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APPLICATION OF USLE IN ESTIMATION OF SOIL LOSS FOR GHOD RIVER BASIN, PUNE DISTRICT, MAHARASHTRA

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Abstract

Soil is a very important resource as it serves ecological functions that supports life on earth. An increasing population, deforestation, improper methods of agriculture, uncontrolled grazing and unplanned use of natural resources is leading to irreversible degradation of soil. Soil erosion prediction models play an important role both in meeting practical needs of soil conservation goals and in advancing the scientific understanding of soil erosion processes.The objective of the study is to quantify soil loss and to map areas affected due to soil erosion which will facilitate to devise the guidelines for conservation strategy to control the soil loss.Universal Soil Loss Equation (USLE) has been used to estimate the annual soil loss in the Ghod river basin in Pune district. The parameters for USLE i.e. RKLSCP, have been derived from the various thematic layers. For the present study, the daily rainfall data of ten years has been analysed to calculate the erosivity (R- factor). The slope length and slope steepness (LS factor) is derived from the DEM and C factor from LULC classification of LISS III data. Severe soil loss is observed both in the valley as well as in ridge region of the Ghod basin. The upper basin portion is hilly and of high rainfall erosivity, however, presence of dense forest cover in that area has reduced the erosion rate. The number of causative factors of soil erosion tends to decrease from source towards mouth. Particularly R and K are least influencing as rainfall decreases and clay proportion in soils increases downstream. Conservation and support practices are very scantily noted throughout the basin. The integration of remotely sensed data with GIS proved to be a very useful tool for modelling soil loss.

Introduction:

Soil is an important resource as it serves ecological functions that supports life on earth. Man is not only dependent on soil for agriculture but also for the non-agricultural activities like recreation, engineering projects such as building foundation and waste disposal. Although we often take soil for granted, it is a very thin and often fragile layer of life-supporting material. Many experts have noted that the part of rhythm of human history is the rise and fall of cultures founded on the use, abuse, and final exhaustion of soil and water resources (Plaster 2003). An increasing population, deforestation, improper methods of agriculture, uncontrolled grazing and unplanned use of natural resources is leading to irreversible degradation of soil. Soil erosion is the dominant cause of soil degradation at a global scale (Scherr 1999, Morgan 2005). It has been estimated that in India about 5334 m-tonnes of soil are being removed annually due to various reasons (Pandey et al., 2007). It is very difficult to measure soil erosion so many models have been developed by the researches to estimate the soil erosion on different scales. Many erosion models such as Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978),Morgan-Morgan-Finney (MMF) (Morgan et al.,1984),Water Erosion Prediction Project (WEPP) (Flanagan and Nearing 1995), Soil and Water Assessment Tool (SWAT) (Arnold et.al. 1998), European Soil Erosion Model (EUROSEM) (Morgan et al., 1998), and Annualized Agricultural Non- Point Source (AnnAGNPS) (Bingner and Theurer 2001) have been developed and used data inputs generated through GIS. Among these models, the USLE has remained the most practical method of estimating soil erosion potential for more than 40 years (Fox and R. B. Bryan 2000; Kinnell 2000), despite the fact that it has many limitations for application at catchment-scale (Tesfahunegn et al., 2014). Soil erosion prediction models play an important role both in meeting practical needs of soil conservation goals and in advancing the scientific understanding of soil erosion processes (Nearing et. al. 2007).

Study Area:
The study area comprises the Ghod river basin upto Chinchi dam. The river originates at the place called Ahupe located in the western ghat at an altitude of 1090 m and drains into River Bhima. The major tributaries of Ghod river are river Meena and river Kukadi. The river is 158.34 km long covering an area of 1958.91 Sq.Km. (18°40' N to 19°14' N latitude and 73 ° 33'E to 74°34' longitude). Administratively the area is located in Ambegaon and Shirur Tehsils, northern part of Pune District of Maharashtra, India (Figure 1).

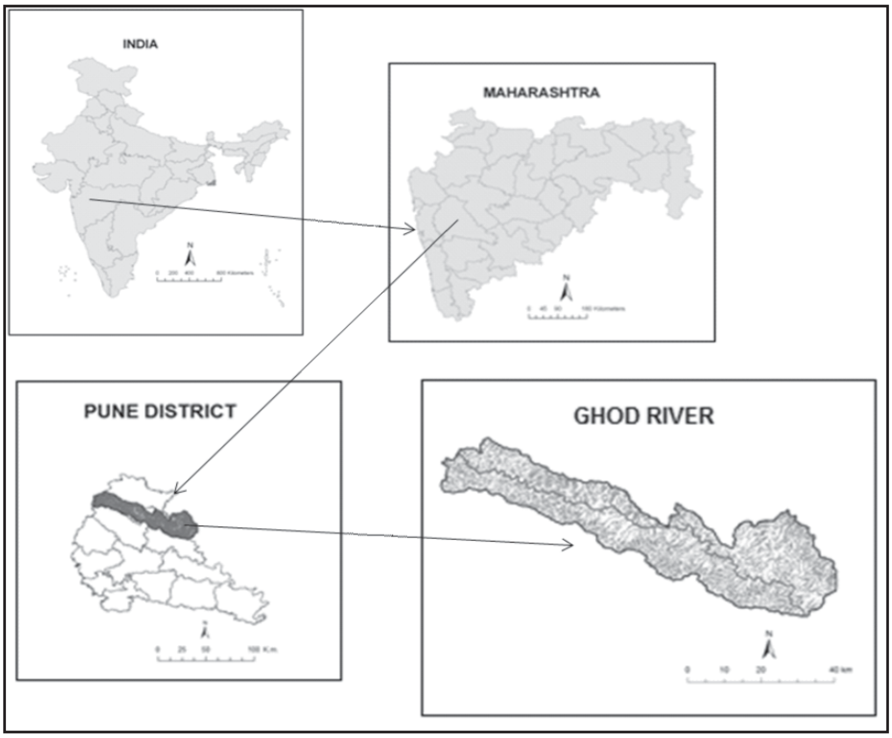


Fig. 1. Study Area

Methodology:
Universal Soil Loss Equation (USLE) has been used to estimate the annual soil loss in the Ghod river basin in Pune district. This equation has been developed to predict the average soil loss from sheet and rill erosion. The USLE is an empirical erosion model based on data sets from the U.S.A. (Wischmeier and Smith 1978).
The equation is as follows:

$$A = R * K * LS * C * P$$

Where, A is computed soil loss (t/ha/yr), R is the rainfall-runoff erosivity factor, K is the soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is the cover-management factor, and P the supporting practices factor. The parameters for USLE i.e. RKLSCP, have been derived from the various thematic layers.
For the present study, the rainfall data of 10 years obtained from IMD has been analysed to calculate

the erosivity (R) using model developed by Panigrahi et.al. (1996).

$$R = P\,[0.119 + 0.0873 \log 10\ (P / 24)]$$

$$R = P\,[0.119 + 0.0873 \log 10\ (P / 24)]\ (P / 24)$$

$$= P\,2\ (0.00364 \log 10\ P - 0.000062)$$

where, P is the daily rainfall

The spatial interpolation techniques in the ArcGIS software were used for preparation of rainfall erosivity map.

The K factor was derived by collecting soil samples for 15 sites which were well distributed in the study area covering most of the geomorphic units from ridge to valley and from source to mouth. Soil samples were collected from top 5 cm (2 inches) layer of soil. The samples were analyzed in the laboratory to find out soil texture (sand, slit, and clay composition), structure, permeability and organic matter content. The corresponding K values for the soil types were identified from the soil erodability nomograph (USDA 1978) by considering the particle size, organic matter content and permeability class.

The slope length and slope steepness (LS factor) was derived from the DEM (Digital elevation model). The slope maps were prepared in Arc GIS 9.3 and the LS factor was derived by the following equation:

If slope $\leq$ 21%,

$$LS = (L/72.6) * [65.4 * Sin(S) + 4.56 * Sin(S) + 0.065]$$

If slope >21%,

$$LS = (L/22.1)^{0.7} * [6.432 * Sin\ (S^{0.7}) * Cos\ (S)]$$

Where, L = Slope length in meters and S = Slope steepness in radians

C factor was derived from LULC classification of LISS III data. An analysis of the current land use based upon the imagery obtained on Nov, 2009 (Fig.5). Depending upon the LU/LC, C Factor values were assigned to all classes considering the literature based on Indian as well as international studies and the maps were obtained.

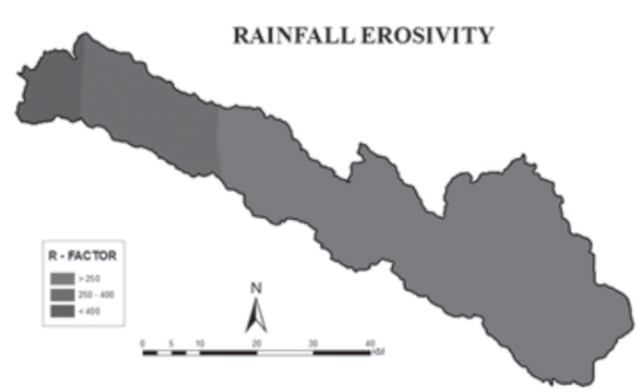


Fig. 2

The values for P factor were derived from the combination of the slope and land use. During the fieldwork, ground data were collected for different management and conservation practices opted in the study area were also used.

The computed raster layers of R,K,LS,C, and P factors were then integrated using the raster multiplication option in GIS for estimation of potential soil loss.

Results and Discussion:

Rainfall Erosivity:

Fig. 3.Erosion is a form of work, and work takes energy. The energy for water erosion comes from the energy of a falling raindrop or running water (Plaster 2003).The rainfall erosivity (R) describes the ability of rainfall to erode soil (Wischmeier and Smith, 1978). The energy of the falling raindrop depends on its size and speed. More the erosive energy, water can detach and move more and larger soil particles. The erosive energy of running water depends on its volume and speed of flow (Plaster 2003). Thus, erosive energy relates directly to the amount of soil carried off a field.

Ghod river has its source in the Western Ghats. The rainfall varies gradually over the space and time. The annual rainfall varies from more than 1000 mm in the western part and decreases to less than 400 mm in the eastern part. Decreasing rainfall amount from source to mouth is because of the rain-shadow effect of the Western Ghats on their eastward slopes. Erosivity values shows decreasing trend from west to east with variation of about 570 to 232 (Fig.2).

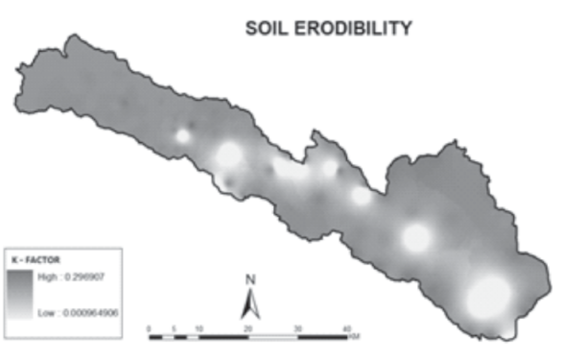


Fig. 3

Soil Erodibiliy:

Soil erodibiliy (K) refers to the inherent susceptibility of soils to erosion by rainwater and runoff and it is a function of complex interaction of physical and chemical properties of soils affecting detachability, transportability and infiltration capacity (Deore 2011). Soil erodibility depends upon the texture, structure and organic matter content. In the source region, erodibility is observed to be low to moderate which is because of the high proportion of coarse material, sand and organic matter and low to moderate proportion of erodible matter in the soil (fig. 3). In the mouth region low organic matter and clay amount along with high erodible fraction have led to moderate to high erodibility of soils.

Topographic factor (LS):

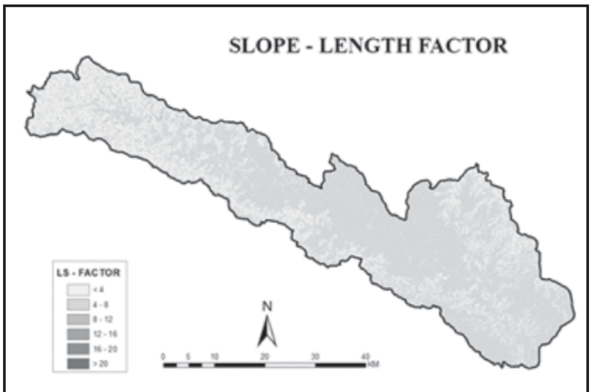


Fig. 4

Slope length may be defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition to begin, or the runoff water enters a well-defined channel (Smith and Wischmeier, 1957).

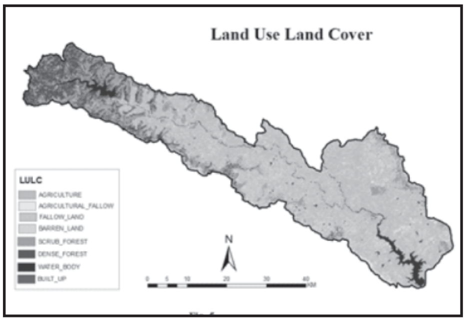
Soil erosion occurs in three stages detachment transport and deposition, where topography plays an important role.

Ghod river has its source in the Western Ghats. Elevation in the basin varies from 400 m in the east to 1192 m in the west. Erosion increases with increasing slope length.

C factor

The C factor is the crop cover which protects the soil from splash erosion. It was proposed by Wischmeier and Smith (1978) as the expected ratio of soil loss from land cropped under specified conditions to soil loss from clean tilled fallow on identical soil and slope and under the same rainfall. The canopy protection depends on the type of vegetation, the stand, and the quality of growth and it varies greatly according to season and days after sowing in case of crops (Deore 2011).

Class N ame	Area in Sq.Km	C FACTOR	P FACTOR
Agriculture	658.58	0.8	0.4
Fallow land	546.21	0.5	0.8
Barren land	153.22	0.5	0.9
Scrub forest	288.21	0.05	0.7
Water body	64.31	0.9	0.1
Dense forest	185.38	0.005	0.6
Built up	5.52	0.25	0.5
Agricultural	57.45	0.6	0.4
Total Area	1958.92		



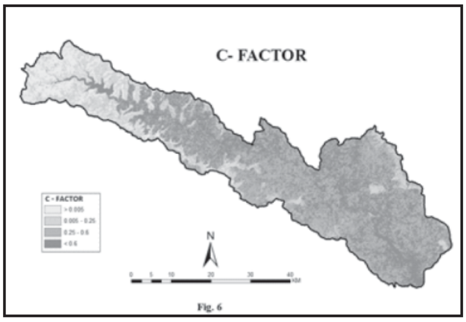


Fig. 6

Conservation factor (P): Different agricultural uses require different soil management practices. Various practices adopted in the area are contour bunding, graded bunding or contour terraces, strip cropping and bench terracing for agricultural lands and continuous contour trenching (CCT) structures, stone bunds and live bunds are observed on the sloping and/or forested areas.

The values of P-factor ranges from 0.1 to 0.9, in which the highest values are assigned to areas with no conservation practices like barren lands and fallow lands. The hill-slope areas with scrub with scrub forest are supported by Continuous Contour Trenching structures (CCTs) and at a very few sites by live bunds. Effect of CCT, live bunds and check-dams is reported mainly in reduction in runoff which in turn reduces transport of the particles, but not affect much splash erosion.

Soil Loss:

The soil loss depends upon the existing condition of the rainfall erosivity, soil erodibility, topographic factor, cover condition and management factor of the region. The estimated annual soil loss in the Ghod river basin ranges between 0 - 40 t/h/yr. Single factor is not dominating or controlling the process of soil erosion.

Severe soil loss is observed both in the valley as well as in ridge region of the Ghod basin. The upper basin portion is hilly and of high rainfall erosivity, however, presence of dense forest cover in that area has reduced the erosion rate (Fig. 8). The canopy of the trees intercepts the raindrop from directly reaching the ground. Thus the erosive energy of the raindrop is reduced which in turn reduces the detachment of the soil and slows down the runoff. Middle basin shows moderate to low soil loss though R is least influencing as rainfall decreases, and K is most influencing as silt and fine sand proportion in soils increases downstream. Conservation and support practices are very scantily noted throughout the basin.

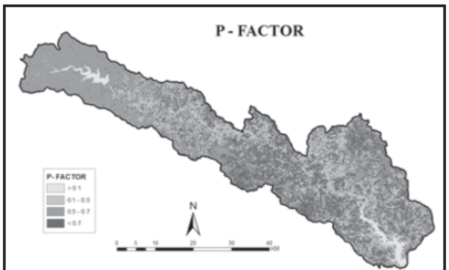


Fig. 7

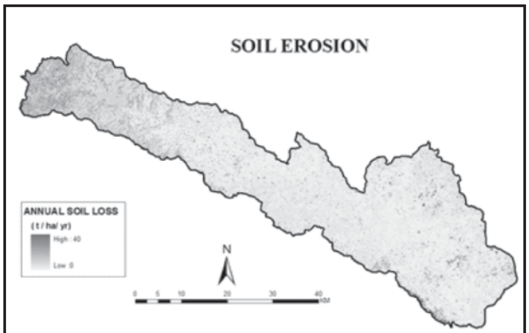


Fig. 8

The integration of remotely sensed data with GIS proved to be a very useful tool for modelling soil loss.

In USLE model the complex processes involved in soil erosion is worked out in a very simplified procedure. The accuracy of the predicted soil loss rates depend on how exactly the erosion parameters are described.

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