CASE STUDY

CS(AR) - 186

INTEGRATION OF GIS AND REMOTE SENSING IN SOIL EROSION STUDIES

आपो हिष्ठा मयोभुवः

NATIONAL INSTITUTE OF HYDROLOGY
JALVIGYAN BHAWAN
ROORKEE - 247 667
1994-95

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

1.1 GENERAL

Soil erosion caused by man's activities is sometime called accelerated erosion to distinguish it from geological erosion. The latter is part of a constant process of change in the earth's surface due to weathering. Soil erosion is of great concern to humanity because, it effects food production through land degradation, limits the supply of hydro electric power through siltation of reservoirs and create catastropic floods damaged huge area of low lying fields and human settlements . Impact of direct rainfall on the soil surface is crucial to the start of erosion process. Overland flow detaches soil particles but mostly transports previously detached sediment to surface stream and to accelerate erosion than are managed ecosystems. Despite the high rainfall and rugged topography generally associated with highland head water, run-off and erosion are minimum from natural ecosystems.

When human activity, such as indiscriminate forest clearing without proper precautions is allowed in these area, the stability of natural ecosystem is disturbed and leads to excessively high rates of uncontrolled run-off and erosion. Excessive run-off and erosion rates may occur also on pasture land if animal stocking rates and grazing are not controlled and adequate conservation practice are not implemented. Forest disturbance and uncontrolled grazing and cropping, alone or together, may lead to rates of run-off and erosion high enough to produce catastropic floods and burial by sediments of low-lying fields and residential communities. A rampaging flood that finds its way to the sea not only causes human disasters but also may cause permanent disappearance of precise soil and water.

The problem has been further aggravated due to high rate of population growth-both, human and livestock resulting in ever increasing demand of food, fodder, fuel, fiber and fertilizers. Thus continuous degradation of production base and imbalance in land-plant, human-animal systems is leading to ecological imbalance and economic insecurity, through severe soil erosion and threat to the quality of human life and cultivation. It has been estimated that in India about 6000 m tones of soil are eroded every year from about 80 M ha of cultivated land, loosing about 8.4 M tones of nutrients (2.5 M tones of N, 3.3 M tones of P and 2.6 M tones of K).

The top soil layer which is susceptible to erosion are generally rich in plant nutrients and most favourable physically for water storage and transmission. These top soil are also most suitable structurally for the rapid growth of plant root. Hence soil layer exposed by serious erosion are less able to support healthy vegetative growth.

The problem of assessing the effect of erosion over the longer term is more difficult. To assess the effect of erosion on crop productivity some assumptions have to be made not only on the frequency of erosion of top layer but also about the relationship of crop yield to depth of soil. depth, profile characteristics, level of management and technology provided to achieve more favorable growing conditions.

Soil erosion occurs when individual soil particles or small aggregates of soil particles are detached from the main body of soil and transported down slope, Soil particle detachment can be caused by any of the following two methods.

- By the impact of rain drop falling on the soil surface.
- By scouring effect of water movement over the soil surface.

Transport of detached soil particles can occur when they are splashed into the air by rain drop impact and fall down slope under the influence of gravity or when detached particles are transported down slope in suspension by surface run-off waters.

Silt rises the level of river beds and the beds of water reservoirs and hence increasing the danger of the inundation of the adjoining area and also results in water logging. Silt also reduces the life and of functioning of structures on water courses. Soil erosion is becoming the main source of water resources pollution. The chemical fertilizers and different types of pesticides, herbicides and fungicides applied in large quantities in agriculture as well as the industrial and agricultural wastes discharged on or into the soil are transported by water or wind. These chemical substances which are put into motion are the main causes of surface, subsurface and ground water quality deterioration.

1.2 CLASSIFICATION OF EROSION

Soil erosion has been classified by erosive agents (agents causing the occurrence and affecting the course of erosion processes): water, glacier, snow, wind, man, animals, etc.; by form (forms which are derived from the effects of exogenous agents on the soil surface; by intensity (intensity expressed by the extent the soil particles are detached and transported.

Surface Water Erosion

Water erosion is removal of soil from land's surface by running water,including run-off. Water erosion is sub-divided into rain drops,sheet,rill,gully and stream channel erosion.

Factors affecting erosion by water: There is a direct relationship between total run-off and soil loss from agriculture areas, the factors influencing variables affecting soil erosion are climate,soil,vegetation and topography. Of these the vegetation and to some extent the soil may be controlled. The climatic factors and topographic factors except slope,length are beyond the power of man to control.

(1) Climate : Climate factors affecting erosion are precipitation,temperature,wind,humidity and solar radiation. Temperature and wind are the most evident through their effects on evaporation and transpiration. Wind also changes raindrop velocities and angle of impact. Humidity and solar radiation are somewhat less directly involved in that they are associated with temperature.

(2) Soil : Physical properties of soil affected the infiltration capacity and the extent to which it can be dispersed and transposed. These properties which influence erosion include soil structure, texture organic matter, moisture content, and density or compactness, as well as chemical and biological characteristics of the soil. As yet not one soil characteristics or index provides a satisfactory means of predicting erodibility.

(3) Vegetation : The major effects of vegetation in reducing erosion are:

(a) interception of rainfall by absorbing energy of the raindrops and thus reducing run-off.
(b) retardation of erosion by decreased surface velocity.
(c) physical restraint of soil movement.
(d) improvement of aggregation and porosity of the soil by roots and plant residue.
(e) increased biological activity in the soil and
(f) transpiration which decreases soil moisture,resulting in increased storage capacity. These vegetative influence vary with kind of vegetative material namely roots, plant tops and plant residues.

(4) Topography: Topographic features that influence erosion are degree of slope , length of slope, and size and shape of the watershed. On steep slopes high velocities cause serious erosion by scour and sediment transportation.

Types of water erosion

Sheet erosion: Sheet erosion is the uniform removal of soil in thin layers from sloping surface of soil between rills. Although important, sheet erosion is often unnoticed because it occurs gradually. The rain drop causes the soil particles to be detached and the increased sediment reduces the infiltration rate by sealing the soil pores.

Rill Erosion: When water takes the path of least resistance to flow over the soil surface it forms minute channels. Rill erosion is the removal of soil by water from small but well advanced channels when there is a concentration of overland flow. Detachability and transportability are both greater in Rill erosion than in Sheet erosion because of higher velocity. Rill erosion is of most serious when storm are of high intensity and top soils are loose and shallow.

Gully Erosion: If the channel formed in the land are so deepened and widened by erosion that their size is greater than those of common Rills, the land is no longer readily usable, and the effect is then termed as Gully erosion. These channels carry water during and immediately after rains. Gullies are usually formed by (i) water fall erosion at the gully (ii) channel erosion caused by water flowing through the gully (iii) alternate freezing and thawing of exposed soil banks and (iv) slides and mass movement of soil in the gully. Gullies are often also referred to as ravines.

Tunnel Erosion: Tunnel erosion occurs where there is intense penetration of the ground water. This is an underground forms of soil disintegration which occur practically in any thick layer of finely grained sediment. In most cases it develops into intense gully erosion, and therefore tunnel erosion is sometimes referred as a special from of gully erosion. It frequently occurs on forested land causing both soil loss and water losses.

1.3 THE UNIVERSAL SOIL LOSS EQUATION, USLE

Estimating soil losses from crop field by means of empirical equation,has become a valuable tool for the conservation farm planner in USA such equation have been used for about 15 years. They have served to estimate annual soil losses under specific combinations of soil, slope, cropping system and other management.

Universal soil loss equation developed by U. S. Dept. of Agriculture have improved the reliability of soil loss equations used earlier. This was achieved by applying more research data obtained from a detailed analysis of about 8,000 experimental plot years of soil loss and related data. Although this equation has universal application, its use is dependent upon development of local applicable data.

This equation improves localized soil loss predictions without drastically changing basic concepts and application procedure of the older equations. The method of evaluating the erosion producing capacity of rainstorms expected to occur throughout the year is its back bone and accounts for most of the versatility.

Prediction of soil loss by USLE was first introduced by Wischmeier and Smith (1965). The USLE is an empirical model most widely used for estimation of soil loss from sheet and rill erosion. Schematic representation of soil erosion model is given in Fig.1.1. USLE is given by the following equation:

SOIL LOSS = f(RAINFALL EROSIVITY, SOIL SUSCEPTIBILITY, TOPOGRAPHY, AND MANAGEMENT)

$$A = R * K * L * S * C * P \quad \text{.................} \quad (1.1)$$

Where,

A = Annual soil loss from specific site (t/ha)
R = Rainfall erosivity factor
K = Soil susceptibility factor
L, S = Topographic factor
C = Cropping - management factor
P = Erosion - control practice factor

The different parameters are described in the next chapter.

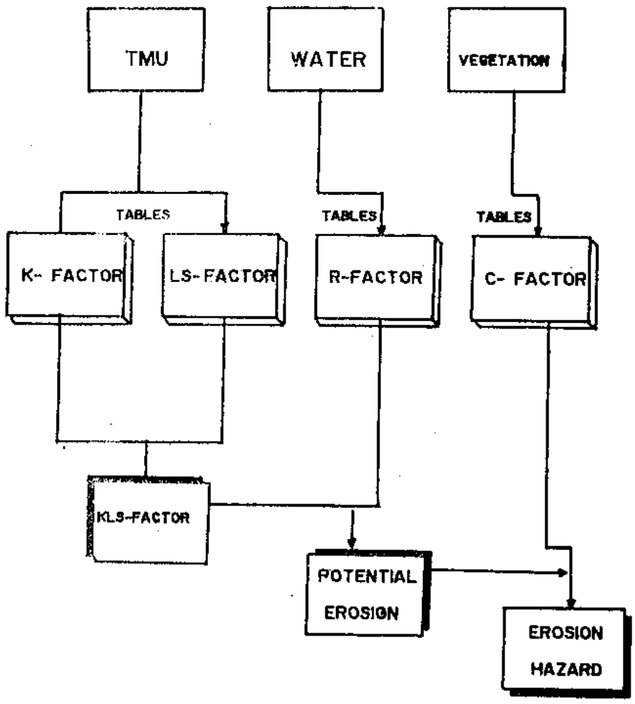


FIG. 1.1 : SCHEMATIC REPRESENTATION OF AN EROSION MODEL

2.0 REVIEW OF LITERATURE

2.1 USLE PARAMETERS

Prediction of soil loss by USLE was first introduced by Wischmeier and Smith (1965). The USLE is an empirical model most widely used for estimation of soil loss from sheet and rill erosion. USLE is given by the following equation:

Soil Loss A = R * K * L * S * C * P

In the following paragraphs description of different parameters of USLE is given :

2.1.1. RAINFALL EROSIVITY INDEX, R

The erosivity of a rainfall storm is a function of its intensity and duration, and the mass, diameter and velocity of the rain drop. Erosivity is expressed as the long term mean annual rainfall erosion index based on the kinetic energy of the rain. The term rainfall erosion index implies a numerical evaluation of a rainstorm or of a rainfall pattern which describes its capacity to erode soil from unprotected field. Eroding potential of a given storm is not only influenced by its characteristics but also by other conditions like antecedent climatic conditions, surface conditions, interaction effect and other extraneous variables. The most useful rainfall erosion index is one whose magnitude represents a composite measurements of various rainstorm characteristics which influence the rate of erosion (Wischmeier and Smith, 1978). Keeping the soil and slope parameters constant, studies indicated that the most valuable combination of indicators of erosion loss from fallow soil is rainfall energy, a product term which measures the interaction effect of storm energy and maximum prolonged intensity, antecedent moisture index and total antecedent rainfall energy since the last tillage operation.

In India, using 45 stations, distribution in different rainfall zones, simple linear relationship between erosivity index and annual or seasonal (June to September) rainfall has been developed (Singh et al, 1981).

$$Ra = 79 + 0.363 * X \quad \ldots\ldots\ldots\ldots \quad 2.2$$
$$Rs = 50 + 0.389 * X \quad \ldots\ldots\ldots\ldots \quad 2.3$$

where, Ra/Rs = annual/seasonal erosivity index
X = average annual/seasonal rainfall (mm)

The coefficient of correlations were found to be 0.83 for annual and 0.88 for seasonal regression equations.

2.1.2. SOIL ERODIBILITY FACTOR, K

The soil erodibility in the Universal Soil Loss Equation is the quantitative measures of the inherent erodibility of a particular soil. It represents soil loss in tones/ha/EI from a standard plot of 22.13m long under continuous fallow and tilled parallel to the slope of a uniform 9 percent.

Erodibility defines the resistance of the soil to both detachment and transport. Although soil resistance to erosion depends in part on topographic position, slope steepness, cover and the amount of disturbances created by man (e.g. during tillage), the properties of the soil (both physical and chemical) are the most important determinants. Erodibility varies with soil texture, aggregate stability, shear strength, infiltration capacity and organic matter content.

Investigations on the effects of the soil texture on erosion processes have shown that sandy soils are least susceptible to erosion (Holy, 1980). This is because they are relatively resistant to transport as a result of their bigger size, and greater force is required to entrain them, and they are also highly permeable. On the other hand, clay soils with low permeability have high content of colloidal particles and show a high level of consistency, and due to their cohesiveness character they are resistance to detachment. The least resistant particles are silts and fine sands.

Another important characteristic of soil which affects soil erodibility is its structure. Its influence is manifested on the infiltration capacity which is dependent up on the the pore size, pore stability and the form of soil profile. In general, soil conditions which are the sum of the individual properties of the soil affect the infiltration of precipitation into the soil and the resistance of soil to the destruction effect of the rain drops and surface run-off.

Under situations from which detail input soil information to the above equations and/or the nomograph is not available, Table 1.1 may be used. From this table knowing the organic matter content and textural class of the soil, the magnitude of soil erodibility can be found. The values shown are estimated averages of specific soil values.

Table 2.1: Magnitude of soil erodibility (adopted from Vladimir et al, 1981)

Texural class	K for organic matter content (%)		
	< 5	2.0	4.0
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
loamy very find sand	0.44	0.38	0.30
sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.25

Silt loam	0.48	0.42	0.29
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay		0.13 - 0.20	

2.1.3. TOPOGRAPHIC FACTOR, LS

The topography of the terrain is important in determining levels of precipitation erosion. Included among the factors of topography which are represented in the Universal Soil Loss Equation are the slope length and the slope gradient.

a) Slope Length

Slope length is important mainly with respect to the increase in the flow of water on slopes and the degree of confluence. As the quantity and its confluence grow, the velocity and transporting capacity change. It is defined as the distance from the point of origin of overland flow to either of the following (whichever is limiting for the major part of the area under consideration): (i) the point where the slope decreases to the extent that deposition begins, or (ii) the point where run-off enters a well defined channel that may be part of the drainage network or a constructed channel such as a terrace of diversion (Arnoldus, 1977).

The slope length factor, L, which is the ratio of the soil loss from field of slope length to that from a 22.13 meters long plot on the soil and gradient was defined by Wischmeier and Smith (1965). After long term field observations, they derived the following expression for the relation between soil loss and slope length:-

$$L = (u/22.13)^{m} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.4)$$

Where : u = Slope length measured from the water divide of the slope (m)

m = Exponent dependent upon slope gradient and may also be influenced by soil properties, type of vegetation, etc.

Recommended exponent values (Wischmeier and smith, 1978) are giver in the following table:-

Table 2.2 : Recommended value of m

Slope gradient %	m
S < 1.0	0.2
1.0 < S < 3.5	0.3
3.5 < S < 4.5	0.4
4.5 < S <	0.5

b) Slope Gradient Factor, S

Theoretical analysis of the effect of slope gradient on water erosion and numerous field observations and measurements as well as laboratory experiments have shown that slope gradient is the major erosion factor (Holy, 1980). Its effect on the initiation and on subsequent erosion process may be reduced by other factors such as soil properties, the soil vegetative cover, etc. but is never fully suppressed. The intensity of erosion process increase with growing tangential stress and velocity of the surface run-off which are prevalently the function of the slope gradient. The ratio of soil loss on actual gradient to that from 9% slope under otherwise identical condition is termed as slope gradient factor.

c) Combined Effect of Slope Gradient and Slope Length, LS

The effect of the slope gradient and slope length on the intensity of the erosion process are significant for deciding the type and location of erosion control measures. It is the ratio of the soil loss per unit area on a field slope to that from a 22.13 meters long and 9 percent slope under otherwise identical conditions.

2.1.4. CROP MANAGEMENT FACTOR, C

The main role of vegetation cover in the interception of the rain drops is that their kinetic energy is dissipated by the plant rather than imparted to the soil, i.e. vegetation cover protects the soil surface from the direct impact of the falling raindrops. It enhances the degree of infiltration of rainfall into the soil, maintains the roughness of the soil surface, slows down the surface run-off, binds the soil mechanically by root effect, diminishes the micro-climatic fluctuations in the upper most layers of the soil and improves the physical, chemical and biological properties of the soil.

The effectiveness of plant cover in reducing erosion depends upon the height and continuity of the canopy, the density of ground cover and the root density. Mrszek et al., (1975) concluded that the forest with a dense canopy, good undergrowth and undisturbed litter have the most significant effect on the surface run-off and thereby on the intensity and course of erosion. On the other hand,studies have indicated that whilst interception by the canopy reduces the volume of rain reaching the ground surface, it doesn't significantly alter its kinetic energy which may even be increased compared with that in the open ground (Chapman, 1948; Mosely, 1982). This is because of the greater percentage of large drops in the rainfall as a result of the coalescence of the rain drops on the leaves. This condition holds true where there is no appreciable ground cover under the canopy.

Crop cover effect on soil erosion is represented by an index called crop management factor, C, in the USLE empirical erosion model. The factor describes the total effect of vegetation, residue (litter), soil surface and management of soil loss. It is expressed as a numerical ratio that relates soil loss from land having specified cropping management to soil loss from continuous cultivated fallow with identical soil, slope and rainfall.

To estimate the C-value of agricultural crops, Wischmeier and Smith (1965) divided the crop season into five growth periods and latter into six growth periods (Wischmeier and Smith, 1978): period F (rough fallow), SB (seed bed), 1 (establishment), 2 (development), 3 (maturing crop), and 4 (residue or stable). But for Indian condition, where crop season is short as compared to the place for which this division was made (USA), the following crop season division is normally adopted (Narayan, 1982):-

Stage 1: Germination and seedling establishment,
Stage 2: Active vegetative stage,
Stage 3: Final growth and maturity (harvest),
Stage 4: Crop residue, cultivation till sowing of next crop.

For the watershed management, it is not possible to carry out the field experiment as needed,to find out the C value. Hence based on various experiments conducted at different stations, appropriate value may be selected for use in the USLE for purpose of watershed management.

2.1.5 CONSERVATION PRACTICES FACTOR, P

Conservation practice (technical) conditions consists mainly in the methods of land use and land tillage, the choice and distribution of cultures and the agrotechnology. Technical conditions are typical anthropogenic factors.

The P factor in the USLE is expressed as a ratio which compares the soil loss from the investigated plot with soil loss from the standard plot cultivated up and down the slope gradient. The amount of the soil loss from a given land is substantially influenced by the land management practice adopted. The value of P ranges from 1.0 for up and down cultivation to 0.25 for contour strip cropping of gentle slope.

Based on the results of intensive studies from run-off plots Wichmeier and Smith (1978) suggested the erosion control factor value for various situations (Table: 2.3)

Table 2.3: P-values for contouring on different slope gradients

Sl.No.	Slope%	P value	Max. slope length
1.	1.0 - 2.0	0.6	131.2
2.	3.0 - 5.0	0.5	98.4
3.	6.0 - 8.0	0.5	65.6
4.	8.0 - 12.0	0.6	39.4
5.	13.0 - 16.0	0.7	26.2
6.	17.0 - 20.0	0.8	19.7
7.	21 0 - 25.0	0.9	16.4

2.2 GEOGRAPHIC INFORMATION SYSTEM (GIS)

A geographic Information System (GIS) is a computer based system for collecting, storing, retrieving, analysis and displaying of spatial data (Fig.2.1). The increasing volume of available environmental information with all its complexity and subsequent demands for its storage, analysis and display of these large quantities of environmental data, have led in recent years to the rapid development in the application of computers to environmental and natural resources data handling and the creation of sophisticated information system. Effective utilization of large volumes of spatial data depends upon the existence of an efficient data handling and processing systems that will transform these data into usable information.

The GIS is designed to store process and analyze spatial data and their corresponding attributes. Advances in recent technologies have made it possible to integrate a wide range of information. Technological advances have increased input techniques, storage and retrieval capabilities. GISs have renewed spatial data collection and analytical procedures.

Employing manual techniques to integrate the vast amount of data from a variety of sources for the purpose of obtaining the desired logical results for use in the watershed management aspects is both time consuming and expensive. On the other hand the present advance of technology made it possible to easily handle and analyse large volumes of data using computer based system. A GIS in particular provide enormous potential for effectively storing, handling, manipulating, and analysing multiple spatial data sets in a single analysis at a high speed unmatched by any other method.

Besides the other applications of GIS, the major applications related to hydrology of GIS includes:

i) Land use planning and management
ii) Natural resources mapping and management
iii) Land information systems
iv) Urban and regional planning
v) Management of well log data

DATA INPUT :

Data collection and input are major problems in using GIS and these are partially solved by the advances in remote sensing technology. Before any spatial analysis or modelling operations can be carried out in a GIS, it is necessary to input the requisite data. Data input is the procedure of encoding data into computer readable form and writing the data to the GIS data base.

The data to be entered in a GIS are of two types - Spatial and associated non-spatial attribute data. The Spatial data represent the geographic location of features. Points, lines and areas are used to represent geographic features like a street, a lake and a forest land (Fig.2.2). These data will normally be obtained from one or more of the following sources:

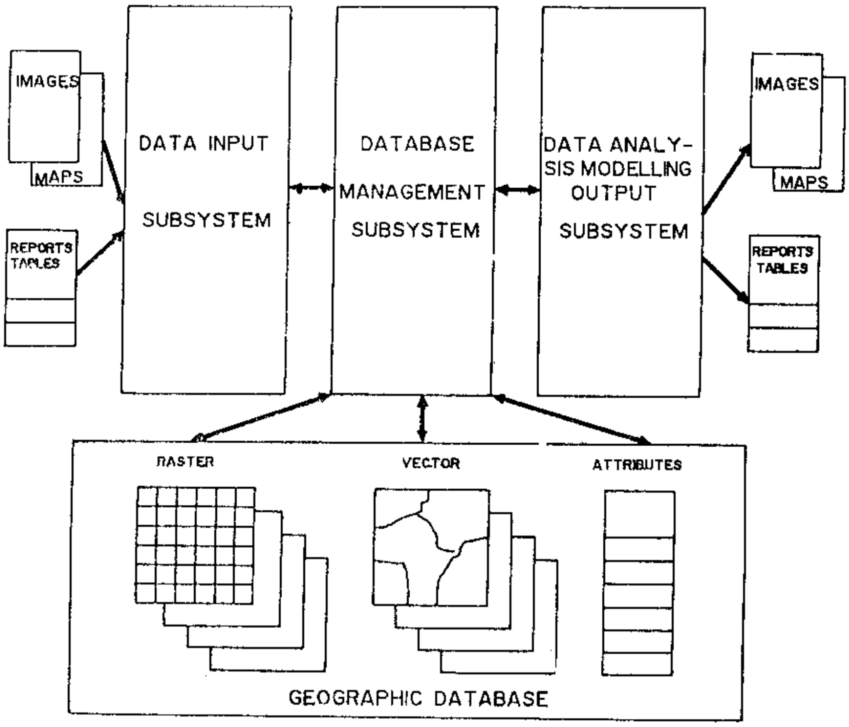
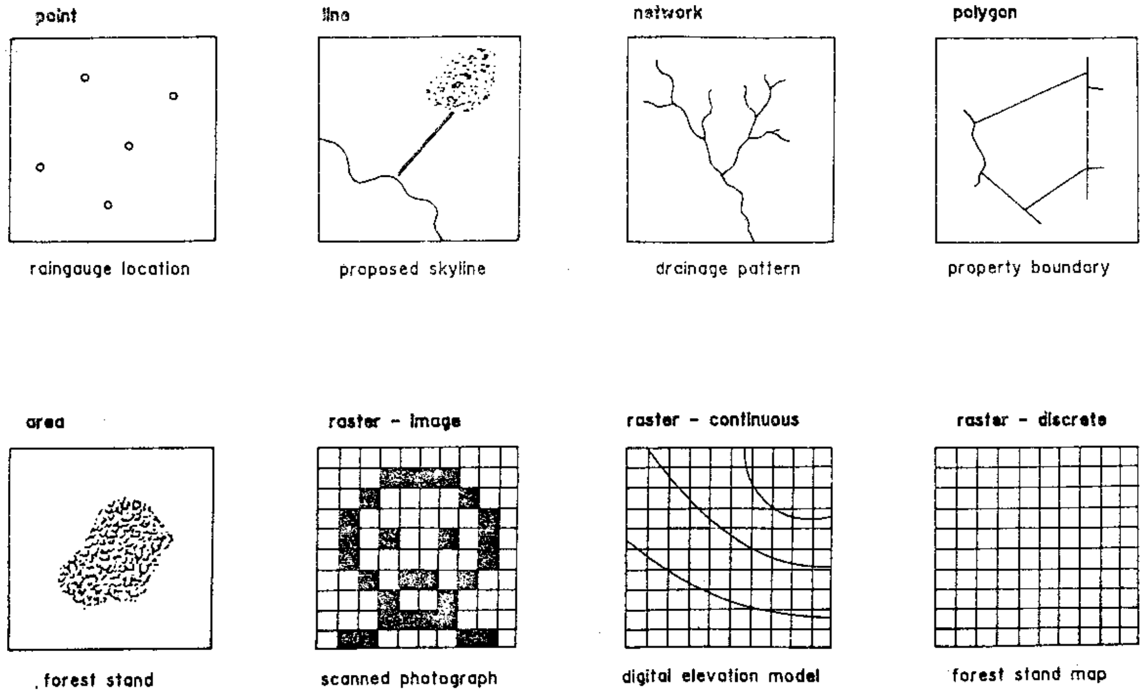


FIG. 2.1 SCHEMATIC REPRESENTATION OF A GIS

FIG. 2.2 TYPES OF SPATIAL DATA



Existing map
- Aerial Photographs
- Satellite imagery
- Existing digital data
- And other GIS data base (may be seen in Fig.2.2 and 2.3)

Data Entry System:

The method of spatial data input depends primarily on the source of the data. The actual method of data input is also dependent on the structure of the data base of the geographical system. There are five data entry methods commonly used in GIS:Key board entry, Co-ordinate geometry, manual digitizing, scanning and the input of existing digital files.

Key Board Entry:

This involves manual entering of the data at computer terminal. Attribute data are commonly input by key board.

Coordinate Geometry:

In coordinate geometry procedures, the survey data (land record information) are commonly entered by key board. From this data the coordinates of the spatial features are calculated and a GIS compatible file is created.

Manual Digitizing:

Manual digitizing is the most widely used method for entering spatial data from maps.. The map is mounted on a digitizing table and a hand held device, termed as puck or cursor, used to trace each map feature. The position of the cursor is accurately measured by the device to generate the coordinate data in digital form.

Scanning:

Scanning provides a faster means of data entry than time consuming manual digitizing. In scanning a digital image of the map is produced by moving an electronic detector across the map surface. At present digital scanners fall into three types: the raster scan digitizer, drum scanner and line followed scanner.

Tape drive:

Spatial and attribute data sets can be obtained by reading computer compatible tapes (CCTS) that have data on them already in digital format. These CCTS can contain either vector data (Such as streams, watershed boundaries at or raster data such as Digital Elevation Models (DEMS) or remotely sensed data derived from various satellites or airborne scanners such as Land sat, SPOT or Daedulus scanner.

SPATIAL DATA MODEL :

There are two types of fundamental approaches for representation of the spatial components of geographic information: The vector model and raster model. (Fig.2.3)

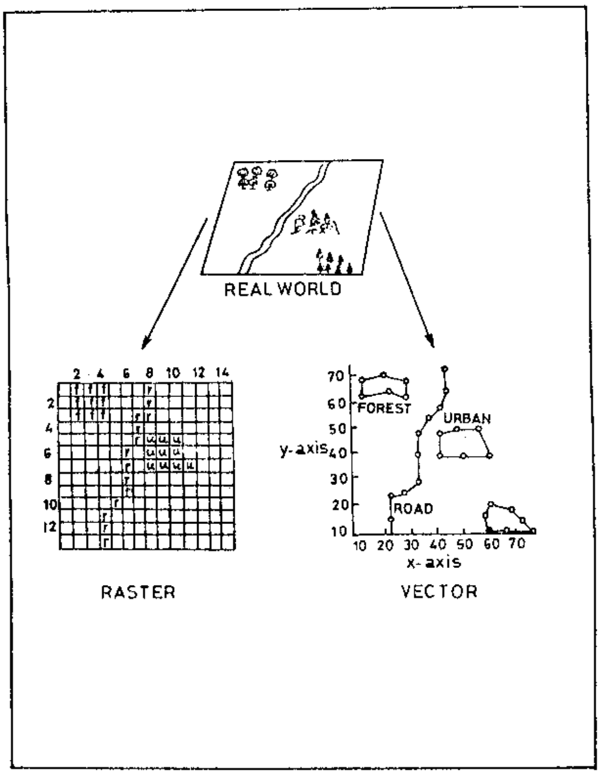


Fig2.3Representation of data in vector and raster models

The Vector Model: In the vector model objects or conditions in the real world are represented by the points and lines they define their boundary such as if they were being drawn on a map. The fundamental primitive in the vector model is the point. Objects are created by connecting points with straight lines areas are defined by set of lines. Vectors models have the line as the basic logical unit in a geographic context.

The Raster Data Model: The raster data model is the simplest form. It consists of a regular grid of square or rectangular cells. The location of each cell or pixel is defined by its row and column numbers. Each cell in a raster file is assigned only one value. The main raster models are the grid and other regular tessellation.

DATA ANALYSIS AND MODELLING :

The most significant characteristic of GIS are the provision of the capabilities for data analysis and spatial modelling. These functions use the spatial and non spatial attribute data of the GIS data base to answer questions about the real world. The data base in GIS is the model of the real world that can be used to simulate certain aspects of reality. A model may be represented in words, in mathematical equations or as a set of spatial relationship displayed on a map. The general problem in data analysis is:

Users query ---> data base link ----> output

The user has particular specification, constraints or query. The data base contains information in the form of maps that can be used to answer the users query. All that is necessary is to establish a link between data base and output that will provide the answer in the form of a map, table or figure. The link is any function that can be used to convert data from one or more input maps into an output.

Analysis Functions :

The power of GIS lies in its ability to analyse spatial and attribute data together. A large range of analysis procedure function have been divided into four categories :

i) Retrieval, reclassification and measurement
ii) Overlay (iii) distance and connectivity
iv) Neighbourhood

Retrieval, Reclassification and Measurement Operation:-

In these functions retrieval of both spatial and attribute data are made and only attribute data are modified. Creation of new spatial elements are not made.

Retrieval Operations:- This involves the selective search and manipulation and output data. Retrieval operation includes the retrieval of data using:

- Geometric Classifications
- Symbolic Specifications

- A name of code of an attribute
- Conditional and logical statement

Reclassification Procedures :

This procedure involves the operation that reassign thematic values to the categories of an existing map as a function of the initial value, the position, size or shape of the spatial configuration associated with each category, for instance a soil map reclassified into a permeability map. In a raster based GIS, numerical values are often used to indicate classes. A cell might be assigned the value to indicate classes. A cell might be assigned the value 1 to indicate a agriculture land, 2 for forest land and so on. Classification is done using simple data layers as well as with multiple data layers as part of an overlay operation.

Measurement Functions :

Every GIS provides some measurement functions, measurement of spatial data involves the calculation of distance, lengths of lines, area and perimeter of polygons, measurement involving points include distances from a point to a point, lines or a polygon enumeration of total number as well as the enumeration of points falling within polygon.

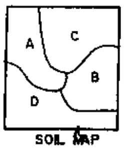
Overlay Operations :

Overlaying of maps result in the creation of a map where the values assigned to every location on that map are computed as a function of independent values associated with that location on two or more existing maps. Overlaying operation creates a new data set containing new polygons formed from the intersection of the boundary of the two or more sets of separate polygon layers. Arithmetical and logical overlay operations are common in all GIS software packages.

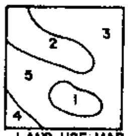
Arithmetical overlay includes operations such as addition, substraction, division and multiplication of each value in a data layer by the value in the corresponding location in the second data layer. Logical overlay involves the selection of an area where a set of conditions are satisfied. Fig.2.4 depict the overlaying concept in a vector structure (topologic overlay).

Interpolation :

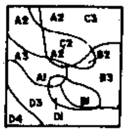
Interpolation is the procedure of predicting unknown values using the known values at neighbouring locations. The neighboring points may be regularly or irregularly spaced. Interpolation programmes employ a range of methods to predict unknown values including polynomial regression, fourier series moving averages and krigging etc. The quantity of the interpolation results in a function of the precision accuracy, number and function to calculate proximity (Straight line distance) and area to be analysed. A buffer zone may be the result of a proximity analysis.



SOIL MAP



LAND USE MAP



SOILS AND LAND USE MAP

LAND USE

USE CO	USE NA
1	FOREST
2	AGRICULTURE
3	PASTURE
4	SHRUBS

SOILS

SOILS CO	DEPTH
A	150
B	200
C	180
D	190

LAND USE / SOILS

SOIL-USE	USE NA	DEPTH
A1	FOREST	150
A2	AGRICULTURE	150
A3	PASTURE	150
B1	FOREST	200
B2	AGRICULTURE	200
B3	PASTURE	200
C2	AGRICULTURE	180
C3	PASTURE	180
D1	FOREST	190
D3	PASTURE	190
D4	SHRUBS	190

FIG 2.4: OVERLAY PROCEDURE IN AVECTOR SYSTEM

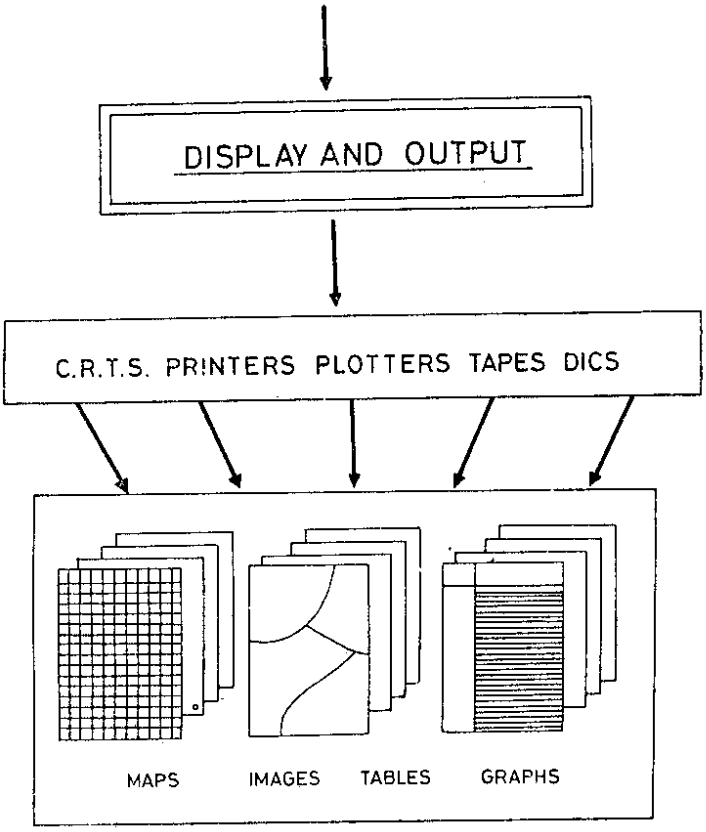


FIG. 2.5 DATA OUTPUT

DATA OUTPUT :

Data output is the operation of presenting the results of data manipulation in a form suitable to the user. Data are output in one of the three formats - Hard Copy, Soft Copy and Electronic (Fig.2.5)

Hard copy output are permanent means of display. The information is printed on paper, photographic film or similar. Maps and historical tabulations are output in the hard copy format by the help of hard copy output devices such as dot matrix printers, ink jet plotters, pen plotters, matrix camera, color laser printer, etc.

Soft copy output is the format as viewed on a computer monitor. It may be text or graphics in monochrome or colors. Soft copy display are used only for temporary display. The soft copy device most often used in GIS is computer monitor, cathode ray tube. Output in electronic formats consists of compatible files. They are used to transfer data to another computer system either for additional analysis or to produce a hard copy output at a remote location.

2.3 WORK CARRIED OUT :

A brief review of the work carried out by a number of scientists to interrelate the USLE factors with the aim of obtaining erosion intensity expressed by soil loss from a soil unit over a unit of time. Most of the work done in GIS applications of erosion studies deal with the use of the USLE model.

Nema et al(1978) worked out some parameters of USLE for run-off plot study conducting of Vasad. The soil erodibility factor "K" in the USLE for soil and climatic condition of vasad, Average rainfall factor and crop management factor 'C' have been computed.

S.Chinnamanai et. al.(1982) applied USLE for the estimation of soil erosion in mountain watersheds of the Bhawani basin in South India. In this study main factors considered were landuse changes(from forest to agriculture). The computed annual soil loss (t/ha) agrees fairly well with the observed soil loss data provided by plot studies. The soil loss in the basin has been broadly subdivided into eight categories namely extremely low,very low,low,moderately low to medium, moderately to high, high, very high and extremely high. The study has revealed that improper rural and urban management in the root cause of erosion.

Pelletier (1985) described the general procedure as follows. In developing a USLE database, the information is geographically referenced to the UTM or other coordinate system, so that points from any data source having the same (x,y) position in the digital database. All subsequent data files, including the USLE factors derived from them, can therefore be spatially overlaid. The ease of applying the USLE in GIS context is apparent; the problem lies in the validity and/or applicability of the model itself. For gully erosion, for example, this model is not appropriate

Spanner (1982,1983) combined Landsat MSS data and a digital elevation model (DEM) in a GIS context. A stratification of the landscape according to relief (elevation,steepness) allowed accurate discrimination between orchards and natural vegetation that had not been possible using Landsat data processing alone. The DEM helped to quantify three of six coefficients of the USLE (slope gradient and length, and cover).

Gesch and Naugle (1984) used a GIS to compare Landsat MSS and TM data and a DEM as input for the USLE coefficients. They concluded that the use of C (cover) factors derived from classified MSS and TM data in the USLE resulted in different erosion estimates. The use of slope data from the DEM resulted in erosion estimates significantly different from those obtained by using soil survey slope data.

Wheeler and Ridd (1985) also merged remote sensing and GIs procedures in building a database for planning purpose (natural hazards,resources management).for the North Cache Soil Conservation District (United States)geographic database. Land use and cover from the lowlands were mapped from various scale aerial photos and fields check. Vegetation and land cover from the mountains were mapped using Landsat products. Geomorphic terrain units were delineated from aerial photos and field work. Digital terrain mapping was used to assemble elevation ,slope steepness length and aspect data.

Millingtion (1986) developed a GIs for soil erosion risk Evaluation in SIerra Leone. The objective were to assess the current spatial distribution of soil erosion and the change in this distribution with or without conservation policies (scenario development). Data handling involved the transformation of existing datasets to a grid square and the collection of new data within this format. A potential maximum erosion risk map was generated by overlaying erosivity index slope angle drainage density and erodibility index and by applying factorial score transformations and sieve overlay analysis.

Gerado Bocco et al (1988) evaluated gully erosion in an area in central Mexico using GIS and image processing technique. The objective of this study were to :

- perform multispectral classification of cover, using Landsat TM and SPOT data, wherein erosion classes could be determined.
- Classify the landscape into terrain mapping units by means of a visual interpretation of stereoscopic SPOT data.
- Combine both sets of data at a GIS level to test and improve the quality of interpolation for the assessment of spatial distribution of erosion in the study area.

O.P.Dubey et al (1988) mapped erosion prone area considering rock soil type,slope and landcover. Use of satellite data and aerial photographs was made for preparing landcover map and grouping the rock-soil classes according their erodibility. Slope analysis was carried out on contoured map and on digital elevation model. A semi automatic method for erosion mapping was developed and tested in a part of Himalaya.

C.Jurgens et al.(1993) carried out study using the well known USLE to assess the long term soil erosion in a small catchment area and to simulate various soil protection alternatives. The land cover factor (C-Factor) was determined by a multi-temporal landuse classification of two satellite images from May and July 1990. The other factors have been determined in the field (K factor) or assistance of a digital elevation model(L and S factor). All the parameters have been established in the GIS (as a map and in the data base), and multiplied according to the USLE for assessment of the long term soil erosion for every pixel.

S K Saha,J Bhattacharjee, C Lalengguwa & U M Pande (1992), In this study was undertaken to determine priority classes of subwatersheds of part of song river watershed, esteren doon valley, based on spatial erosional soil loss estimates using IRS-IA- LISS II data using USLE, The results indicated that out of total fifteen subwatersheds,nine subwatersheds belongs to high to very high priority classes (over estimated soil loss between 50.5 to 225.4 t/ha/yr.) covering 36.2% area of the watershed. Rest subwatersheds covering 63.8% area of the watershed were classified as low to moderate priority categories(average estimated soil loss between 7 to 17.7t/ha/yr.).

Charles omoregie et al in this study soil erosion was investigated on the barmic vegetation, landuse, soil map, rainfall map and slope map. vegetation & landuse was developed using satellite data and other maps were generated from toposheets & field organisation. It was found that by clubbing different maps such as landuse\landcover,soil,rainfall and slope map respectively, the erodable zone mapping is achieved with higher accuracy.

Choudhry et al (1992) - This study was under taken with the objective of delivering watersheds and subwatersheds of the river Dohan and Krishnawati using RS technique. Soil loss has been calculated using wishchmeier & smithes soil loss equation. In hill slope followed by pediment area. There is insignificant soil lose in flat areas.

Narain P. et al. (1993) prepared a soil erosion map of West Bengal. The soil erosion rates in west bengal ranged from less than 5t/ha/yr. in deltaic and dense forest regions to more than 40 t/ha/yr. in western parts of Chhotanagpur plateau and hilly regions having open forest in Darjeeling,Jalpaiguri and Kooch Bihar. About 10% of the area of the state revealed severe erosion(>20t/ha/yr.) needing immediate attention to treat the area with soil conservation measures on priority. The area under moderately several(15-20t/ha/yr.) and moderate erosion classes(10-15t/ha/yr.) are about 6 and 13 percent respectively. About 70% area of West Bengal lies under slight to moderate erosion classes depicting(<10t/ha/yr.) The map will prove a handy tool for identifying priority areas for developing landuse plans and devising conservation strategies for effective resources management.

Geleta (1993) carried out soil erosion study for Nalota nala watershed using ILWIS. He applied USLE and different parameters of USLE were generated in USLE. Soil erosion under physical condition, present landuse and proposed landuse were estimated.

V.Sridhar and I.V.Muralikrishna (1994), In this study soil erosion study was carried out using IRS- 1B, LISS II data at 1:50,000 and toposheets. various maps such as landuse\landcover, slope and Isohyetal map was prepared by visual interpretation . By the superimposition of the four base maps, the final maps showing of erosional zones is prepared.

3.0 STATEMENT OF THE PROBLEM

All the factors of the Universal Soil Loss Equation empirical models are geographic in character, i.e. they can be referenced to a particular location. In most of the cases, rainfall distribution, soil characteristics, topographic parameters, vegetative cover, and information on conservation support (erosion control) practice; from which the factors can be derived, are often available in the form of maps or can be mapped through collection of data from possible sources or field investigation or/and remote sensing studies. Due to the geographic nature of these factors, USLE can easily be modeled into GIS. In other words, assessment and prediction of soil erosion from any watershed or agricultural fields will be much simpler using GIS given that data on each factor is available.

In the present study USLE has been applied to a part of Banjar sub basin of Narmada basin. A review of the studies carried so far using conventional techenique and using GIS tech. has been given in chapter two. No such type of study has earlier been carried out for the present study area. First the different parameters were generated and stored in ILWIS,then all these parameters are integrated to produce soil erosion under three conditions - Physical (RKLS), during monsoon and off-monsoon season.

4.0 DESCRIPTION OF THE STUDY AREA

The study area chosen for the present is a part of Banjar sub basin of Narmada basin. This is covered is Mandla district of M.P. The area lies between longitude 80 30' to 80 45' E and latitude 20 22' to 22 30' N. The area of the study area is 80 sq. km.

Climate

The area is covered by tropical type of climate having considerable variations in rainfall, temperature and humidity. The changes in behaviour of the weather and the climate are the direct result of changes of pressure and movement of air currents from the Indian Ocean across the Bay of Bengal and the Arabian Sea. The year has three distinct seasons-the wet season (June to October , the winter season (November to February) and the hot weather (March to mid-June).

Rainfall :

The rainy season in the area extends from June to September under the influence of the South-West monsoon. The area also receives some rainfall during January and February from the North-East monsoon. July and August are the heaviest rainy months. The rainfall data reveals that there is a considerable variation in rainfall from year to year as well as month to month in a year.

Temperature

The area lies in the hot region of the country. The temperature begins to rise rapidly from about March till may which is generally the hottest month. with the on-set of the monsoon in the second week of June, there is an appreciable drop in day temperature. From mid-November onwards both day and night temperature decreases rapidly. December and January are the cloudiest months of the year. In winter cold waves effect the area in the wake of western disturbances passing across North India. On such occasions the minimum temperature drops to about the freezing point.

5.0 DATA AVAILABILITY AND METHODOLOGY

5.1 DATA AVAILABILITY

A description of the required data for carrying out the present study such as hydromat data, satellite data and topographic data is given below.

Rainfall data : Monthly rainfall data of the raingauges falling inside and outside the basin was collected. From this data average seasonal (for the month of June to September) and average annual rainfall were computed and given in the table given below.

Table 5.1: Average rainfall data in the study area

Raingauge	Monsoon (June-Sep.)	Annual	Non Monsoon Oct.-May
Kisli	1380.80	1448.88	
Bahihar	1119.10	1299.98	
Bichhia	612.17	694.53	
Palhera	869.02	1019.48	
Simariya	1209.80	1400.65	
Karanjia	1115.16	1278.73	
Mandla	1202.36	1400.70	
Bhimlat	965.95	1137.22	
Paraswara	1284.40	1387.60	

TOPOGRAPHIC DATA :

The study area is covered in Survey of India toposheets no. 64 B/11. The toposheets at a scale of 1:50,000 are available in the institute.

SATELLITE DATA :

The study area is covered in one frame of IRS, LISS - II data, 25-52, B2, 18th Nov., 1989.

5.2 METHODOLOGY :

GIS SOFTWARE USED :

The GIS software used in this study is ILWIS (Integrated Land and Water Information System). It was developed at the Computer Centre of International Institute of Aerospace Survey and earth sciences (ITC) Enschede, The Netherlands. ILWIS provides user with state of art of data gathering, data input, data storage, data manipulation and analysis and data output capabilities, merging and integrating conventional GIS procedures with image processing use with microcomputers and uses both vector and roster graphics data (Valenznela 1988).

A conversion program attains the importation of remote sensing data, tabular data raster maps, and vector files in several other formats. Analog data can be transferred into vector format by means of digitizing program.

Complex modelling of features can be executed by the map calculation. Map calculation includes an easy to use modelling language and the possibility of using mathematical functions and macros. It integrates tabular and spatial data bases. Tabular and spatial data bases can be used independently and on an integrated bases. Calculation, queries and simple statistical analysis can be performed by table calculator.

5.3 DERIVATION OF MODEL INPUT PARAMETERS :

The process of data base creation for the basin in ILWIS involved collection of relevant available data, including these data into digital format, digitization error checking and correction, polygonization of segment files and finally conversion of data acquired in vector structure to raster format. In developing USLE models data base, original source maps have been digitized using a digitizing tablet linked to a personal computer through ILWIS and related attribute data have been entered at the key board. The steps followed further are as follows:

Errors involved in digitization and editing the error :

Manual cartographic digitizing, due to its tedious process often involves errors. Therefore before any further step is taken after digitization the segments should be checked for errors. The most common possible errors that are likely to occur during digitization are over and under shooting of the lines, failure to snap lines together at nodes, omission of lines and points incorrect feature coding, incorrect location of features etc. The errors were checked and corrected by the facilities available in ILWIS under VECTOR-digitize module.

Polygonization : After each segment file was checked and corrected, polygon files for soil and landuse were created by the polygon generator program. The polygons for any given polygon file were assigned identification name and color values. It is worth to note that polygon features attributes labels are normally entered only after the topology of the digitized data has been checked and corrected if necessary. In the GIS package used program facilities are also available to automatically create polygon information file containing the areas and parameters of different polygons. Area and perimeter calculations are performed by an interactive in-built program.

Vector to Raster Conversion : Because high spatial variability and overlay operations are easily and efficiently implemented in a raster model, all maps encoded in vector structures (both in polygon and segment) were converted into raster structure. Soil and landuse maps which were rasterised through polygon to raster mode in the vector to raster module.

The process of creating new derivative data files from input source data files can be accomplished either by creating new attribute map from related tabular data files or overlay operations. Almost all USLE model factors were generated by both methods :(i) Overlay of source data layers and (ii) through linkage between attribute data and spatial data. Generation of different parameters are explained below:

5.3.1. RAINFALL EROSIVITY FACTOR (R): For generation of R factor equation 1.2 and 1.3 were used . In these equations unknown values are average annual rainfall and average monsoon (seasonal) rainfall. In the study only one station Simaraiya which is located nearby was considered. The rainfall data of Simaraiya sta -tion was taken from table no. 5.1. Now using annual and seasonal values in eq. 1.2 and eq. 1.3 rainfall erosivity factors were computed. The value of R for annual and seasonal rainfall are 567.5 and 520.5 respectively.

5.3.2. SOIL ERODIBILITY FACTOR (K): Assessment of soil erodibility factor in USLE model requires the knowledge of soil characteristic information mentioned under chapter 1. As the detailed soil data were not available, in this work estimated average values of broad ranges were used in order to approximate the value of K-factor. Gurmel Singh et al (1981) presented soil erodibility factor K on the basis of research conducted in some of the selected research stations in India and are given below:

Table 5.2 Soil Erodibility Factor for various soil

Station	Soil	computed K value
Agra	Loamy sand,alluvial	0.07
Dehradun	Dhulkot silt loam	0.15
Hyderabad	Red chalk sandy loam	0.08
Kharagpur	Soils from lateritic rock	0.04
Kota	Kota clay loam	0.11
Ootacamund	Laterit	0.04
Rehmankhera	Loam,alluvial	0.17
Vasad	Sandy loam, alluvial	0.06

The soil types of the study area could not be collected. The soil of the area resembles with laterite soil, hence the soil erodibility factor of 0.04 was used in this study.

5.3.3. TOPOGRAPHIC FACTOR (LS): As compared to other USLE factors determination of the LS-factor involves some analytical procedures. First the contour map of the study area was prepared from survey of india toposheets at scale of 1:50,000. These contours were digitized in ILWIS. In ILWIS interpolation is available using different technique. Elevation data (contours) which represent the topography of the watershed were interpolated (From isolines) to create digital elevation model (DEM). From isolines performs a linear interpolation on a raster map. for each pixel the distances to the two nearest isolines are calculated. Then a linear interpolation is performed for each pixel. DEM represents the continuous variation of relief over the area. In DEM the altitude value of a given location or point can be identified reading in the value of the grid cell (or pixel) which has a dimension of2.666m. A classified image of digital elevation model for the watershed is presented in Fig. 5.1.

Once the elevation data have been gathered and transformed into the altitude matrix (DEM), using standard procedures, production of maps showing terrain parameters like slope, etc. will be much easier. Slope, the most important terrain parameter, is defined by a plane tangent to the surface as modeled by DEM at any given point and comprises two components: gradient, the maximum rate of change of altitude; and aspect, the compass direction of the slope (Burrough, 1986). In the present study , ILWIS standard filter method has been used and described below :

In this method the east - west and south - north gradients were calculated applying standard ILWIS first derivative filters (dfdx and dfdy) on digital elevation model and the slope was obtained from these derivatives by applying standard slope function as given below:

SLOPE := (SLOPE(DX,DY)/ u)*100

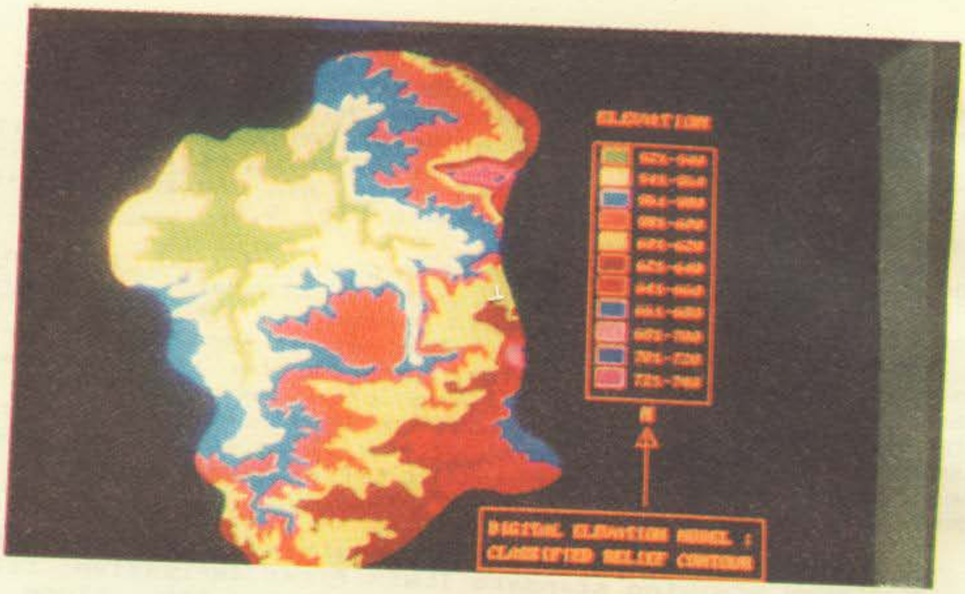
Using above function a slope map of the study area, taking the value of pixel size (u) as 20.18, was generated and classified slope map is shown in Fig. 5.2.

To generate the topographic factor L-factor, and S-factor were calculated separately. Employing the slope map and taking the pixel size as the slope length, L-factor values were obtained. In this analysis, the slope map was reclassified according to the recommended m values (Table 2.2) for different slope classes. Then these two factors were combined to give the LS factor map which is shown in Fig. 5.3

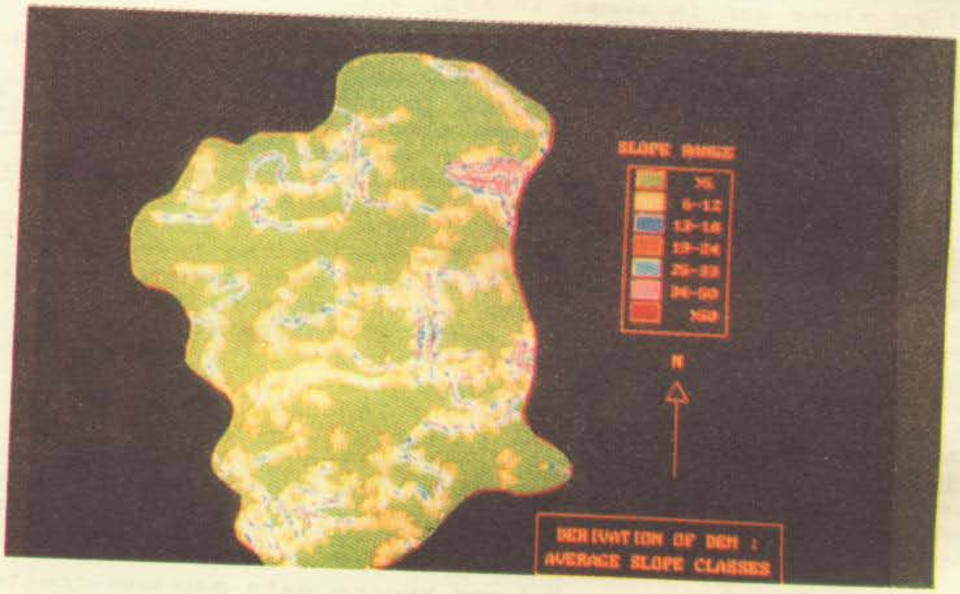
5.3.4 CROP MANAGEMENT FACTOR (C): To develop the C-value for the watershed various land mapping units were considered. The primary source of information for landuse was an image of the study area acquired by the IRS , LISS II data of in the form of FCC. The visual interpretation approach was adopted for classification in which the pattern of reflectance gives the type of land use. Based on the signature of different landuse categories , the landuse was classified in four classes i.e. Agricultural land (Cultivation in plain land, cultivation in undulated land), Forest , Eroded land and waterbodies. The area is mainly covered by forest and agriculture land. The paddy and maize/wheat are the main crops.

Land use map was encoded and source data map was created. The broad classification as obtained from remote sensing data, related attributes describing each unit in the classification were created and stored. (Fig 5.4)

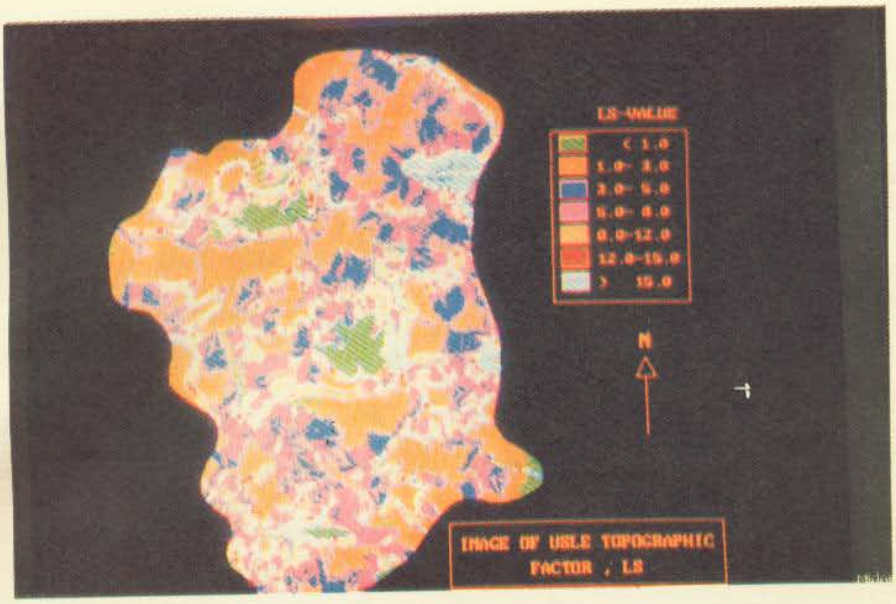
Land use/land cover input data was used to assign the C-value to each cover type or group of covers. The evaluation



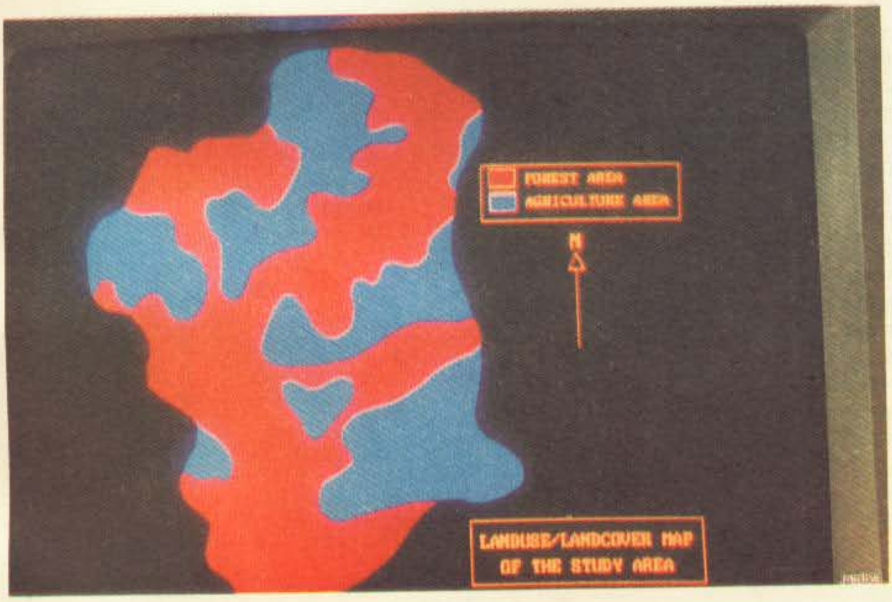
5.1 Digital elevation model - classified relief contours.



5.2 Derivation of Digital elevation model, Average slope classes



5.3 Image of USLE topographic factor, LS.



5.4 Lasduse/landcover map of study area.

and calculation of C-value for each cover unit was made on the basis of information available on the level of management practices, physical conditions and characteristics of the cover units.

Crop cover in the agricultural field was given in broad classification for seasonal and non seasonal period. Crop management factor value for each group was approximately estimated by giving more weightage to predominant crops like Paddy (50% area coverage in Kharif season), and Wheat (50% area coverage during Rabi season).

Gurmel Singh et.al (1981) presented various experimenta results conducted in India. Results presented by the above authors are compiled and given in table 5.2 below:

Table 5.3 Crop management factor (C) at various research stations of India

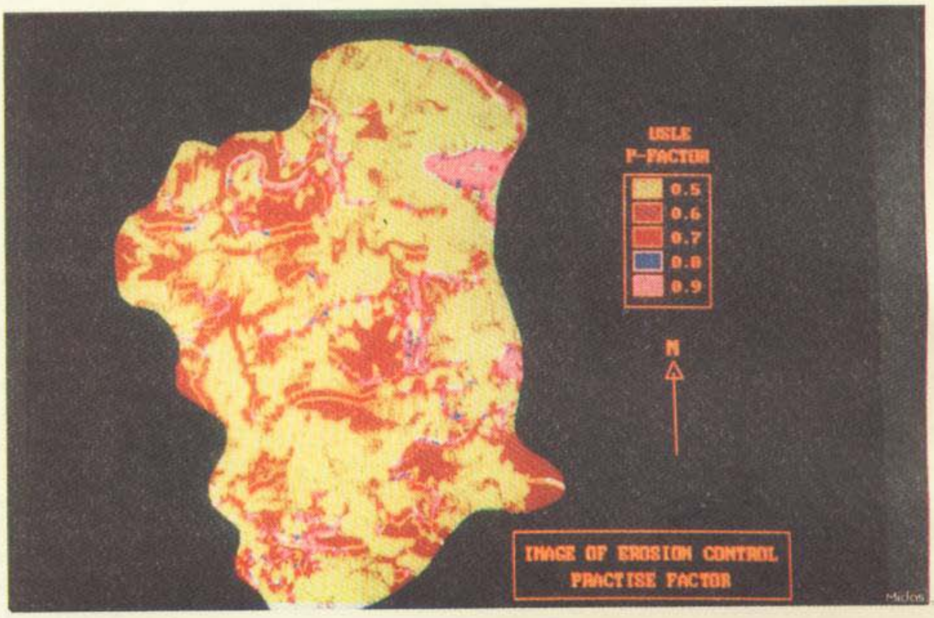
Crops	A	B	C	D	E	F	G
Moong	0.27						0.45
Ground nut	0.19	0.41					0.42
Cowpea	0.16	0.39		0.17			
Green gram		0.39					
Black gram		0.54					
Soyabeen		0.42					
Guar		0.59	0.42				0.35
Maize		0.50		0.35	0.54		
Johar		0.62				0.64	
Johar + Arhar		0.33					0.28
Natural cover		0.14				0.12	
Cynodon dactylon		0.22					
Dichanithium annulatum		0.01	0.13				
Fallow			1.00		1.00	1.00	1.00
Til			0.51				0.39
Bajra			0.61			0.40	
Paddy				0.28			
Pigeonpea				0.38			
Strawberry with weeds					0.27		
Pineapple with weeds					0.10		
Pineapple clean					0.34		
Pomegranate with weeds					0.08		
Pomegranate clean					0.56		
Combopogen citratus					0.13		
Johar-horse gram						0.38	
Castor						0.79	
Bajra- Cowpea						0.38	

A: VASAD
B: KOTA
C: AGRA
D: KHARAGPUR
E: DEHRADUN
F: HYDERABAD
G: REHMANKHERA

The C values for monsoon season for agriculture was taken as 0.28 and for off monsoon season as 0.54. The C value for forest cover is taken as 0.025.

5.3.5 CONSERVATION PRACTICES FACTOR (P): The P value not only depends on the type of treatment or practice adopted but also on the slope of the field. In the table no. 2.3 given in chapter 2, P-factor value is given for different slope ranges. Applying these values in the classified slope map, P-factor map is generated and shown in fig. 5.5

In this way all the parameters of USLE were generated in spatial form for further analysis.



5.5 Image of erosion contour practice factor.

6.0 ANALYSIS AND RESULTS

After converting the original source data into digital format a database has been created for further analysis in GIS environment. From these data, another derivative data files have been developed through various techniques of data analysis. In this study the assessment and prediction of erosion hazard was made under three conditions : (i) Without management (considering only the physical factors. (ii) Monsoon seasonal i.e. for the month June-September; and (iii) Non monsoon season i.e. for the months October -May.

6.1 WITHOUT MANAGEMENT (Considering only the physical factors) :

Under this condition, maximum potential erosion losses were estimated under prevailing rainfall erosivity without crop cover or supporting control practices (C=1 and P=1) for the soils and the topography. R,K,L and S factors were integrated to produce output map. This map was then reclassified using the table given below:

The result of this calculation is presented in Fig.6.1. In spite of the erosion resistance of the soils, almost all the values obtained were extremely high, reflecting the effect of very erosive rainfall and harsh topography. These values by far exceeded the soil tolerance limit of 5 t/ha/year.(All India Soil & Landuse and space application Center(ISRO),1987. The area breakup and the percentage of area covered in each class is given in table 6.1 below:

Table 6.1 Percentage of maximum potential erosion classes under physical condition

Erosion (t/ha/yr.)	Class	Area (%)
< 20	1	7.2
20 - 40	2	16.2
40 - 80	3	26.8
80 - 160	4	23.6
160 - 240	5	10.6
> 240	6	15.4

6.2 DURING MONSOON SEASON :

Under this condition, erosion loss was made after considering the values of C and R factor. R factor was taken using equation . For C factor value of C for agriculture was taken for paddy crops from table no.5.2, as this is the main crops growing in this season. Rest of the factors will not change and will be taken as same. After integration of all the factors derived, the soil erosion was estimated and this is further classified in different classes with the help of table 6.2.

below and shown in Fig. 6.2.

Table 6.2 Percentage of maximum potential erosion classes for monsoon season.

Erosion (t/ha/yr.)	Class	Area (%)
< 1	1	50.7
1 - 3	2	10.6
3 - 5	3	8.3
5 - 7	4	8.6
7 - 10	5	5.3
10 - 15	6	5.0
15 - 20	7	2.7
> 20	8	8.1

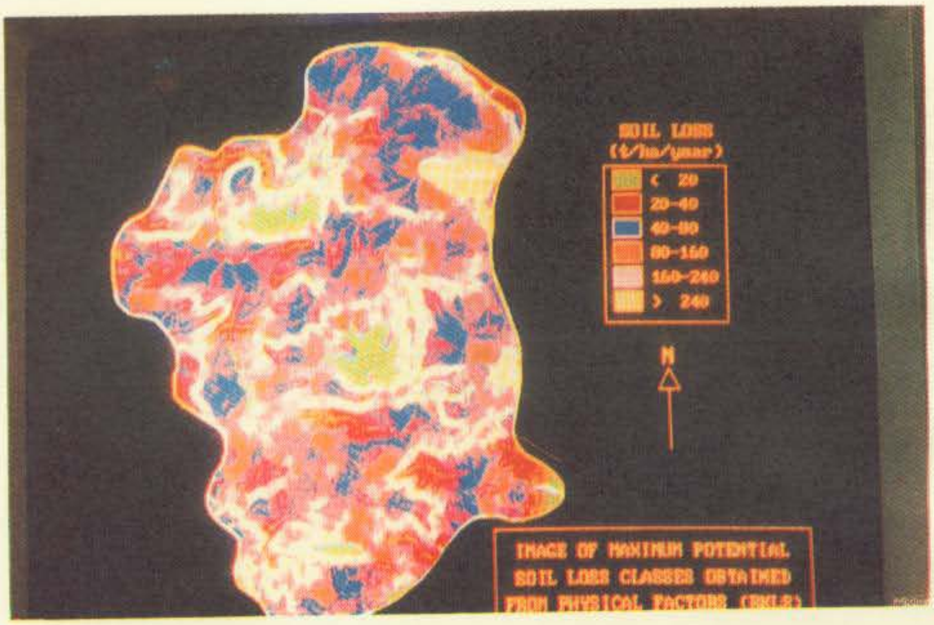
6.3 DURING NON-MONSOON SEASON :

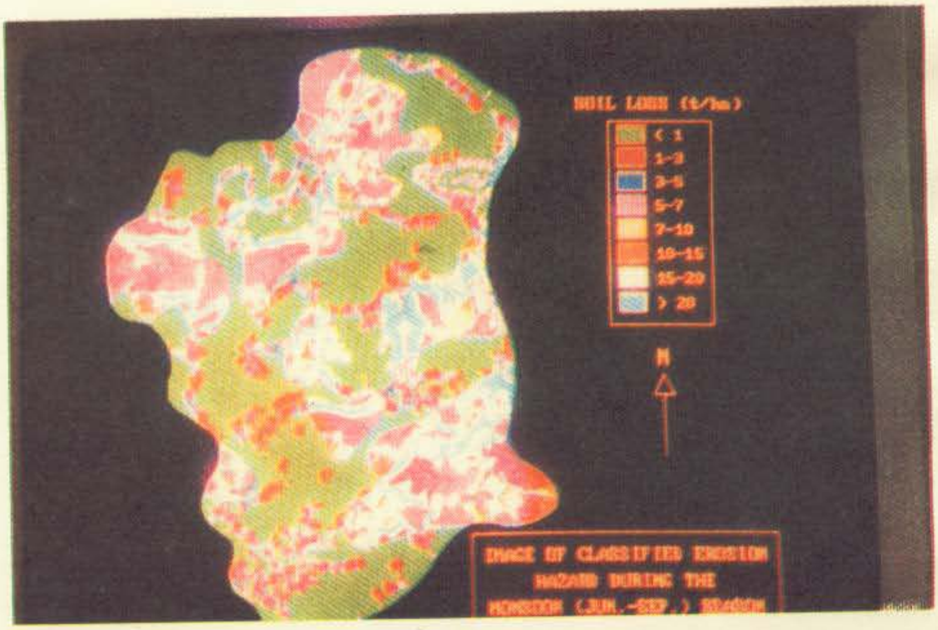
Under this condition, erosion loss was made by changing the values of C and R factors again. R factor was taken using equation . For C factor value of C for agriculture area was taken for maize crop, as this is the main crops growing in this season from table no. . Rest of the factors will not change and will be taken as same. After integration of all the factors derived, the soil erosion was estimated and this is further reclassified in different classes using table 6.3. The different classes and the area covered are given in table no. below and shown in Fig. 6.3.

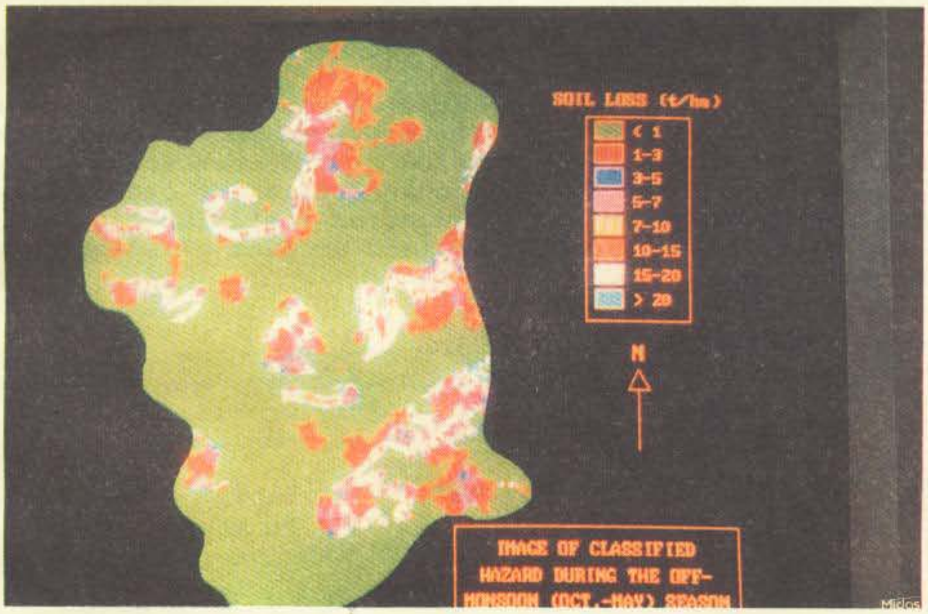
Table 6.3 Percentage of maximum potential erosion classes for non-season

Erosion (t/ha/yr.)	Class	Area (%)
< 1	1	79.7
1 - 3	2	9.6
3 - 5	3	3.1
5 - 7	4	1.8
7 - 10	5	2.0
10 - 15	6	2.1
15 - 20	7	0.9
> 20	8	0.7

The table no. 6.1 given above indicatest that under physical conditions the rate of erosion is high, reflecting the effect of rainfall and harsh topography. These values covering about 95 % of the area by far exceeded the soil tolerable limit of 5 t/ha/year. It may be noted that this quantity of erosion (Maximum value 240 t/ha/year) refers only to the amount of soil particles which were detached from their original place. The result from USLE does not indicate the sediment yield at the watershed outlet. The result under monsoon season table 6.2 shows values of eroison rates at lower side than the results of physical condition. In this case crop management and conservation practice factors were also considered. Due to these factors the values of erosion rates have decreased and a small area (approx. thirty percent of the total) in beyond the soil tolerance limit. Under the third category i.e. for non monsoon season erosion rates were further on lower side (maximum value about 20 t/ha/year). Because in the study area the rainfall which in one of the main source of soil erosion is very low, that is why the erosion rate is very less. A very small area covering about eight percent of the total area is beyond soil tolerance limit.


SOIL LOSS
(t/ha/year)
< 20
20-40
40-80
80-160
160-240
> 240
N
IMAGE OF MAXIMUM POTENTIAL
SOIL LOSS CLASSES OBTAINED
FROM PHYSICAL FACTORS


SOIL LOSS (t/ha)
< 1
1-3
5-7
7-10
10-15
15-20
> 20
N
IMAGE OF CLASSIFIED EROSION
HAZARD DURING THE
MONSOON (JUN.-SEP.) SEASON



6.3 Image of classified erosion hazard during the off-monsoon (Oct. - May) Season.

CONCLUSION

This study shows that for a small area , the long term soil ;ion can be assessed with satellite data and ancillary digital ι in a GIS. For each pixel that is represented in all data ›rs it is possible to determine the soil erosion rates by .ication of USLE.

Using the database the USLE factors (Rainfall Erosivity :or, R; Soil Erodibility Factor, K; Topographic Factor, Crop Management Factor, C; and Conservation Practice :or, P) were evaluated. The maximum potential soil loss mate using the physical components of of USLE (RKLS) cated very high values. The soil loss predicted from under ·ting land use units during the monsoon season shows that erosion in the area is high in some portion. The soil loss uted for non monsoon season is not so severe.

Generally, integration of spatial and non spatial data and ying decision models in GIS provides a useful technique erosion assessment. Application of this procedure to other s will depend upon the soil characteristics ,topography and ation cover. However it is suggested that USLE can give only h estimates of erosion taking into account of sheet and rill ion only.

REFERENCES

1. All India Soil & Land Use Survey & Space Application Center (IRSD). (1987). "Application of Remote Sensing Techniques for Watershed Characterization in a part of UKAI Catchment".

2. Arnoldus, H.M.J. (1977). "Predicting Soil Losses Due to Sheet and Rill Erosion". Guide Lines for Watershed Management. FAO, ROME.

3. Aronoff,S. (1989). "Geographic Information System". WDLP publications, P.O.Box 585, Station B, Ottawa, Ontario KIP 5P7, Canada, 294 Pages.

4. Baxter E. Vieux & Scott Needham (1993). "Non-point Pollution Model Sensitivity to Grid-Cell Size". Journal of Water Resources Planning and Management, Vol. 119(2): 141-157.

5. Bocco Gerardo and C.R.Valenzuela (1988),'Integration of GIS and image processing in soil erosion studies using ILWIS'ITC Journal 1988-4.

6. Burrough, P.A. (1986). "Principles of Geographical Information Systems for Land Resources Assessment". Clarendon Press, Oxford, UK.
664-70.

7. Chaudhry B.S., M.C.Manchanda and B.M.Singh (1992),'Watershed prioritization and site selection for control measures- A case study of Mahendragarh district , Harayana area, Proc. National symposium on remote sensing for sustainable development, 1992.

8. C.jurgens and M.Fander (1993),'Soil erosion assessment and simulation by means of SGEOS and ancillary digital data,IJRS, 1993,Vol.14,No.15, pp 2847-2855.

9. Cully Hession , W & V.O. Shanholtz (1988). "A" Geograp Information System for Targeting Non-point Source Agricultural Pollution". J. of Soil & Water Conservation, 43(3): 264-66.

10. Dubey O.P. and S.Singh (1988), Remote Sensing Application for mapping of erosion prone areas, Proc. Remote Sensing in rural development, No.17-19, 1988, HAU, Hissar.

11. Gesch D B and B I Naugle (1984),An analysis of the utility of Landsat TM and DEM data for predicting soil erosion, Proc. symp. on machine processing of remotely sensed data', pp 260-265.

12. Geleta M.T. (1993), Application of Geographic Information System in watershed management', Unpublished M.Tech. thesis, WRDTC, U.O.R., Roorkee.

13. Jain S.K. and S.K. Goyal (1992) ,' Geographic Information System using ILWIS', TR-159, National Institute of Hydrology, Roorkee.

14. Morgan R.P.C. (1986). "Soil Erosion & Conservation". Longman Scientific & Technical, Longman Group Ltd., England.

15. Millington A.C. (1986),' Reconnaissance scale soil erosion mapping using a simple GIS in humid tropics.In:W.siderius(ed.) Land evaluation for landuse planning and conservation in slopping areas, ILRI Pub.40 Wageningen, pp 64-81.

16. Narain ,P., B.Varma and D.H.Rao (1982),' Prediction of rainfall erosion potential and some parameters of USLE at Kota (Rajashtan)', Indian J. of soil conservation, 10(II & III): 60-9.

17. Narain Pratap, Ram Babu, M.S.Rama Mohan Rao, J.L.Sehgal, R.K.Batta, D.Sarkar and C.J.Thampi (1993),'Soil erosion map of West Bengal'Indian J. soil conservation, Vol.21,No.2,pp 6-10, August, 1993.

18. Nema J.P , Balvir Verma and A.P.Patel (1978),'Predicting some universal soil . loss parameters, Indian Journal of soil conservation, Vol.6, No.2, Oct. 1978.

19. Parajuli, U.N. (1989). "Food and Fuel Model for Sustained Development of Hilly Region". M.E. Dissertation. Water Resources Development Training Center, University of Roorkee, Roorkee-247 667, India.

20. Pelletier, R.E. (1985). "Evaluating Non-Point Pollution Using Remote Sensing Data in Soil Erosion Models". J. Soil & Water conservation, 40(4): 332-35.

21. Raghuwnanshi, N.S. & K.K.S. Bhatia. (1987). "Study of Soil Erosion for Different Land Use and Vegetal Covers Using Universal Soil Loss Equation". National Institute of Hydrology, Jal Vigyan Bhawan, Roorkee-247 667 (U.P.), India.

22. S. Chinnamani, V. Sairam Venkta and R. Sakhivadivel (1982),' Applicability of the universal soil loss equation in mountain watersheds in semiarid and humid regions', Proc. of the Exeter symposium, July,1982, IAHS Pub. No. 137.

23. Singh G., Rambabu, and Subhas Chandra (1981),' Soil loss prediction research in India', Bull. No. T-12/D-9, CSWCR & TI, Dehradun, India.

24. Singh, K. (1987). " Watershed Management in North-Western Himalayas : A Case Study of Nalota Nala Watershed". M.E. Special Problem. after Resources Development Training Center, Roorkee-247 667, India.

25. Sridhar V. and I.V.Muralikrishna (1994),' Assessment of soil erosion using remote sensing techenique, ICORG-1994, Remote sensing ang GIS for envionmental planning, Tata McGraw Hill Publishing, New Delhi.

26. Saha S.K., J.Bhattacharjee ,C.Lalengzuva and L.M.Pande (1992) ,' Prioritization of subwatersheds based on erosional soil loss estimates- A case study of part of Song river watershed, Doon valley, using digital satellite data', Proc. of National symp. on remote sensing for sustainable development, 17-19 Nov., 1992, Lucknow.

27. Spanner, M.A. (1982),' The use of digital elevation model topographic data for soil erosion modelling within GIS , Proc. 49th. Ann meeting ASPRS Techn papers,pp314-321.

28. Spanner, M.A., A.H. Strahler and J.F.Estes (1983),' Soil loss prediction in a GIS format, Proc. 17th Int. Symp Rem. Sen. of Enviornment, pp 89-102.

29. Valenzuela , C.R. (1990). "Introduction to Geographic Information Systems". ITC Publication No. 22. ITC, Enschede, The Netherlands.

30. Vijay P. Singh. (1989). " Hydrologic Systems: Watershed Modeling ". Vol. II. Prentice Hall, Englewood Cliffs, New Jersey 07632.

31. Vladimir Novotny and Gordon Cherters (1981),' Hnadbook of Non-point pollution: source and management', Van Nostrand Enviornmental Engineering series.

32. Wanada B. Potter, Martha W. Gilliland, M. David Long. (1986). "A Geographic Information System for Prediction of Runoff and Non- Point Source Pollution potential". Hydrologic Applications of Space Technology (Proceedings of the Cocoa Beach Workshop, Florida, August 1985), IASH Publ. No. 160.

33. Wishmier , W.H. & D.D. Smith. (1965). "Predicting Rainfall Erosion Losses from Crop land East of Rocky Mountains". Agricultural handbook, No. 28.2A. R.S., USDA. Wischmeier.

34. Wishmier , W.H. & D.D. Smith. (1965). "Predicting Rainfall erosion Losses", USDA Agr. Res. Serv. Handbook 537.

35. Wheeler, D.J. and M.K.Ridd (1985),'A GIS for resource managers based on multilevel RS data. Proc. 51st. An meeting ASPRS, techenical papers.

36. Zachar, D. (1982). " Soil Erosion Development in Soil Science 10 VEDA". Publication House of the Slovak Academy of Sciences, Bratislava.