Effect of tillage management and soil slope on annual soil loss under cereal crops in central India

ABSTRACT

The negative impacts of soil erosion on productivity are mainly attributed to the decline in soil fertility and water availability. Continuous tillage practices combined with removal of crop residue from the soil surface greatly increase the risk of soil erosion and nutrient depletion. Soil erosion creates many adverse impacts on the environment and soil health which influence the food security and the quality of life. In present study the effect of three tillage management (conventional tillage, ridge and furrow system and no tillage system) and soil slopes (1%, >1% to < 3%, >3 to <5% and >5%) on soil loss in twelve different soil series under cereal cropping in central India has been studied. The results of the study indicated that the tillage management plays an important role to reduce soil loss. No tillage system found showed minimum annual soil loss whereas the conventional tillage practice recorded the most. The soil loss found decreased with decrease in slope and vice-versa. The Bararia soil series found most vulnerable to the soil loss whereas the Dhodar soil series found resistant to soil loss across the slopes and tillage management practices studied under cereal cropping in central India.

KEYWORDS: Tillage management, cereal cropping, soil erosion, soil slope, soil loss, Universal Soil Loss Equation

INTRODUCTION

The negative impacts of soil erosion on productivity are mainly attributed to the decline in soil fertility and water availability. Continuous tillage practices combined with removal of crop residue from the soil surface greatly increase the risk of soil erosion and nutrient depletion. Soil erosion creates many adverse impacts on the environment and soil health which influence the food security and the quality of life. Therefore, proper management of soil organic matter is important for sustaining the agricultural growth (Aher et al., 2019). The intensification of production and the loss of organic carbon associated with agriculture reduce the efficiency of production and the quality of the environment, especially in relation to areas exposed to erosion. No-till farming increases the amount of water that infiltrates into the soil, organic matter retention and cycling of nutrients (Mandale et al., 2019) and can reduce or eliminate soil erosion (Kurothe et al., 20014). Along with organic matter depletion, physical and climatic features of a catchment such as topographic conditions, land use land cover (LULC), rainfall intensity, and the soil characteristics are the key significant factors of the soil erosion (Yan et al., 2018). The loss of the top fertile soil nutrients is intensely increasing due to this natural phenomenon (Chuenchum et al., 2020). Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) are the most widely used soil loss estimation models (Bekele & Gemi, 2021). RUSLE uses an empirical equation and associates different physical and climatic features.

Geographical Information System (GIS) and the data retrieved from remote sensing (RS) technology are integrated in GIS platform to quantify the soil loss (Kayet et al., 2018).

Among the food grains, cereals contribute 77.5 per cent and pulses contribute 22.5 per cent in the central Indian state Madhya Pradesh. The main cereals are rice, wheat, maize, bajra, barley, jowar and small millets. Madhya Pradesh has about 5 per cent share in the country in the production of cereals, with its production of 83.7 lakh tones. The production of the cereals is increasing continuously in the state since 1951. It has recorded nearly four times increase between 1950-51 and 2002-03, from 21.3 lakh tons to 83.7 lakh tones during the period Wheat ranks first in terms of production (49.23 lakh tones, 59 %) which is also the main crop of Madhya Pradesh. Maize comes second (14.9 lakh tons, 17.8 % and rice third (10.32 lakh tons, 12.32 %) in terms of production. Other important cereals are jowar, barley and small millets, their production was about 9.24 lakh tones, and their share in the cereals was about 11 per cent, in the year 2002-03 (Mishra, 2020). In central India, wheat is the dominant crop in the winter (rabi) season (Aher et al., 2022). Beside this, rice, maize, bajra, barley, jowar and small millets are also predominant crops in this region. However, these are erosion- permitting crops. The soils of Madhya Pradesh suggested that crop covers proved effective in controlling runoff and soil loss in the region (Lakaria et al. 2012). The scientific evidences related to the effect of tillage management and soil slopes on soil loss for different soil series under cereal cropping in vertisols of Central India are lacking. Considering the research gaps, present investigation was carried out to study the soil loss for different soil series, tillage management and slopes under cereal cropping in central India.

MATERIALS AND METHODS

Study site

The state of Madhya Pradesh occupies a total geographical area of 44.348 mha out of which 55.9% (24.804 mha) 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^{o}C and mean maximum is 25^{o}C. In the winters, minimum temperature can go down to 1^{o}C. During summers, the mean minimum temperature is 22^{o}C and mean maximum temperature during summer can go up to 48^{o}C, especially in May and June which are the hottest months. 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.

Vertisol and associated soils (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 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 major soil series of of the region as identified by NBSS&LUP are Kheri, Bararia, Junapania, Namali, Dhamaniya Diwan, Dhodar, Surajpura, Paroliya, Ratangarh, Khermaliya, Morwan and Hathipura. In present study the soil loss was estimated for these soil series considering three tillage managements viz., conventional tillage, ridge and furrow system and no tillage system under soybean crop. The soil loss for four different sloes viz., 1%, >1% to < 3%, >3 to <5% and >5% under these soil series and management practices has been studied.

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 EI30 and PI30 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 (I30) is the most reliable single estimate of rainfall erosion potential (EI30). This erosion index (EI30) is rainfall factor “R” in USLW. The equation was utilized for the estimation of erosion index (EI30) 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 × (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.

RESULTS AND DISCUSSION

Annual soil loss for various soil series at different soil slopes

The annual soil loss from different soil series in central India at four different slopes is presented in Table 1. At 1% Slope, >1% to <3% slope, >3% to <5% slope and at >5% slope the annual soil loss under different soil series ranged 0.250-1.021 t acre-1 y-1, 0.578-2.366 t acre-1 y-1, 0.998-4.084 t acre-1 y-1 and 1.239-5.070 t acre-1 y-1, respectively. The highest and lowest annual soil loss was recorded under the Bararia and Dhodar soil series across all soil slopes, respectively. Thus, the Bararia soil series under cereal cultivation is the most vulnerable soil series with respect to the soil loss whereas the Dhodar soil series is the safest soil series to carry cereal cultivation.

Table 1. Annual soil loss for various soil series under different soil slopes

Soil Series	Soil slope			
	1% slope	>1% to <3% slope	>3% to <5% slope	>5% slope
Kheri	0.641	1.569	2.709	3.363
Bararia	1.021	2.366	4.084	5.070
Junapania	0.663	1.535	2.650	3.289
Namali	0.338	0.784	1.353	1.679
Dhamaniya Diwan	0.402	0.932	1.609	1.997
Dhodar	0.250	0.578	0.998	1.239
Surajpura	0.324	0.751	1.297	1.610
Paroliya	0.467	1.083	1.869	2.320
Ratangarh	0.607	1.406	2.428	3.014
Khermaliya	0.520	1.205	2.081	2.583
Morwan	0.602	1.394	2.407	2.988
Hathipura	0.545	1.262	2.178	2.704

Annual soil loss for various soil series under different tillage managements

The effect of tillage management on annual soil loss from different soil series under cereal crop cultivation is depicted in Table 2. Under conventional tillage, the annual soil loss ranged 2.510-3.474 t acre-1 y-1 and higher soil loss was observed under Ratangarh soil series followed by Khermaliya soil series (3.473 t acre-1 y-1). In ridge and furrow management the lowest and highest soil loss was found under Namali soil series (0.879 t acre-1 y-1) and Ratangarh soil series (1.216 t acre-1 y-1), respectively. Further, under no tillage management, the soil loss ranged 0.628-0.869 t acre-1 y-1. It is evident from the data that, Namali soil series is the best series for cereal cultivation to minimize the soil loss.

Table 2. Annual soil loss for various soil series and tillage managements

Soil Series	Tillage management

	Conventional Tillage	Ridge & Furrow System	No-Tillage
Kheri	2.942	1.030	0.735
Bararia	2.869	1.004	0.717
Junapania	2.619	0.917	0.655
Namali	2.510	0.879	0.628
Dhamaniya Diwan	2.566	0.898	0.642
Dhodar	2.604	0.911	0.651
Surajpura	2.860	1.001	0.715
Paroliya	3.220	1.127	0.805
Ratangarh	3.474	1.216	0.869
Khermaliya	3.473	1.215	0.868
Morwan	3.432	1.201	0.858
Hathipura	3.319	1.162	0.830

Annual soil loss under different tillage managements at different soil slopes

The interactive effect of soil slope and tillage management is presented in Table 3. The data clearly indicated that irrespective of the tillage management, the soil loss increases with increase in slope. However, the quantum of loss is found minimum under No-tillage system. The No-tillage system showed minimum soil loss as compared to conventional and ridge and furrow system across all soil slopes studied. Thus, the no tillage system counters soil loss against increasing soil slope when compared with the rest two management systems under cereal cropping.

Table 3. Annual soil loss for various tillage managements at different slopes

Tillage management	Soil slope			
	1% slope	>1% to <3% slope	>3% to <5% slope	>5% slope
Conventional Tillage	0.997	2.323	4.010	4.978
Ridge & Furrow System	0.349	0.813	1.403	1.742
No-Tillage	0.249	0.581	1.002	1.244

Soil loss in different soil series

The soil loss under different soil series across tillage management and slopes is presented in Fig. 1(A). The soil loss under different soil series across tillage management and slopes ranged 0.766-3.135 t acre^{-1} y^{-1}. The results indicated that the Bararia soil series (3.135±2.800 t acre^{-1} y^{-1}) found most vulnerable to the soil loss whereas the Dhodar soil series (0.766±0.684 t acre^{-1} y^{-1}) found resistant to soil loss across tillage managements and slopes under cereal cropping in central India.

Effect of tillage management on soil loss

The soil loss under different tillage managements across soil series and slopes is presented in Fig. 1(B). The soil loss under different tillage managements across soil series and slopes ranged 0.769-3.077 t acre^{-1} y^{-1} under cereal crops. The tillage managements followed following order Conventional tillage > Ridge and furrow tillage > No tillage. The results indicated that the conventional tillage (3.077±2.011 t acre^{-1} y^{-1}) found most vulnerable to the soil loss whereas the No tillage management (0.769±1.613 t acre^{-1} y^{-1}) found resistant to soil loss across soil series and slopes under cereal cropping in central India.

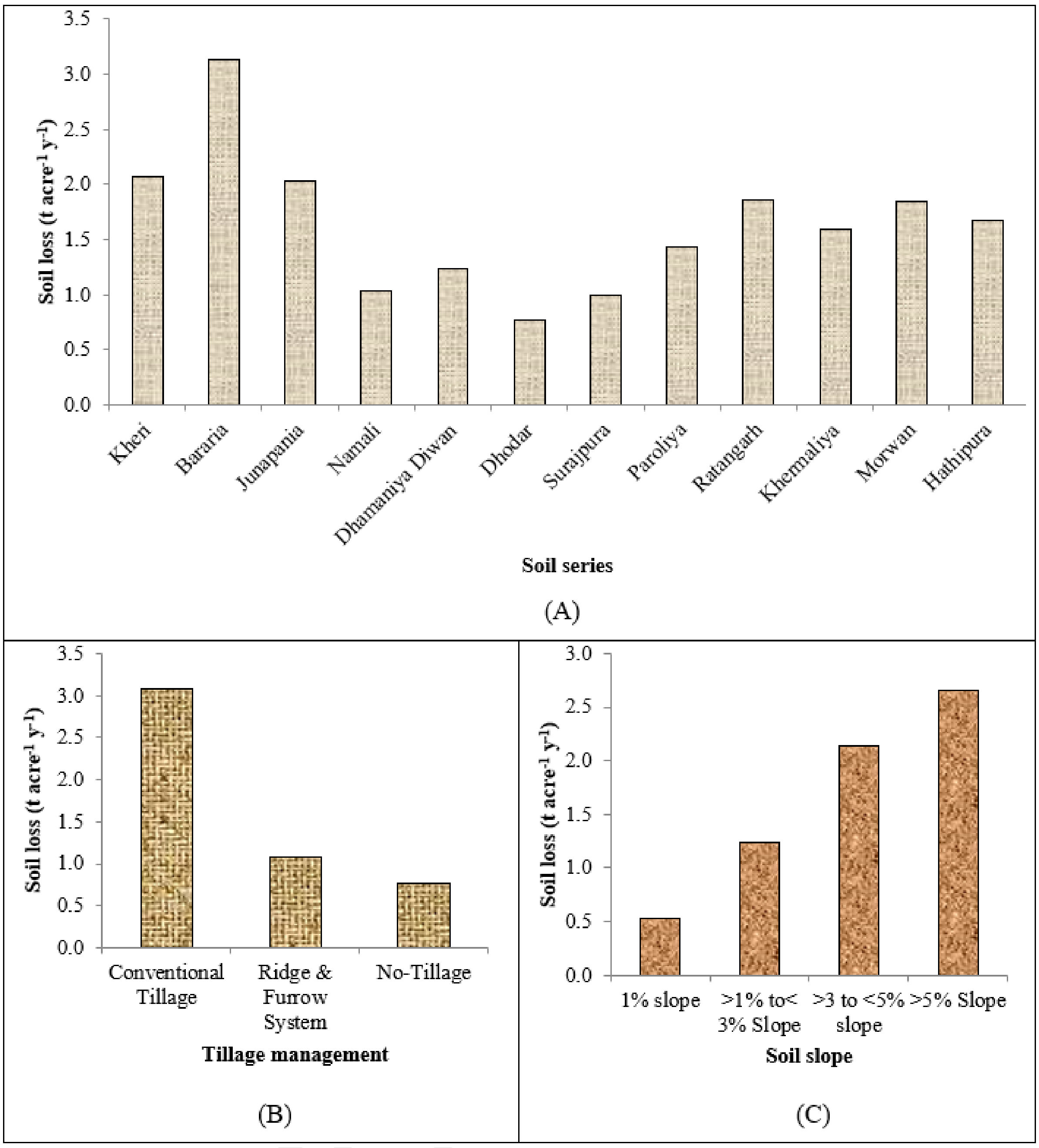

Fig 1. Annual soil loss under cereal cropping in central India (A-Soil series; B-Tillage managements; C-Soil slopes)

Effect of soil slopes on soil loss

The soil loss under different slopes across tillage managements and soil series is presented in Fig. 1(C). The soil loss under different slopes across tillage managements and soil series ranged 0.532-2.655 t acre^{-1} y^{-1}. The results indicated that the slope >5% (2.655±0.321 t acre^{-1} y^{-1}) found most vulnerable to the soil loss whereas the slope <1% (0.532±0.410 t acre^{-1} y^{-1}) found resistant to soil loss across soil series and tillage management under cereal cropping in central India.

It is evident from the data that, under cereal crops 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. Thus, the results emphasized that by selecting proper tillage operation for soybean crop, the soil loss can be reduced tremendously. 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). Parmar and Sharma (2020) also reported higher soil loss under higher slopes and under conventional tillage management as compared to the lower slope and no tillage system in central India. The results of Kurothe et al. (2014), Mahapatra et al. (2018), Suryawanshi et al. (2021) and Singh et al. (2023) are in good agreement with the present findings.

CONCLUSION

The tillage management plays an important role to reduce soil loss. No tillage system showed minimum annual soil loss whereas the conventional tillage practice recorded the most. The soil loss found decreased with decrease in slope and vice-versa. The Bararia soil series found most vulnerable to the soil loss whereas the Dhodar soil series found resistant to soil loss across the slopes and tillage management practices studied under cereal cropping in central India.

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