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Estimation of Soil Loss and Soil Erodibility for Different Crops, Nutrient Managements and Soil Series

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ABSTRACT

In present study the weather data of 81 years (1930-2010) of Indore was analyzed and studied. The rainfall data was used for calculating the soil loss under three cropping system (soybean, cereals and fruit plantation), three management practices (conventional tillage, ridge and furrow system and no tillage system) and four different slopes (0.5, 1≤ to <3, 1≤ to <3 and >5). Similarly, the soil erodibility was estimated for five different soil series viz. Sarol, Kamliakheri, Baloda, panchdheria, Malikheri and Jindakheri. The results of the present study revealed that soil loss decreased with decrease in slope. Similarly, the soil loss found higher under conventional tillage as compared to the ridge and furrow system and no tillage system. The soybean cropping found more vulnerable to the soil loss whereas the orchard system found most safe for soil erosion. The data on soil erodibility revealed that the Pancgheria and Malikheri soil series showed lowest whereas Sarol, Kamliakheri, Jindakheri and Baloda soil series showed the highest erodibility.

Keywords: *Soil erodibility, Soil loss, Soil erosion, Soil series, Soil management, Cropping system*

INTRODUCTION

Weather plays an important role in agricultural production. It has a profound influence on air quality (Aher et al., 2014), crop growth (Mandale et al., 2018), development (Lenka et al., 2017) and yields (Aher et al., 2015); on the incidence of pests and diseases (Argal et al., 2015); on water needs; and on fertilizer requirements (Mishra et al., 2014). This is due to differences in nutrient mobilization as a result of water stresses, as well as the timeliness and effectiveness of preventive measures and cultural operations with crops (Rajput et al., 2014). Weather aberrations may cause physical damage to crops and soil erosion. However, the organic matter present in the soil may prevent the soil erosion as seen under organic nutrient management (Aher et al., 2012). The organic nutrient management enhances the soil aggregation (Aher et al., 2019) through increased microbial properties of soil (Aher et al., 2018a).

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The quality of crop produce in the field under different nutrient management and fertilizer application (Yashona et al., 2018; Aher et al., 2018b) and also during movement from field to storage and transport to market depends on weather. Bad weather may affect the quality of produce during transport, and the viability and vigour of seeds and planting material during storage.

Vertisol and associated sols (black clay soils of varying depth) cover an area of about 76.4 m ha, constituting almost 22.2% of the total geographical area of India. The major portion of the soils lies in states of Maharashtra, Madhya Pradesh, Gujrat, Andhra Pradesh, Karnataka, where semi-arid to sub humid monsoonic conditions persist. Of total area under black soils in India about 22 m ha i.e. 28.8% area fall under high (>1000mm annual) rainfall mainly in the states of Maharashtra, Madhya Pradesh and Gujrat (Bhattacharyya et al., 2013). Soil and rain water are the two basic natural resources which determine the productivity of crops particularly under rainfed situations. The runoff from these soils can be as high as 40% and soil loss is as much as 60t/ha/annual. In the state of M.P. these soils are located in assured rainfall (more than 700mm) regions and occur on relatively flat to slopping lands (Kundu et al., 2015). Soil and water erosion is a serious problem in these soils under their present land use. These soils by and large are quiet susceptible to erosion as is evident from the presence of higher proportion of water dispersible clay. Steep land slop, high intensity of rains, poor infiltration rate of water, kharif fallowing and lack of adoption suitable conservation measures are some of the factors contributing runoff induced soil and nutrient erosion and related hazards. Although, these soils are potentially productive but soils and water erosion accompanied by substantial losses of essential plant nutrients are the serious problems even on flat topography, which often lead to poor and unstable productivity of arable crops. Hydrological studies conducted over a period of two decades on medium and deep black clay soils in central parts of India have clearly revealed that of the total annual precipitation, 21 to 54% on medium depth black soils (0.5 to 0.9 m depth) and 4 to 24 % on deep black clay soils (1m or more depth) is lost through runoff. Further depending on soil, environmental and management conditions, on an average 7 to 24 kg N, 0.02-0.80 kgP, 0.7-1.5 kg K and 3- 15 kg S per hectare per rainy season are lost from arable lands due to water runoff. Poor land and water management practices further aggravate the situation (Karthikeyan & Prasad, 2014). The soils of Malwa region are shallow to deep black with variable depth. The soils are generally in available, low to medium in P and high in K. the soils are highly erodible particularly when they are without plant cover. Considering these facts the present study was conducted to evaluate the soil loss and eodibility.

MATERIALS AND METHODS

Study area

The state of Madhya Pradesh occupies a total geographical area of 44.348 mha out of which 55.9% (24.804 m ha) is planted to crops. The state is predominantly rainfed farming state, as only, 29.5% of the net cultivable area (6.07mha) is irrigated. Madhya Pradesh enjoys sub-tropical climate with three distinct seasons viz. winter from December to February followed by summer season from March to May and rainy season extending from June to October. During winters, the mean minimum temperature is around 10°C and mean maximum is 25°C. In the winters, minimum temperature can go down to 1°C. During summers, the mean minimum temperature is 22°C and mean maximum temperature during summer can go up to 48°C, especially in May and June which are the hottest months. The climate is relatively moderate in the western districts such as Dhar, Indore, Barwani and Jhabua and in the Betul- Chhindawara region. Average annual rainfall in the state is 1160mm. Western districts including most of those in the Malwa plateau and Sheopur and Shivpuri in the north receive in 800-1000mm range. Most of the rainfall in the state is received from the south –west monsoon during June to September. Indore represents Malwa region is situated at 76°, 54'E longitude and 22°, 43'N latitude, at an altitude of 618m above MSL. It is bounded by Vindhyan ranges on the North West.

Soils of the region

Vertisol and associated sols (black clay soils of varying depth) cover the major portion of the state Madhya Pradesh. The runoff from these soils can be as high as 40% and soil loss is as much as 60t/ha/annual as semi-arid to sub humid monsoonic conditions and high rainfall (>1000mm annual) persists in the region. The soils are located in assured rainfall (more than 700mm) regions and occur on relatively flat to slopping lands. Soil and water erosion is a serious problem in these soils under their present land use. These soils by and large are quiet susceptible to erosion as is evident from the presence of higher proportion of water dispersible clay. Steep land slop, high intensity of rains, poor infiltration rate of water, kharif fallowing and lack of adoption suitable conservation measures are some of the factors contributing runoff induced soil and nutrient erosion and related hazards. The soils are generally having low to medium available N and P; and high K. The soils are highly erodible particularly when they are without plant cover. The infiltration rate of soils under water saturated condition is low (10-15mm/hr). Deep black soils belong to sarol and baloda series which comprise members of the fine montmorillonitic hyperthermic deep family of verticustochrepts and pellusterts respectively. Shallow soils belong to fine clayey montmorillonitic hyperthermic family of lithic ustochrepts. The major soil series of Indore districts as identified by NBSS&LUP are Sarol, Kamliakheri, Baloda, panchdheria, Malikheri and Jindakheri.

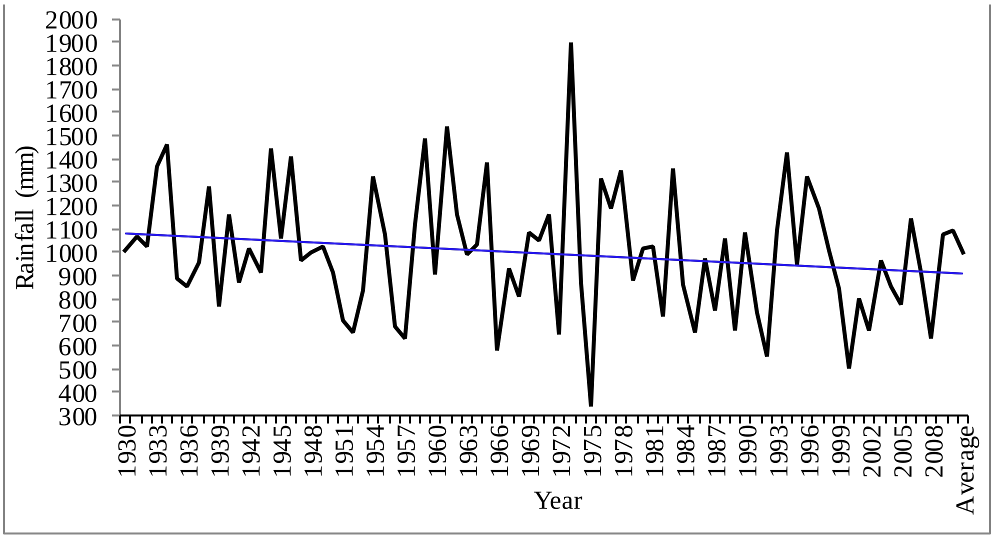

Fig. 1: Average annual rainfall in Indore during 1930 -2010

Meteorological data collection, processing and analysis

The daily meteorological data required for present study was obtained from recorded at Meteorological Observatory of College of Agriculture, Indore. The weather data of 81 years were obtained (1930-2010). The obtained data were subjected to various processing and bias correction. The obtained data was statistically analyzed to obtain distribution (Incomplete Gamma Distribution), probabilities (Markov chain probability), frequencies, mean, mode, median, kurtosis, skewness, standard deviation, and coefficient of variation for rainfall and temperature (Parmar et al., 2017). The annual average rainfall (Fig. 1), minimum temperature (Fig. 2) and maximum temperature (Fig. 3) have been derived from the raw data.

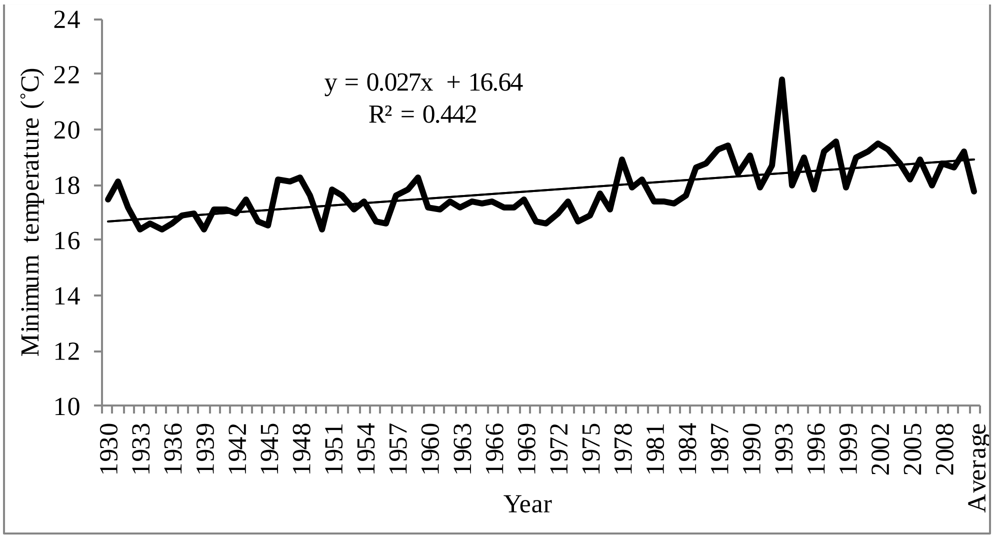

Fig. 2: Average annual minimum temperature in Indore during 1930 -2010

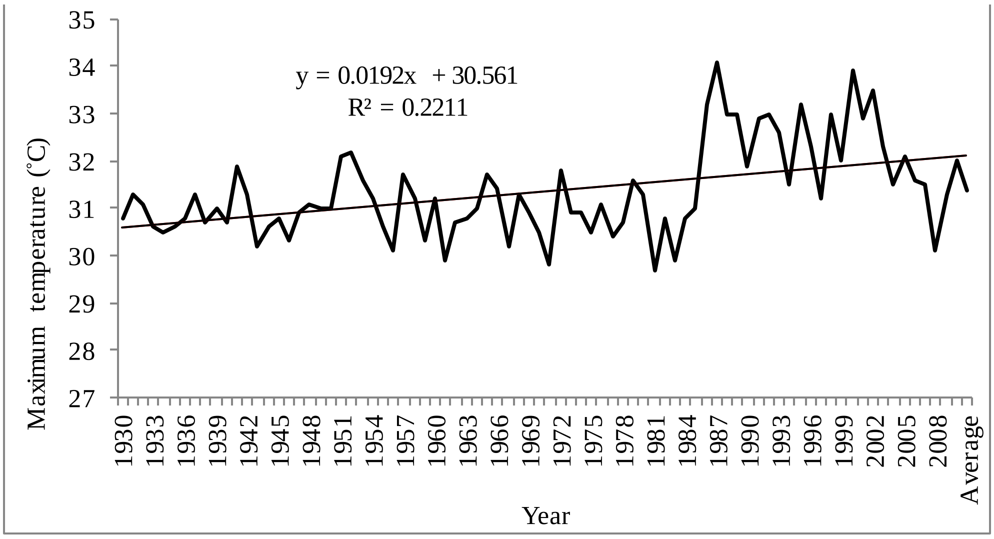

Fig. 3: Average annual maximum temperature in Indore during 1930 -2010

Determination of annual soil loss

The average annual soil loss (t/acre/year) as influenced by crop and tillage management was estimated using Universal Soil loss equation and EI_{30} and PI_{30} for Indore district. The Universal Soil Loss Equation (USLE) predicts the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system, and management practices Five major factors are used to calculate the soil loss for a given site. Each factor is the numerical estimate of a specific condition that affects the severity of soil erosion at a particular location. The erosion values reflected by these factors can vary considerably due to varying weather conditions. Therefore, the values obtained from the USLE more accurately represent long term-term averages. Universal Soil Loss equation used is as follows:

$$A = R \times K \times LS \times C \times P$$

Where,

A is the potential long term average annual soil loss in tons per acre per year;

R is the rainfall and runoff factor. The rainfall factor "R" in soil USLE defines the erosivity of rainfall which is the energy of raindrop that breaks soil aggregates and causes splesh scouring and transportation of soil particles. Wischmeier (1959) found that one hundredth fraction of the product of the kinetic energy of the rain storm and the 30 minutes intensity (I_{30}) is the most reliable single estimate of rainfall erosion potential (EI_{30}). This erosion index (EI_{30}) is rainfall factor "R" in USLW. The equation was utilized for the estimation of erosion index (EI_{30}) for Indore region as a numerical substitute for rainfall factor in USLE;

K is the soil erodibilty. K value is based on soil texture, structure, organic matter content etc. The K value used for the analysis was 0.24;

LS is the slope length –gradient factor. The equation used for estimating slope factor was;

$$LS = [0.065 + 0.0456(slope) + 0.006541(slope)^2 \times (slope\ length / const)^{NN}$$

Where,

Slope = slope steepness (%)

Slope Length (ft.),

Constant = 72.5

NN= 0.20 for < 1 % slope; 0.30 for slope 1≤ and < 3 % slope; 0.40 for 3≤ and < 5 and 0.50 for > 5% slope.

C is the crop type factor and tillage method factor for the crop grown. By multiplying these two factors together C factor can be obtained. The crop factors for soybean, cereals and fruit crops were 0.50, 0.35 and 0.10 and for tillage practices viz. conventional tillage, Ridge and furrow system and No-tillage were 1.0, 0.35 and 0.25.

P is the support practice factor. It reflects the effect of practices that will reduce the amount of amount and rate of water runoff and thus reduce the amount of erosion. The p factor used in this study was 0.75.

Estimation of Soil Erodibility

The Soil Erodibility of major soil series *viz.*, Sarol, Kamliakheri, Baloda, Panchdheria, Malikheri and Jindakheri of Indore district was estimated using following equation given by Atwoo and Heerasing (1997).

$$100K = 2.1 \times 10^{-4} \times (2\text{-}OM) \times M^{1.14} + 3.25 \times (St - 2) + 2.5 \times (Pt - 3)$$

Where,

K is the soil erodibility;

OM is the organic matter content (%);

M is the silt + sand content (%);

St is the Soil structure code (very fine granular =1; fine granular = 2; coarse granular = 3; blocky, platy or massive = 4);

Pt is the permeability class (rapid = 1; Moderate to rapid = 2; moderate = 3; slow to moderate = 4; slow = 5; very slow = 6).

The data of soil properties is used as given by Tomar et al. (1995) and NBSS&LUP publication on soil series of Madhya Pradesh (Tamgadge et al., 1999).

RESULTS AND DISCUSSION

Average annual soil loss (t/acre/year)

The soil loss estimated for three tillage systems created at different slopes and different crop covers when planted across the slope are presented in Table 1. It is evident from the data that the under soybean crop cover the maximum soil loss was estimated under conventional tillage at all the slopes, followed by Ridge and Furrow System of cultivation and lowest under No-till system. As the slope Increases the soil loss per year also increases. There was a tremendous reduction in soil loss was observed under No-tillage system as compared to conventional tillage system at all the slope percentage. Similar trend was also observed for cereal crops when planted with three tillage treatments at four slopes i.e. 0.5, 1≤ to < 3, 3 ≤ to < 5 and < 5. Under Fruit tree plantation also the soil loss was increased with increasing slope per cent. When we compare crops the soil loss was higher under soybean plantation followed by cereal crop plantation and minimum under tree plantation. Thus the results emphasized that by selecting proper crop and tillage operation the soil loss can be reduced tremendously. The estimation made for conventional tillage seems to be higher, which requires further verification on the basis of experiment to be carried out for evaluating soil loss under controlled conditions. The soil loss is the function of rainfall, slope, crop cover, tillage management and soil organic carbon content and the present study reflected the same results (Ramos et al., 2019; Ebabu et al., 2019; Yaekob et al., 2020).

Table 1: Average annual soil loss as influenced by crop and tillage management (t/acre/year)

Slope %	Tillage practices		
	Conventional tillage	Ridge & furrow System	No-Tillage
A: Soybean Crop			
0.5	14.59	2.85	0.45
1≤ to < 3	23.80	8.33	5.95
3 ≤ to < 5	29.43	10.30	7.36
> 5	36.38	12.73	9.10
B: Cereals			
0.5	10.22	1.99	0.31
1≤ to < 3	16.66	5.83	4.16
3 ≤ to < 5	20.60	7.21	5.15
> 5	25.47	8.91	6.37
C: Fruit Trees			
0.5	2.92	0.57	0.09
1≤ to < 3	4.76	1.67	1.19
3 ≤ to < 5	5.89	2.06	1.47
> 5	7.28	2.55	1.82

Estimated Soil Erodibility

The data of estimated soil erodibility are presented in Fig 2. The soil erodibilty for different soil series are ranged from 0.11 to o.o56. The lowest erodibility (0.056) was estimated for Pancgheria soil series followed by Malikheri (0.057), Baloda (0.10), and the highest estimated soil erodibility was for Sarol, Kamliakheri, Jindakheri soil series i.e. 0.11. Singh et al. (1981) reported the range of soil erodibility from 0.4 to 0.23 for soils of different textures. The calculated soil erodibility values are also within this range for soils of Indore district. Therefore it is suggested that the above equation may be used for estimating soil erodibility. Although most of the soils are clayey in nature, but are of different depths and organic matter content. Yashona et al. (2016) studied some adsorption properties of Sarol and Malikheri soil series with respect to the cadmium. The soil adsorption behavior also determines the erodibility. Therefore erodibility is also varying (Giovannini et al., 2001; Singh and Khera, 2008). Higher organic matter content reduces soil erodibility (Dutal & Reis, 2020).

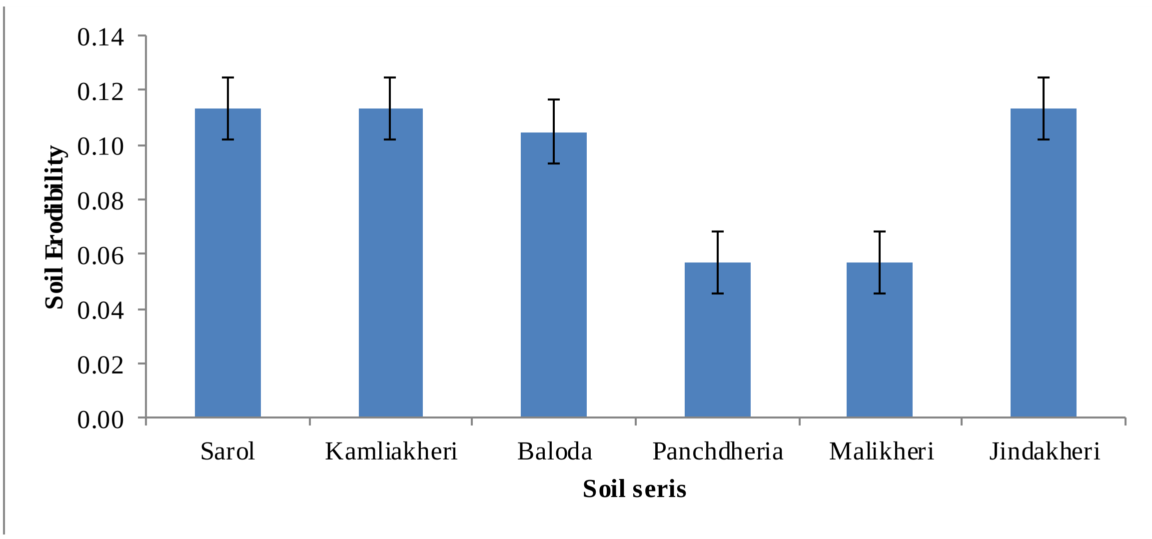

Fig. 4: Estimated Soil Erodibility for different soil series of Indore District

CONCLUSION

The study revealed that the soil loss for Indore district varied depending upon the slope, cropping system and tillage management. The orchard plantation found beneficial towards soil conservation followed by cereals. The regions with high slope are more vulnerable to higher magnitude of soil loss. The Pancgheria and Malikheri soil series showed lowest erodibility whereas Sarol, Kamliakheri, Jindakheri and Baloda soil series showed the highest estimated soil erodibility.

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