ESTIMATION OF SOIL LOSS FOR DIFFERENT SOIL SERIES, TILLAGE MANAGEMENT AND SLOPES UNDER SOYBEAN CROPPING IN MALWA AGRO-CLIMATIC ZONE

ABSTRACT

The soil erosion can cause the reduction in agricultural productivity, ecosystem disturbances, and pollution of water. Physical and climatic features of a catchment such as topographic conditions, land use land cover, rainfall intensity, and the soil characteristics are the key significant factors of the soil erosion. The loss of the top fertile soil nutrients is intensely increasing. In present study soil loss for 12 soil series viz., Kheri, Bararia, Junapania, Namali, Dhamaniya Diwan, Dhodar, Surajpura, Paroliya, Ratangarh, Khermaliya, Morwan and Hathipura and 3 different tillage management viz., conventional tillage, ridge and furrow system and no tillage system under soybean crop in Malwa Agro-climatic Zone in central India has been estimated. 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. The results of the study revealed that soil loss found decreased with decrease in slope and vice-versa. Similarly, the soil loss found higher under conventional tillage (4.134 t $acre^{-1}$ y^{-1}) as compared to the ridge and furrow system (1.447 t $acre^{-1}$ y^{-1}) and no tillage system (1.033 t $acre^{-1}$ y^{-1}). The Bararia soil series (4.196 t $acre^{-1}$ y^{-1}) found most vulnerable to the soil loss whereas the Dhodar soil series (1.036 t $acre^{-1}$ y^{-1}) found resistant to soil loss under soybean cropping in Malwa Agro-climatic Zone.

KEYWORDS: Soil loss, Malwa Agro-climatic Zone, soil series, soybean, topography, slope

INTRODUCTION

A growing realization of agriculture can only be sustained through the more efficient and effective use of natural resources. Land and water are the two basic natural resources and therefore, an understanding of climate, the most basic natural resource for agriculture, is fundamental for better natural resource management (Shivakoti et al., 2019). Despite green revolution, the agricultural scenario of the state is still heavily dependent on annual rainfall and rainfall distribution. So, studying rainfall and its variability and change pattern is becoming important for agriculture production management. The information about rainfall amount, probability of occurrence of different amount of rainfall in different weeks of rainy season, probability of occurrence of dry spells, temperature change pattern etc. would be of great use for planning better resource management because the cropping pattern of any region is solely governed by both rainfall and temperature distributions (Krishna Kumar et al., 2004; Kumar et al., 2010).

The soil erosion can cause the reduction in agricultural productivity, ecosystem disturbances, and pollution of water (Bhattacharyya et al., 2015). 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). Researchers have been searching for effective tools and methods to quantify the total annual soil loss in a given catchment. 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).

In central India, soybean is the dominant crop in the rainy (kharif) season (Aher et al., 2019). Beside this, maize and pigeon peas are also predominant crops in this region. However, these are erosion- permitting crops and must be grown in combinations with erosion-resistant crops preferably leguminous crops, which help in attaining quick and thick canopy cover to reduce the soil and nutrient losses at the times of high-intensity rainfall. Red soils of Bundelkhand region of Madhya Pradesh suggested that crop covers proved effective in controlling runoff and soil loss in the region (Lakaria et al. 2012). Yet, limited information is available on soil loss under different vegetative covers in vertisols of Central India. The scientific evidences related to the soil loss for different soil series, tillage management and slopes under soybean cropping in Malwa Agro-climatic Zone. Considering these facts, an attempt has been made to estimate the soil loss for different soil series, tillage management and slopes under soybean 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

Soil loss under different soil series, tillage management and slopes

The estimated annual soil loss for various soil series under different tillage management at 1% slope under soybean cropping in Malwa Agro-climatic Zone is presented in Table 1. The data showed that the annual soil loss ranged 0.226-0.617 t acre-1 y-1 for conventional tillage and 0.079-0.216 t acre-1 y-1 for ridge and furrow tillage management. Similarly the soil loss ranged 0.056-0.154 t acre-1 y-1 for no tillage system. The mean soil loss across tillage management ranged 0.120-0.329 t acre-1 y-1 for various soil series under study. The minimum and maximum soil loss under conventional tillage, ridge and furrow tillage management; and no tillage was recorded for Dhodar series (0.226 t acre-1 y-1, 0.079 t acre-1 y-1 and 0.056 t acre-1 y-1) and Bararia series (0.617 t acre-1 y-1, 0.216 t acre-1 y-1 and 0.154 t acre-1 y-1), respectively. The results indicated that the Bararia soil series (0.329±0.251 t acre^{-1} y^{-1}) found most vulnerable to the soil loss whereas the Dhodar soil series (0.120±0.092 t acre^{-1} y^{-1}) found resistant to soil loss at 1% slope under soybean cropping in Malwa Agro-climatic Zone.

Table 1. Annual soil loss for various soil series and tillage managements under soybean cropping in Malwa Agro-climatic Zone (1% slope)

Soil Series	Conventional Tillage	Ridge & Furrow System	No-Tillage	Mean	SD (±)
Kheri	0.580	0.203	0.145	0.309	0.236
Bararia	0.617	0.216	0.154	0.329	0.251
Junapania	0.599	0.210	0.150	0.319	0.244
Namali	0.306	0.107	0.076	0.163	0.124
Dhamaniya Diwan	0.243	0.085	0.061	0.130	0.099
Dhodar	0.226	0.079	0.056	0.120	0.092
Surajpura	0.246	0.086	0.062	0.131	0.100
Paroliya	0.355	0.124	0.089	0.189	0.144
Ratangarh	0.367	0.128	0.092	0.196	0.149
Khermaliya	0.314	0.110	0.079	0.168	0.128
Morwan	0.364	0.127	0.091	0.194	0.148
Hathipura	0.329	0.115	0.082	0.176	0.134
Mean	0.379	0.133	0.095		
SD (±)	0.141	0.049	0.035		

The estimated annual soil loss for various soil series under different tillage management at >1% to <3% slope under soybean cropping in Malwa Agro-climatic Zone is presented in Table 2. The data showed that the annual soil loss ranged 1.549-6.336 t acre-1 y-1 for conventional tillage and 0.542-2.218 t acre-1 y-1 for ridge and furrow tillage management. Similarly the soil loss ranged 0.387-1.584 t acre-1 y-1 for no tillage system. The mean soil loss across tillage management ranged 0.826-3.379 t acre-1 y-1 for various soil series under study. The minimum and maximum soil loss under conventional tillage, ridge and furrow tillage management; and no tillage was recorded for Dhodar series (1.549 t acre-1 y-1, 0.542 t acre-1 y-1 and 0.387 t acre-1 y-1) and Bararia series (6.336 t acre-1 y-1, 2.218 t acre-1 y-1 and 1.584 t acre-1 y-1), respectively. The results indicated that the Bararia soil series (3.379±2.580 t acre^{-1} y^{-1}) found most vulnerable to the soil loss whereas the Dhodar soil series (0.826±0.631 t acre^{-1} y^{-1}) found resistant to soil loss at >1% to <3% slope under soybean cropping in Malwa Agro-climatic Zone (Table 2).

Table 2. Annual soil loss for various soil series and tillage managements under soybean cropping in Malwa Agro-climatic Zone (**>1% to < 3% Slope)**

Soil Series	Conventional Tillage	Ridge & Furrow System	No-Tillage	Mean	SD (±)
Kheri	4.203	1.471	1.051	2.242	1.712
Bararia	6.336	2.218	1.584	3.379	2.580
Junapania	4.111	1.439	1.028	2.193	1.674
Namali	2.099	0.735	0.525	1.120	0.855
Dhamaniya Diwan	2.497	0.874	0.624	1.331	1.017
Dhodar	1.549	0.542	0.387	0.826	0.631
Surajpura	2.013	0.704	0.503	1.073	0.820
Paroliya	2.900	1.015	0.725	1.546	1.181
Ratangarh	3.767	1.319	0.942	2.009	1.534
Khermaliya	3.228	1.130	0.807	1.722	1.315
Morwan	3.734	1.307	0.934	1.992	1.521
Hathipura	3.380	1.183	0.845	1.803	1.376
Mean	3.318	1.161	0.830		
SD (±)	1.282	0.449	0.321		

The estimated annual soil loss for various soil series under different tillage management at >3% to <5% slope under soybean cropping in Malwa Agro-climatic Zone is presented in Table 3.

Table 3. Annual soil loss for various soil series and tillage managements under soybean cropping in Malwa Agro-climatic Zone (**>3% to <5% Slope)**

Soil Series	Conventional Tillage	Ridge & Furrow System	No-Tillage	Mean	SD (±)
Kheri	7.256	2.540	1.814	3.870	2.955
Bararia	10.938	3.828	2.735	5.834	4.454
Junapania	7.097	2.484	1.774	3.785	2.890
Namali	3.624	1.268	0.906	1.933	1.476
Dhamaniya Diwan	4.310	1.508	1.077	2.299	1.755
Dhodar	2.674	0.936	0.668	1.426	1.089
Surajpura	3.474	1.216	0.869	1.853	1.415
Paroliya	5.006	1.752	1.251	2.670	2.038
Ratangarh	6.503	2.276	1.626	3.468	2.648
Khermaliya	5.573	1.951	1.393	2.972	2.270
Morwan	6.447	2.256	1.612	3.438	2.625
Hathipura	5.835	2.042	1.459	3.112	2.376
Mean	5.728	2.005	1.432		
SD (±)	2.213	0.775	0.553		

The data showed that the annual soil loss ranged 2.674-10.938 t acre-1 y-1 for conventional tillage and 0.936-3.828 t acre-1 y-1 for ridge and furrow tillage management. Similarly the soil loss ranged 0.668-2.735 t acre-1 y-1 for no tillage system. The mean soil loss across tillage management ranged 1.426-5.834 t acre-1 y-1 for various soil series under study. The minimum and maximum soil loss under conventional tillage, ridge and furrow tillage management; and no tillage was recorded for Dhodar series (2.674 t acre-1 y-1, 0.936 t acre-1 y-1 and 0.668 t acre-1 y-1) and Bararia series (10.938 t acre-1 y-1, 3.828 t acre-1 y-1 and 2.735 t acre-1 y-1), respectively. The results indicated that the Bararia soil series (5.834±4.454 t acre^{-1} y^{-1}) found most vulnerable to the soil loss whereas the Dhodar soil series (1.426±1.089 t acre^{-1} y^{-1}) found resistant to soil loss at >3% to <5% slope under soybean cropping in Malwa Agro-climatic Zone (Table 3).

The estimated annual soil loss for various soil series under different tillage management at >5% slope under soybean cropping in Malwa Agro-climatic Zone is presented in Table 4. The data showed that the annual soil loss ranged 3.319-13.579 t acre-1 y-1 for conventional tillage and 1.162-4.753 t acre-1 y-1 for ridge and furrow tillage management. Similarly the soil loss ranged 0.830-3.395 t acre-1 y-1 for no tillage system. The mean soil loss across tillage management ranged 1.770-7.742 t acre-1 y-1 for various soil series under study. The minimum and maximum soil loss under conventional tillage, ridge and furrow tillage management; and no tillage was recorded for Dhodar series (3.319 t acre-1 y-1, 1.162 t acre-1 y-1 and 0.830 t acre-1 y-1) and Bararia series (13.579 t acre-1 y-1, 4.753 t acre-1 y-1 and 3.395 t acre-1 y-1), respectively. The results indicated that the Bararia soil series (7.742±5.530 t $acre^{-1}$ y^{-1}) found most vulnerable to the soil loss whereas the Dhodar soil series (1.770±1.352 t $acre^{-1}$ y^{-1}) found resistant to soil loss at >5% slope under soybean cropping in Malwa Agro-climatic Zone (Table 4).

Table 4. Annual soil loss for various soil series and tillage managements under soybean cropping in Malwa Agro-climatic Zone (**>5% Slope)**

Soil Series	Conventional Tillage	Ridge & Furrow System	No-Tillage	Mean	SD (±)
Kheri	9.008	3.153	2.252	4.804	3.668
Bararia	13.579	4.753	3.395	7.242	5.530
Junapania	8.811	3.084	2.203	4.699	3.588
Namali	4.498	1.575	1.125	2.399	1.832
Dhamaniya Diwan	5.350	1.873	1.338	2.853	2.179
Dhodar	3.319	1.162	0.830	1.770	1.352
Surajpura	4.313	1.510	1.078	2.300	1.756
Paroliya	6.214	2.175	1.554	3.314	2.531
Ratangarh	8.073	2.826	2.018	4.306	3.288
Khermaliya	6.919	2.422	1.730	3.690	2.817
Morwan	8.003	2.801	2.001	4.268	3.259
Hathipura	7.244	2.535	1.811	3.863	2.950
Mean	7.111	2.489	1.778		
SD (±)	2.747	0.962	0.687		

Soil loss under different soil series across tillage management and slopes

The soil loss under different soil series across tillage management and slopes is presented in Fig. 1. The soil loss under different soil series across tillage management and slopes ranged 1.036-4.196 t $acre^{-1}$ y^{-1}. The soil series followed following order with respect to the mean soil loss across tillage management and slopes:

Bararia > Kheri > Junapania > Ratangarh > Morwan > Hathipura > Khermaliya > Paroliya > Dhamaniya Diwan > Namali > Surajpura > Dhodar

The results indicated that the Bararia soil series (4.196 t $acre^{-1}$ y^{-1}) found most vulnerable to the soil loss whereas the Dhodar soil series (1.036 t $acre^{-1}$ y^{-1}) found resistant to soil loss across tillage managements and slopes under soybean cropping in Malwa Agro-climatic Zone (Fig. 1).

Soil loss under various tillage managements across soil series and slopes

The soil loss under different tillage managements across soil series and slopes is presented in Fig. 2. The soil loss under different tillage managements across soil series and slopes ranged 1.033-4.134 t $acre^{-1}$ y^{-1}. The tillage managements followed following order with respect to the mean soil loss across soil series and slopes:

Conventional tillage > Ridge and furrow tillage > No tillage

The results indicated that the conventional tillage (4.134 t $acre^{-1}$ y^{-1}) found most vulnerable to the soil loss whereas the No tillage management (1.033 t $acre^{-1}$ y^{-1}) found resistant to soil loss across soil series and slopes under soybean cropping in Malwa Agro-climatic Zone (Fig. 2).

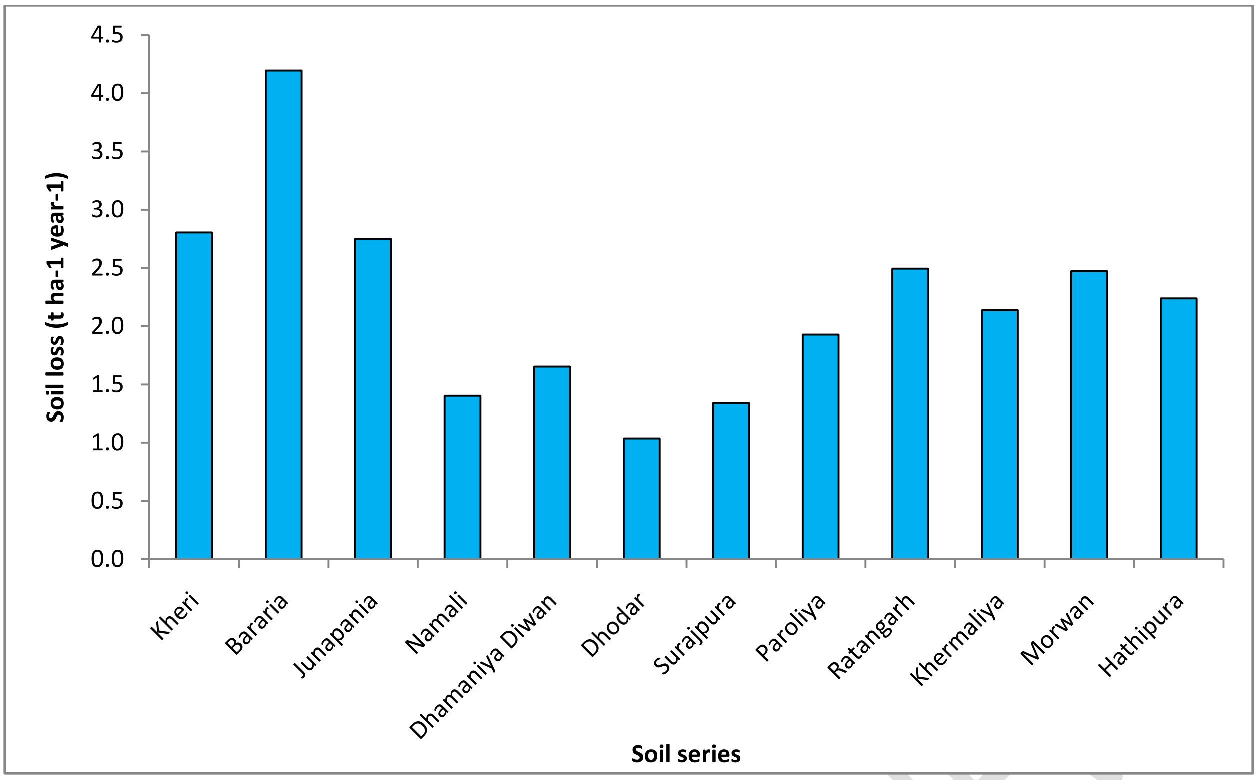

Figure 1. Annual soil loss for various soil series under soybean cropping in Malwa Agro-climatic Zone

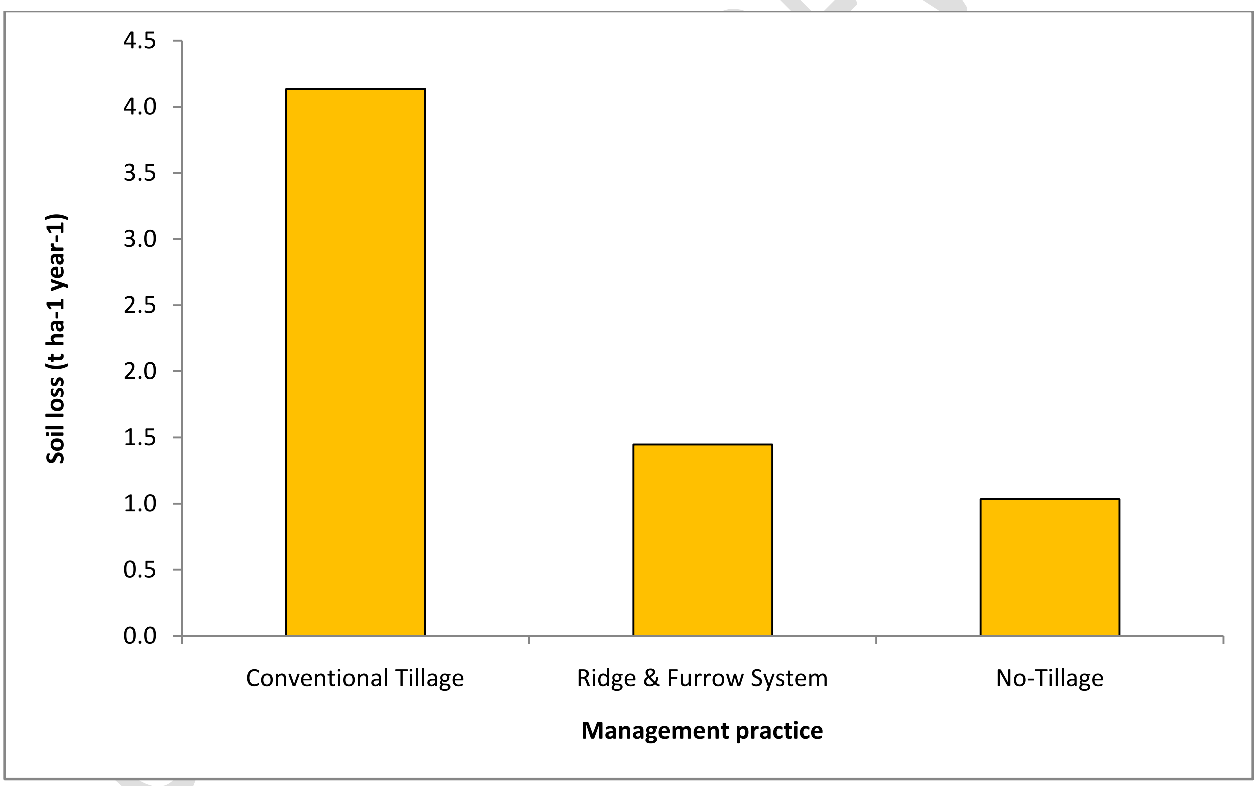

Figure 2. Annual soil loss for various tillage management under soybean cropping in Malwa Agro-climatic Zone

Soil loss under various slopes across soil series and tillage management

The soil loss under different slopes across tillage managements and soil series is presented in Fig. 3. The soil loss under different slopes across tillage managements and soil series ranged 0.202-3.792 t acre^{-1} y^{-1}. The soil slopes followed following order with respect to the mean soil loss across soil series and tillage managements:

(>5% slope) > (>3% to <5% slope) > (>1% to <3% slope) > (1% slope)

The results indicated that the conventional tillage (4.134 t acre^{-1} y^{-1}) found most vulnerable to the soil loss whereas the No tillage management (1.033 t acre^{-1} y^{-1}) found resistant to soil loss across soil series and slopes under soybean cropping in Malwa Agro-climatic Zone (Fig. 2).

It is evident from the data that, 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.

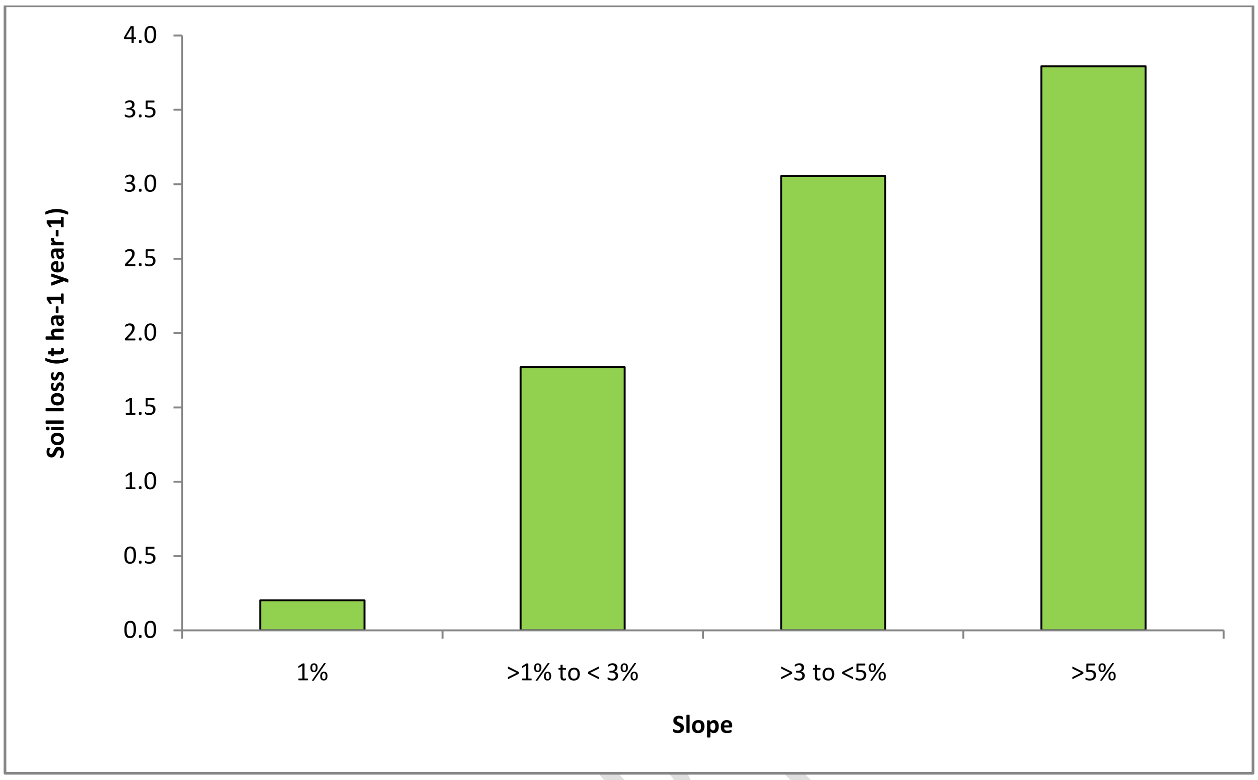

Figure 3. Annual soil loss for various slopes under soybean cropping in Malwa Agro-climatic Zone

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 study revealed that soil loss found decreased with decrease in slope and vice-versa. Similarly, the soil loss found higher under conventional tillage (4.134 t acre^{-1} y^{-1}) as compared to the ridge and furrow system (1.447 t acre^{-1} y^{-1}) and no tillage system (1.033 t acre^{-1} y^{-1}). The Bararia soil series (4.196 t acre^{-1} y^{-1}) found most vulnerable to the soil loss whereas the Dhodar soil series (1.036 t acre^{-1} y^{-1}) found resistant to soil loss under soybean cropping in Malwa Agro-climatic Zone.

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