flow enters toes of hills or channel with small slopes, larger soil particles get deposited. This equation is useful to soil conservationists. They may decide which cover and land management practices to be adopted to bring soil erosion to accepted levels.

$$E=R*K*L*S*C*P \qquad \text{Eq. 1.1}$$

Where,

E is mean annual gross erosion rate in tm^{-2}

R is rain erosivity in $Jm^{-2}mmhr^{-1}$

K is soil erodibility in $tJ^{-1}mm^{-1}hr$.

L is length factor

S is slope factor

C is cover factor

P is management practice factor

R factor

R value shows the total kinetic energy (KE) and maximum 30 minutes intensities (I30) of rain storms. A product of KE and I30 for all major storms in a year is summed up to obtain a 'R' factor. Weischmeier (Goldman 1990) has computed 'R' factors for entire USA at the instance of USDA and plotted iso erodant maps. The map is useful for areas in USA east of 104°W longitudes. For 'R' in western USA, a study completed at Purdue University. The study gives regression equations for three storm types. A higher value is obtained for storms with higher peaks. Rainstorm types are designated as type I, IA and II. Soils in snow-covered areas, possess higher R factors than that estimated by normal procedure given above. Addition R value for snow cover areas is computed as a function of total winter precipitation. A monthly R factor is computed by multiplying an annual R factor by monthly rainfall and dividing the product by annual precipitation (Goldman 1990).

Law and Pearson (Morgan 1980) have derived relationship between median drop size and rainfall intensity for USA. Hudson (Morgan 1980) has computed a regression equation for tropical rains. Size d50 decreases at intensities greater than 100 mm hr^{-1}. High turbulence at higher intensities does not support an increase in drop size. A study has concluded that relationship is also dependent on type of rain. Kinetic energy of a rainstorm is related to the amount and intensities of rainfall. Median rain drop size has been found to be proportional to rainfall intensities. Terminal velocities of rain drop increase with increase in drop size. Kinetic energy depends on mass and velocity. Thus, Kinetic energy is related with rainfall intensities and amount (Raghuwanshi and Bhatia 1987, Morgan 1980).

K factor

The 'K' factor shows susceptibility of soil particles to detachment and removal by rain and runoff. K is dependent on soil texture, organic matter content. Values of K vary from 0.02 to 0.69. Grading operation may expose sub soil, which may have soil properties dissimilar to that of top soil. In land fill operations, soils may be imported from another place. They will have different 'K' values than in-situ soils. Therefore, many soil erodibility factors are used in soil erosion estimation. Highest K value may be used in a conservative estimate, since actual soil and grading operation may not be always known.

In USA, county soil maps are prepared from aerial photographs with lines drawn on them. Tables of physical and chemical properties are also available for several soil series. A tabulated 'K' factor is generally available. The series may be located on ground. Thus, 'K' factor may be obtained for soil series in USA. This is recommended only in cases when detailed soil surveys are not completed and when much disturbance has not taken place.

Nomograph method gives a 'K' factor for a soil texture. The factor is modified for organic matter, permeability and rock content. For soil separates, a 'K' factor is obtained. Isolines of K factors drawn on a soil texture triangle are used. 'K' factors falling between two isolines are interpolated linearly.

LS factor

The 'LS' factor combines the effect of slope length and gradient on soil erosion. It is a ratio of soil erosion from a given area to that from a standard experimental plot. A table is developed from a formula given by Weischmeier (Goldman 1990) for 'LS' factor. Values given in the table for higher slopes are validated in many experiments. The slope is represented, both in percentages and ratios of horizontal to vertical height. Slope length is a distance along a slope up to a nearest channel or diversion. Slope length is a length from an origin of runoff to a place of deposition or a nearest channel. 'LS' factor is more sensitive to gradient change rather than change in slope length. William's method (Raghuwanshi and Bhatia 1987) is used to compute basin average of slope gradient and length. Computations are done from observations taken on topographic maps. Contours of 25, 50 and 75% basin relief are drawn. Base contours are also drawn for each of these contours. Extreme points, lengths of contours and basin relief are input.

C factor

It is a ratio of soil erosion from an area to that from tilled bare soil. Any form of cover on soil reduces soil erosion. Covers may be jute, paper, grasses, plants and wood fibre with grass seeds. Wood fibre with grass seeds does not provide much protection to soil but it allows grasses to establish. Grown grasses provide a protection to land. Grasses take around four weeks to get established. Native vegetation provides highest protection to soils and has C factor equal to 0.01. Grasses with wood fibre have C factor 0.5. Both, jute and paper have value 0.3. Many plants are grown for soil protection. Plants may be retained later or new plants may be grown (Goldman 1990).

P factor

The 'P' factor is a ratio of soil loss in a given condition to soil loss in up and down ploughing. This factor signifies the effect of ploughing and tillage practices in a land. Compacted land fill areas are vulnerable to sheet erosion.

CHAPTER 2 LITERATURE SURVEY

Ram Babu and others (1978) have prepared an iso-erodant map of India. Rain erosivities at 180 points are determined using regression equations on rainfall. At 44 points rain erosivity is computed. Rain storms of total depth greater than 12.5 mm are considered. A new storm is considered to set in if no rain occurs for 6 hrs or more. For other four stations rain erosivities reported in literature are adopted. Annual rain erosivity is arrived at by summing erosivity for individual rain storms in a year. Rain erosivity for seasonal, monthly, minimum, maximum and at 2, 5 and 10-year return period application are estimated, tabulated and mapped. R-value at Vasad, Gujarat has been reported by Nema (1978). Individual storms are more than 10 mm. R-values for the Vidarbha region in Maharashtra, India, are computed by Bhuibhar and others (1989).

Prasad and others (1994) have reported soil conservation measures in a semi arid region of Rajasthan. Several measures to control soil erosion are intercropping, selections of suitable crops, double cropping, plugging, drop structures and diversions for gullies and conservation bench terraces. In gullies wood, boulder temporary bunds have been found to be effective. In conservation bench terraces, many ratios of contribution and receiving areas are tried. A ratio 2:1 has been been found to be of maximum effectiveness in increasing crop production. Fallow land produced maximum soil erosion, followed by crop land. Grass lands produced least soil erosion. Among crops, maize, pigeonpea, sorghum produced more erosion. Short crops namely greengram, soyabean, groundnuts, produced less erosion. Inter cropping of the castor with greenpea and sorghum with pigeonpea (1:1) have been proved useful.

Soil conservation measures in Nilgiri, Western Ghats, include contour bunding, graded bunding, contour trenching, bench terracing and stone bunding. In graded bunds a longitudinal grade of 0.2 to 0.4 is provided. Land use is changed from potato-plantation to tea-plantation. Soil erosion has reduced due to this land use change. High soil erosion is observed from both unmanaged and contour cultivated potato crops. Newly established and up to 15% cover tea plants also produce less soil erosion. Soil erosion reduces by mulching and construction of drains in newly established tea plantations, bench terracing in potato crops, good canopy cover in tea plantations. Greater infiltration has also increased risk of land slides (Tripathi and others 1994).

Tyagi and others (1994) have described erosion conservation measures for the Himalayan region. Measures include contour bunding, graded bunding, bench terracing, strip cropping, contouring and mixed cropping. Contour bunding is suggested on two to 6% slope. Graded bunding is suggested with grades of 0.1% to 0.6%. On areas between bunds, contour cropping is useful. Bench terraces may be level, reverse or inclined. Mixed cropping is more popular than strip cropping.

Narain and others (1993) have mapped erosion quantitatively in East Bengal. USLE is applied at 800 points over the state. Forest cover data are in three categories namely more than 33%, between 19 and 33% and less than 19% tree crown cover density. Dense forest and Gangetic deltaic plain have erosion estimate between zero and five t $ha^{-1}year^{-1}$.

Soil erosion in Dhuandhar catchment is estimated using remote sensing and GIS technique. Available classification maps are assigned classes based on spectral signatures. 'K' factor is estimated using assumed values of organic matter content, structure and permeability and experimental texture data. The 'R' factor at Jabalpur is input. L is computed both from William's method and as estimated length of overland flow for the catchment. 'L' factor from later technique is taken in erosion estimation. The 'S' factor is estimated using William's method and using ILWIS. The percentage slope is derived from contours in a topographic map. C and P values for managed and unmanaged conditions are used (Sahoo 1995).

CHAPTER 3 STUDY AREA

Study area is Dhuandhar catchment in the Narmada basin (Fig. 3.1). Catchment lies between latitudes 22°25'N to 22°29'N and longitudes 80°16'E to 80°22.5'E. Area lies in the Mandla district, Madhya Pradesh, India. Main transportation routes in the area are Mandla Chiraidongri road and Mandla Nainpur railway line. Two streams flow through the catchment namely Dhuandhar and Patpara. Dhuandhar stream is a northern stream. Streams are tributaries of the Banjar river. The confluence of Banjar and Narmada is at Mandla. Bamhni Banjar is a main town. Area is covered by Survey of India topographic map 64B/7.

Type of climate is tropical humid wet and dry. There are three main seasons namely rainy, winter and summer. Rain commences from June and ends in October. Winter spans between November and February. Summer commences from March and ends in May (Critchfield 1983, Battan 1984).

Rainfall occurs between July and October. July and August receive larger rainfall than other rainy months. Percentages of rainfall in the monsoon are between 87 and 89. Percentages of rainfall in July and August are between 59 and 64. Annual rainfall varies between 1528 mm and 1742 mm. Total rainfall in January and February is between 54 and 64 mm, respectively.

Catchment lies in an average temperature zone of 22.5° to 25°C. Minimum and maximum temperatures are respectively 1°C and 45°C at Mandla between 1966 and 1981 (excluding 1975). Highest minimum temperature is 28.6°C (September 1967). Lowest maximum temperature is 23.2°C (January 1981). December and January are coolest months (Kundu 1989, Mishra and others 1979, Rahangdale and others 1984).

Low humidity is recorded in summer months. Humidity in both winter and rainy seasons are high. At Mandla, winter humidity is between 40 and 70%. Summer humidity is between 19 and 38%. Humidity in the monsoon is between 70 and 89% (Rahangdale and others 1985).

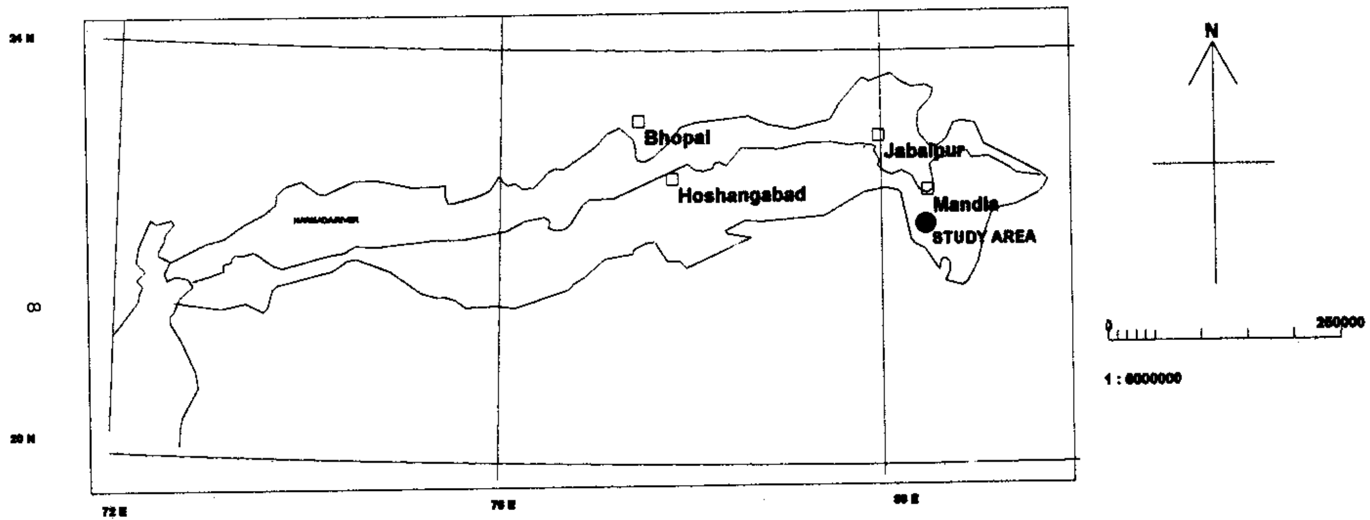


FIG 3.1 LOCATION MAP

CHAPTER 4 STATEMENT OF PROBLEM

USLE is useful in estimating soil erosion from land surface due to sheet and rill erosion by water. Erosion mainly occurs in rainy months in humid areas. Large rain occurs between June and October. Erosion is dependent on factors, namely, rainfall intensity and its amount, soil type, land use, land cover, management practices of land and topography. A catchment in a humid region in India is selected for applying USLE. Catchment lies in the Narmada basin. Soil-erosion due to water occurs between June and September and in January and February. Catchment has many land uses and land covers.

Land use, land cover and soil maps will be collected from literature. Soil-erosion from a catchment will be estimated. Ground truth will be collected. Erosion-features will be noted during ground truth. Land use, land cover and soil maps obtained through remote sensing technique will be input in applying USLE.

CHAPTER 5 DATA AVAILABILITY AND METHODOLOGY

5.1 DATA AVAILABILITY

Maps for the study area are available is digital form. Forests and uplands are having skeletal soils. Agricultural areas possess silt clay loam. Foothill slopes possess silt loam. Three villages are visited, namely Bamhni Banjar, Mogadara and Jahar Mhow. Jahar Mhow is located 100 metres from left of Pipala Nala on left side and close to the road. The Bamhani Banjar is on left of the Bamhni Mogadara road. It is 250 metres from the Nainpur Bamhni Banjar road. The Mogadara site is near stone quarries. Village Bamhni Banjar lies on way from Mandla to Nainpur. It is connected to these towns through rail and road links. Other villages are within few km from Bamhni Banjar. Soil samples have been collected from sites located in these villages.

5.2 METHODOLOGY

Geographic Information System (GIS) is useful to overlay many geographically referenced data. Data in a GIS are encoded in several ways, namely, vector and raster. Vector form is a true representation of map boundaries. In raster form of encoding, data are represented by values at grid locations. Several grid sizes may be chosen in this representation. Many commercial GIS are available and can be used in environmental sciences applications.

Integrated Land and Water Information System (ILWIS)

Both ILWIS version 1.3 and 2.0 are PC based image processing and data base GIS. ILWIS ver. 1.3 uses two monitors, monochrome and colour and many peripherals namely digitizers, plotters, printers. A monochrome monitor is used for text display. System requires a PC with processor 80286 or higher, a minimum 640 KB internal memory, a math coprocessor, monochrome and graphic board, a hardware key and peripherals. Graphic boards supported are Vesa, Trident and other graphic boards. Digitizers and plotters are supported on serial ports. Printers are supported on parallel port. Digitizer needs a 4-botton cursor, Continuous ASCII digitizing delimited with CR and/or LF characters and Xon/ Xoff. It has a menu interface. A menu is displayed on a monochrome screen. Menu items may be highlighted using arrow keys or typing a first letter of a menu item. The highlighted menu item is selected by pressing 'enter' key. Other uses of arrow and control keys, are to change numerical values and to move on a colour screen.

ILWIS ver. 2.0 operates on Microsoft windows systems. On selecting an ILWIS program a window is opened. The window consists of control box, title bar, menu bar, command line, button bar, operations list, catalogue, scroll bars and other buttons for drive, directory selection and reducing a window to a point. Using double click and single click on left mouse-button several programs are run and interactively inputs are completed. On running a program, a dialogue window is opened.

ERDAS

PC-ERDAS version 7.5 used is a PC based image processing software, with data base system and a GIS. Hardware consists of dual monitors, graphic board for image display, pointing device and PC. Many graphic boards are supported, e.g., IMGRAPH image 32 colour graphic controller. The IMGRAPH image 32 board has 1024 X 1024 pixel resolutions, 24 bits image, and 8 bits graphic plane. Four bits of graphic plane are used for overlay and other 4 bits are used for a blank overlay. The display driver is a memory resident program. Software uses a menu driver. Menu items are selected by typing item serial number in the displayed menu. When a pointing device is active on image plane, function keys or numeric keys can be used to zoom, unzoom, roam and reset zoom and roam. Roam 'key' operates in toggle mode.

CHAPTER 6 RESULTS AND DISCUSSIONS

Digital elevation model and slope map

Contours from a Survey of India topographic map at scale of 1:50000 are digitized on ILWIS. The contour interval is 20 metres in the topographic map. Digital Elevation Model (DEM) for the study area is generated from contours on ILWIS. The digital elevation raster map is created at cell size of 18 metres. From DEM, gradient in X and Y directions are created using standard filters. The slope is computed using built-in slope function, X and Y gradients.

Soil texture

Samples for soil texture analysis are prepared using method different from Bureau of Indian Standards (Anonymous 1983). Soils are washed through a 75-micron sieve to break soil aggregates. A higher silt and clay content is likely to result in the procedure. This will provide a conservative estimate for the 'K' factor. Soil samples are collected from agricultural field and foothill slope near village Murgatola. The village is located below an earthen embankment on the stream, Dhuandhar. The foothill slope is located near the stream bank. Percentages of sand, very fine sand, silt and clay for agricultural areas are respectively 0.2, 9.0, 62.2 and 28.8. These percentages for the foothill slope are respectively 0.2, 28.2, 57.2 and 14.6. Percentages of sand, silt and clay are corrected for gravel content.

Erosion estimation

For estimation of average annual soil erosion rate, values for USLE factors in a catchment are needed. Several USLE factors for selected catchment are given in Table 6.1. This table also gives percentages for land use and land cover. Areas and percentage areas for land use and cover classes for several land slope classes are also computed (Table 6.2). This is completed by classifying land slope map in to slope classes and crossing resulting map with land use and land cover map.

The 'R' factor is given in literature for Jabalpur. Nearest location for known estimated 'R' factor is Jabalpur. The percentage slope is computed in a GIS as described above. 'K' factors for agricultural area and foothill slopes are estimated using the soil texture triangle. 'K' factor isolines are superimposed on the triangle. They are respectively 0.42 and 0.47 for soils in agriculture land and on foothill slopes. 'K' for skeletal soil is not known. Thus, a K value is assumed. Due to presence of higher rock content, apparently 'K' will be small. Rock content is the soil fraction greater than 2.0 mm in size. According to an adjustment table presented along with triangular nomograph for K value, selection of small K value is justified.

Length of flow for the catchment is available in literature. Values for cover factors are assumed for agricultural area and forests. Agricultural areas are mainly under paddy cultivation. 'C' factor for paddies is available in literature. Forests are having good crown cover. 'C' factor for forests with good cover condition is available from literature. Agricultural lands are levelled and bunded. The value corresponds to value recommended at Central Soil and Water Conservation Research Institutes's (CSWCRTI) Research Station at Ootakmand (Dhruvanarayana 1993).

The upland area is unmanaged. This land use is primarily without scrub or with sparse scrubs. There is no protection against sheet and rill erosion. Few check dams are built across gullies putting boulders. Deposition of fine grained soil particles on long and flat upland area is visible.

Erosion is estimated on GIS PC-ERDAS version 7.5. Land use and soil maps are available in ERDAS format. Pixel resolution of land use, land cover and soil maps is 72 metres. The slope map is transferred to ERDAS GIS. This map is geometrically corrected to convert pixel size of the map. Percent slope, land use and soil maps are brought in same size. From percentage slopes, indices in 'L' factor empirical equation are estimated. Upper limit in erosion computation is kept one thousand t ha^{-1} for managing null values. A histogram is computed from the estimated map of soil erosion. It is employed to estimate average soil erosion.

Soil erosion and slope map are classified (Fig. 6.1) for creating maps for output.Soil erosion values are grouped in classes of 0 to 5, 5 to 15, 15 to 150 and 150 to 1500 t ha^{-1}. Slopes are classified in classes 0-1, 1-3, 3-5, 5-10, 10-15, 15-25 and 25-33%. Areas are computed for both classified erosion and slopes maps. Areas for land use classes are also cross tabulated against slope and erosion rates.

Soil erosion rates are averaged applying ERDAS 'script' for tabular data base. For computing average erosion rates for individual land use and land cover classes (Table 6.3), first land use and land cover binary map is computed. This map is overlaid with erosion map. Average annual soil erosion rates for agricultural land, forests and upland are 3.32, 7.23 and 74.35 t ha^{-1}. The average rate for the entire catchment is 17.88 t ha^{-1}.

Discussions

The selection of USLE factors controls the estimate of mean annual soil erosion. Here, products of USLE factors (except slope factors) are in proportion of 100:3:1 for respectively upland, agriculture land and forests. Although K for upland area is low due to no cover and nil land management, product of K, C and P is higher than that for forests and agricultural land. This produces high erosion rates for this land use and cover class.

In agriculture land and upland (wasteland) areas, higher slope classes gradually shrinks. In forests, highest area is under 25-33% slope class. Second higher class is 15-25% slope class. Other slope classes have approximately equal areas. Higher average erosion from forest is due to larger land slopes.

It is observed that mean annual soil erosion estimate for the catchment is small. This is due to a large percentage of agricultural land with levelled and bunded fields. Mean annual soil erosion is higher than that from agriculture land due to higher erosion rates in forests and upland (wasteland). This estimation is affected due to use of maps at scale of 1:50000, coarse spatial resolution and order of land use classes. Use of different method in sample preparation has provided a conservative estimate in soil erodibility than an earlier study.

Table 6.1 Land use and USLE factors

Land use	Area Ha.	%	R	K $X10^{-4}$	L metres	C	P
Agricul	3360.3	62.3	501.1	0.42	232	0.28	0.027
Forest	563.0	10.5	501.1	0.1	232	0.01	1
Upland	1092.3	20.3	501.1	0.1	232	1	1
Rock	308.4	5.7	501.1	0	232	1	1
Water	65.8	1.2	501.1	0	232	0	0

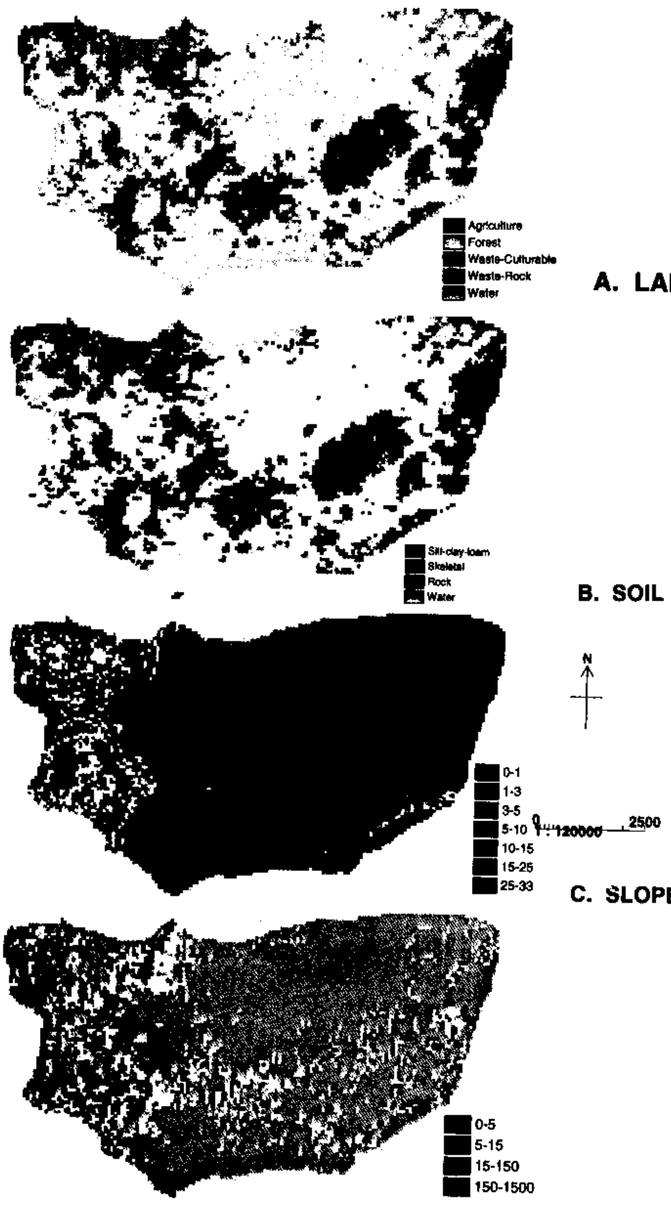
Note R is in $Jm^{-2}mmhr^{-1}$. K is in $tJ^{-1}mm^{-1}hr$.

Table 6.2 Land slope classes and land use

Land slope classes %	Land use area Agriculture Ha.	%	Forest Ha.	%	Upland Ha.	%
0-1	1579.0	29.3	57.5	1.1	497.7	9.3
1-3	642.8	11.9	42.0	0.8	230.7	4.3
3-5	520.0	9.7	45.1	0.8	212.5	3.9
5-10	215.1	4.0	61.2	1.1	70.0	1.3
10-15	102.1	1.9	52.4	1.0	8.8	0.2
15-25	149.8	2.8	105.2	2.0	23.8	0.4
25-33	147.7	2.7	198.5	3.7	45.6	0.8

Table 6.3 Mean annual erosion and land use

Mean annual erosion class t ha^{-1}	Land use area Agriculture Ha.	%	Forest Ha.	%	Upland Ha.	%
0-5	2980.8	55.4	339.0	6.3	231.7	4.3
5-15	169.0	3.1	152.4	2.8	282.0	5.2
15-150	202.2	3.8	70.5	1.3	497.1	9.2
150-1500	4.7	0.1	0	0	78.3	1.5



A. LAND USE

B. SOIL

C. SLOPE (%)

D. MEAN ANNUAL GROSS EROSION (T/HA)

FIG 6.1 DHUANDHAR CATCHMENT IN BANJAR NARMADA BASIN

CHAPTER 7 CONCLUSIONS

1. Erosion causes wearing away of soil mass. It occurs by means of four processes, namely rain splashes, sheet, rill and gully. For sheet erosion alone to occur, land surface must be smooth. Commonly, sheet and rill erosion occur together. Sheet erosion is not visible to an average observer. Thus, bare upland and foothill slopes should be suitably protected from an onslaught of erosion.

2. The estimation here assumes uniform conservation measures. The measure should be strengthened to keep soil erosion to a permissible level from agriculture land. This includes maintenance and construction of bunds and adoption of agronomic measures. Good forest cover may be maintained in forest land.

3. Land use and cover information are available more accurately in satellite data as compared to topographic data. This is due to differences in minimum mapping unit in topographic and satellite data. Land use and cover changes are also reflected in satellite data. Other survey technique/ techniques can also provide these information.

4. GIS have great utility due to their geographic data handling capabilities. This reduces processing time as compared to manual methods for soil erosion estimations.

REFERENCES

Anonymous (1983), 'IS 2720 (Part I)- Preparation of dry soil samples for various tests- 2nd revision', Bureau of Indian Standards, New Delhi.

Battan L.J. (1984), 'Fundamentals of Meteorology', 2nd ed., Prentice- Hall, London

Bhuibhar B.W., V.D. Dalvi, K.P. Gore (1989), 'Distribution of erosion index and iso-erodant map of Vidarbha', Indian Journal of Soil Conservation, Vol. 17 (3), pp 31-38

Critchfield H.J (1983) 'General climatology (4th ed.)', Prentice-Hall, New Jersy

Foth H.D. (1984), 'Fundamentals of soil sciences 7th ed.', John Wiley, New York, 435p.

Goldman S.J., K. Jackson, T.A. Bursztynsky (1990), ' Erosion and sediment control handbook', Tata McGraw Hill, New York.

Kundu A.K. (ed.) (1989), 'Irrigation Atlas of India- Vol. II, National Thematic Mapping organization, Department of Science and Technology, Government of India, Calcutta

Mishra S.N., G.K.Choudhary (1979) 'Detailed soil survey report of Matiyari Tank Project', Rep no. 51, M.P. State Detailed Soil Survey Scheme, Department of Agriculture, Government of Madhya Pradesh, Adhartal, Jabalpur, 79p.

Morgan R.P.C. (1980), 'Soil erosion'. Longman, London, 113p.

Narain P., Ram Babu, M.S. Rama Mohan Rao, J.L. Sehgal, R.K. Datta, D.Sarkar, C.J.Thampi (1993), 'Soil erosion map of West Bengal', Indian journal of Soil Conservation, Vol. 21(2), pp 6-10.

Nema J.P., B. Verma, A.P. Patel (1978), 'Predicting some Universal Soil Loss parameters, Indian Journal of Soil Conservation, Vol. 6 (2), pp 75-79.

Prasad S.N., R. Singh (1994), 'Soil erosion and its control in semi-arid region of south-eastern Rajasthan', Indian journal of Soil Conservation, Vol. 22(1 & 2), pp 102-111.

Raghuwanshi N.S., K.K.S. Bhatia (1987), 'Study of soil erosion for different land use and vegetal covers using Universal

Soil Loss Equation', TR-28, National Institute of Hydrology, Roorkee, India.

Rahangdale S.R., D.P. Dixit (1984), 'Detailed soil survey report of Mukash Tank Project (minor irrigation scheme)', Rep no. JBP/67, M.P. State Detailed Soil Survey Scheme, Department of Agriculture, Government of Madhya Pradesh, Adhartal, Jabalpur, 76p.

Rahangdale S.R., R.K.Choudhary (1985), 'Detailed soil survey report of Sursatola Tank Project (M.P. minor irrigation scheme) ', Rep no. JBP/69, M.P. State Detailed Soil Survey Scheme, Department of Agriculture, Government of Madhya Pradesh, Adhartal, Jabalpur, 48p.

Ram Babu, K.G. Tejwani, M.C. Agarwal, L.S. Bhushan (1978), 'Distribution of erosion index and iso-erodant map of India', Indian Journal of Soil Conservation, Vol. 6 (1), pp 1-12.

Sahoo P.C. (1995), 'Study of runoff and erosion in Narmada basin (part) using GIS and remote sensing technique', Dissertation, UNESCO sponsored XXIII International Hydrology Course, Department of Hydrology, University of Roorkee, India.

Tripathi K.P., P. Samraj (1994), 'Problem of soil erosion and conservation strategies in the Southern hill region with particular reference to the Nilgiris', Indian journal of Soil Conservation, Vol. 22(1 & 2), pp 94-101.

Tyagi P.C., B.P.Joshi (1994), 'Resources conservation techniques for sustainable crop production in Western Himalayan region', Indian journal of Soil Conservation, Vol. 22(1 & 2), pp 72-83.

DIRECTOR DR S. M. SETH

STUDY GROUP

MR. D. S. RATHORE