

Original Research Article

<https://doi.org/10.20546/ijcmas.2019.806.167>

Effect of Tillage Practices on Runoff, Soil Loss, and Nutrient Loss

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ABSTRACT

Keywords

Rainfed, Farming, Runoff, Soil loss, etc.

Article Info

Accepted:

12 May 2019

Available Online:

10 June 2019

Agriculture is the cornerstone of Indian economy and a major part of agriculture in India is rainfed. The uncertainty and uneven distribution of rainfall and loss of water through runoff, which leads to low and unstable productivity of crops due to moisture stress in critical stages of crop growth. So it becomes essential to adopt in situ soil moisture conservation measures for sustainable crop production in rain fed agriculture. There are several soil and water conservation measures for reduction of runoff and soil loss such as contour farming, contour and graded bunding etc. Conservation tillage is one of the most important practices for improving the soil properties and reducing both runoff and soil loss. Tillage creates soil environment favorable for plant growth. Since continuous soil tillage strongly influence the soil properties, it is important to apply appropriate tillage practices that avoid the degradation of soil structure, maintain crop yield.

Introduction

Soil and water are the two important resources on which the well-being of human race as a whole depends. It is therefore, essential to conserve and use judiciously the above resources for higher yields.

Minimizing the risk factor through in-situ moisture conservation, adoption of suitable crops and their varieties are, therefore, vital for the success of rainfed agriculture. Soil and water conservation measures are predominantly applied for the following purposes, to control runoff and thus prevent loss of soil by soil erosion, to reduce soil compaction, to maintain or to improve soil

fertility, to conserve or drain water, to harvest (excess) water.

Conservation tillage is one of the most important practices for improving the soil properties and reducing both runoff and soil loss. Tillage creates soil environment favorable for plant growth. Soil tillage is one of the fundamental agro technical operations in agriculture because of its influence on soil properties (physical, chemical and biological), environment and crop growth. Since continuous soil tillage strongly influence the soil properties, it is important to apply appropriate tillage practices that avoid the degradation of soil structure, maintain crop yield as well as ecosystem stability.

Materials and Methods

Sorghum (*Sorghum bicolor*) was sown in rainy season i.e. 26th June 2013 at 45 cm spacing. The crop was harvested after 117 days i.e. on 20th October 2013. Experiment was conducted with 4 treatments viz. T₁ - Cultivation along the slopes, T₂ - Cultivation across the slope, T₃ - Cultivation across the slope with subsurface tillage and T₄ - Cultivation across the slope with alternate furrow with subsurface tillage. In treatment T₁ cultivation was done along the main slope of experimental field and in treatment T₂ cultivation was done across the main slope.

In treatment T₃ cultivation across slope with a subsurface tillage at a depth ranging from 45 to 55 cm (Vertical interval) was done 15 days before sowing. Tractor drawn subsoiler was used for tillage practice (Fig. 1). In T₄ treatment in addition to subsurface tillage of 45 to 55 cm depth alternate furrows were also opened at 30 days after sowing at a horizontal interval of 90 cm (Table 1).

Rainfall

Recording type rain gauge was installed in the observatory located at the watershed and daily rainfall was recorded.

Maximum precipitation (P) for particular time period, such as 5,10,15,30 and 60 minutes for each rainfall event was observed and noted as P₅, P₁₀, P₁₅, P₃₀ and P₆₀ in terms of cm.

Determination of rainfall intensity and kinetic energy

Out of different rainfall characteristics, rainfall intensity is far the most important one. Rainfall intensity is defined as rate of fall of rainfall, expressed as rate of fall of rainfall, expressed as depth per unit time i.e. mm hr⁻¹ or cm hr⁻¹.

$$\text{Rainfall Intensity (RI)} = \frac{\text{Rainfall Depth}}{\text{Time Interval}}$$

Kinetic energy is assumed as the force, by which an individual water droplet strikes over the soil surface. The force or kinetic energy of individual drop is related to its size and intensity. The kinetic energy and intensity of rainfall are related by the following equation, given by Wischmier and Smith (1958),

$$\text{K.E} = 210.3 + 89 \log_{10} I$$

Where,

K.E = kinetic energy of rainfall (Mt ha⁻¹cm⁻¹ of rain)

I = Rainfall intensity (cm hr⁻¹)

Runoff

The runoff from each plot concentrated at the outlet of runoff plot was measured by H-flume of 0.30m depth installed as a runoff measuring device.

The float type automatic stage level recorder was installed at the outlet of each gauging site and H-flume of 0.30m depth.

The runoff chart obtained from Stage Level Recorder gives a continuous record of depth of flow over the flume with respect to time.

This stage graph will subsequently be processed to obtain the runoff rates and Peak rate of runoff volumes which will later be used for further analysis.

Runoff depth

Usually runoff is expressed in terms of depth over the producing area. To obtain the depth of runoff; volume of runoff will be divided by area over which it would produce.

Peak runoff rate

The Peak Runoff rate will be obtained by observing the maximum values of runoff rate recorded and will be further divided by total area of watershed, to get the peak runoff rate in lps/ha

Percentage surface runoff

By observing the values of rainfall and runoff; runoff occurred as a percentage of rainfall will be computed.

$$\text{Percentage surface runoff} = \frac{\text{runoff}}{\text{rainfall}} \times 100$$

Soil loss

The soil samples from the runoff were collected during the season. The soil loss estimation from the runoff was made by adopting the following procedure:

During each storm the runoff samples were collected manually. Stirred 100ml of runoff water each from individual sample were taken into aluminum box. The weight of dry soil from 100ml runoff water was determined by weighing. The soil loss in total runoff volume was expressed in $t\ ha^{-1}$.

Nutrient loss

Amount of nutrients loss due to the soil loss during the storm is analyzed by the chemical analysis of soil loss samples collected from field.

Results and Discussion

Distribution of precipitation index (PI)

Maximum rainfall (P) for a particular time interval and its intensity (I) were calculated by analyzing daily rain gauge charts. In the

same way P and I were determined for each rainfall event occurred. Precipitation index (PI) is the function of total rainfall and maximum intensity for the particular duration and termed as PI₅, PI₁₀, PI₁₅, PI₃₀ and PI₆₀ (Table 2). Data reveals that maximum PI₅ is recorded in the month of September while PI₁₀, PI₁₅, PI₃₀ PI₆₀ were observed maximum in the month of June.

Runoff

The observations for surface runoff for different runoff producing storms and surface runoff values as the percentage of total rainfall causing runoff event were recorded and presented in Table 3(a). During the kharif season total rainfall was 774.1 mm and the total rainfall depth caused for the occurrences of runoff was 214.70mm.

Four runoff events were occurred in cultivation along the slopes (T₁), cultivation across the slope (T₂) and cultivation across the slope with subsurface tillage (T₃) and three runoff events were occurred for cultivation across the slope with alternate furrow with subsurface tillage (T₄). From Table 3(a), it is evident that maximum surface runoff for the season is 31.87 mm in treatment T₁, while minimum is in T₄. Even higher crop canopy was there, maximum runoff was recorded in October, it may be due to the high intensity of rainfall received for a short duration of time.

It is also clear that out of all treatments cultivation across the slope with alternate furrow with subsurface tillage (T₄) recorded least runoff followed by cultivation across the slope with subsurface tillage (T₃).

There is a decreasing tend of runoff from T₁ to T₄. In treatment T₂ there was 10.89 percent reduction in surface runoff over T₁, while 96.93 percent reduction in runoff was

achieved in T₄. Table 3(b) shows the peak runoff rate in each runoff event. It indicates a decreasing trend from treatment T₁ (cultivation along the slopes) to treatment T₄ (cultivation across the slope with alternate furrow with subsurface tillage) in each runoff event. Rainfall intensity and its duration affects peak runoff rate significantly. For high intensity short duration rainfall events, peak runoff

rates will be more. In case of 26th July rainfall received is very less compared to all other runoff events. But due to the high intensity of rainfall (i.e. 7.5 mm and 8.5 mm rainfall for 5 min duration each) and less crop canopy peak runoff rates are more. The percentage reduction in peak runoff rates in T₄, T₃ and T₂ are 94.86, 89.67 and 85.36 percent respectively over T₁.

Fig.1 Treatment wise runoff depth (mm)

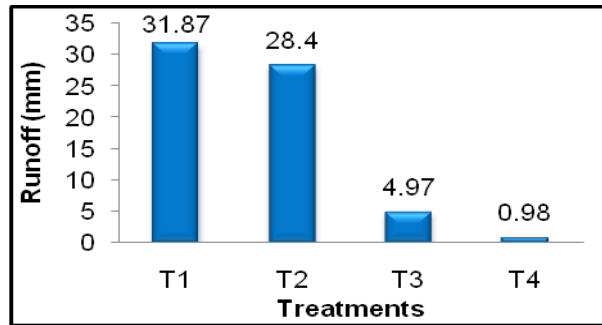


Fig.2 Treatment wise soil loss

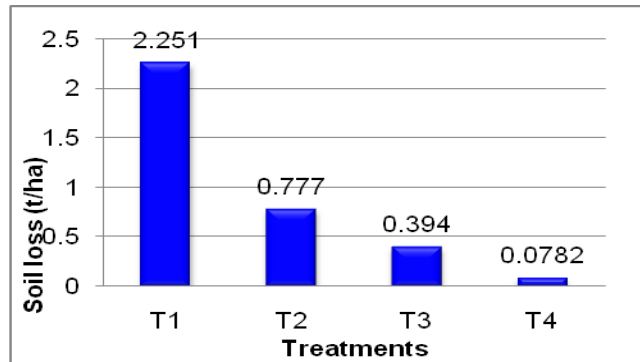


Fig.3 Treatment wise nutrient loss

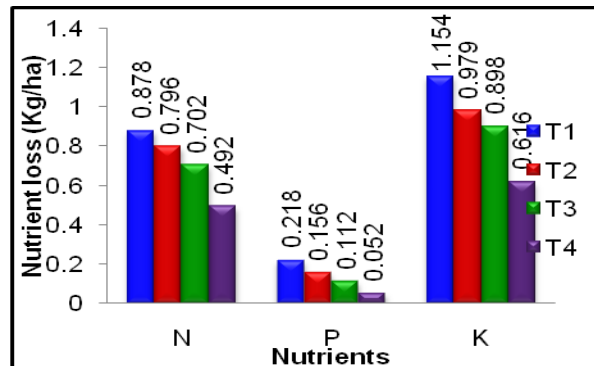


Table.1 Treatment details

Sr. No.	Treatment	Description of treatment	Size (m x m)	Area (ha)
1	T ₁	Cultivation along the slopes	100 x 10	0.10
2	T ₂	Cultivation across the slope	129 x 28	0.36
3	T ₃	Cultivation across the slope with subsurface tillage	100 x 10	0.10
4	T ₄	Cultivation across the slope with alternate furrow with subsurface tillage	100 x 10	0.10

Table.2 Monthly precipitation index for 5,10,15,30 and 60 minutes during the year 2013-2014

Months	Rainfall (mm)	PI ₅	PI ₁₀	PI ₁₅	PI ₃₀	PI ₆₀
June	248.4	22.50	23.92	29.79	20.83	14.41
July	229.6	11.65	13.71	16.50	17.36	13.58
August	138.8	3.13	5.01	5.24	3.07	2.18
Sept.	157.3	28.32	18.97	19.30	14.50	9.19
Seasonal total	774.1	65.65	61.61	69.84	55.76	39.36
October	76.8	7.76	4.92	5.28	4.10	3.21
Feb. 14	20.0	7.98	6.60	4.90	2.87	2.98
March 14	23.1	0.29	0.53	0.82	0.78	0.57
Total	119.9	15.03	12.05	11.00	7.75	6.76
G. Total	894.0	80.68	76.66	80.84	63.51	46.12

Table.3 (a) Effect of tillage practices on surface runoff (mm)

Date	Rainfall causing runoff (mm)	Runoff (mm)				Runoff (%)			
		T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄
26/07/2013	29.50	3.92	3.74	0.79	0.10	13.29	12.68	2.68	0.34
01/08/2013	68.40	7.56	6.68	1.31	-	11.05	9.77	1.92	-
22/09/2013	59.00	5.17	3.17	0.73	0.51	8.76	5.37	1.24	0.86
04/10/2013	57.80	15.22	14.81	2.14	0.37	26.33	25.62	3.70	0.64
Total	214.70	31.87	28.40	4.97	0.98	59.44	53.44	9.53	1.84
Reduction over T ₁ (%)		-	10.09	83.96	96.90	-	10.09	83.96	96.90

Table.3 (b) Effect of tillage practices on peak runoff rate

Date	Rainfall causing runoff (mm)	Peak runoff rate(lps ha ⁻¹)			
		T ₁	T ₂	T ₃	T ₄
26/07/2013	29.5	8.7	0.39	0.31	0.18
01/08/2013	68.4	7.36	0.88	0.56	-
22/09/2013	59.0	0.77	0.65	0.48	0.39
04/10/2013	57.8	1.27	0.73	0.52	0.36
Total	214.7	18.1	2.65	1.87	0.93
Reduction over T1 (%)		-	85.36	89.67	94.86

Table.4 Effect of different tillage practices on soil loss (t ha⁻¹)

Date	Rainfall causing runoff (mm)	Soil loss (t/ha)			
		T ₁	T ₂	T ₃	T ₄
26/07/2013	29.50	0.196	0.113	0.0079	0.0072
01/08/2013	68.40	0.378	0.235	0.227	-
22/09/2013	59.00	0.155	0.095	0.074	0.044
04/10/2013	57.80	1.522	0.334	0.085	0.027
Total	214.70	2.251	0.777	0.394	0.0782
Reduction over T₁ (%)		-	65.48	82.50	96.53

Table.5 Effect of tillage practices on nutrient loss (Kg ha⁻¹)

Date	Rainfall causing runoff (mm)	T ₁			T ₂			T ₃			T ₄		
		N	P	K	N	P	K	N	P	K	N	P	K
26/07/2013	29.50	0.198	0.048	0.278	0.182	0.032	0.262	0.162	0.028	0.242	0.148	0.022	0.21
01/08/2013	68.40	0.212	0.058	0.290	0.196	0.042	0.235	0.152	0.032	0.214	-	-	-
22/09/2013	59.00	0.158	0.048	0.276	0.148	0.030	0.230	0.132	0.020	0.210	0.112	0.012	0.196
04/10/2013	57.80	0.310	0.064	0.310	0.270	0.052	0.252	0.256	0.032	0.232	0.232	0.018	0.21
Total	214.70	0.878	0.218	1.154	0.796	0.156	0.979	0.702	0.112	0.898	0.492	0.052	0.616
Reduction over T₁ (%)		-	-	-	9.34	28.44	15.16	20.05	48.62	22.18	43.96	76.15	46.62

Soil loss

Soil loss was estimated by frequent sampling during runoff events. Soil loss computed for different treatment is presented in table 4. The seasonal soil loss from different treatments showed a similar trend that observed in runoff. From Table 4; it is clear that the maximum soil loss was in treatment T₁ i.e. cultivation along slope (2.251t ha⁻¹), where as in T₄ i.e. cultivation across the slope with alternate furrow with subsurface tillage it was minimum (0.0782 t ha⁻¹). Treatment wise soil loss is graphically shown in Figure 2.

Among the four treatments, cultivation across the slope with alternate furrow with subsurface tillage (T₄) is found to be most effective in reducing soil loss i.e. it reduced 96.53 percent of total soil loss over cultivation along the slope (T₁). A similar trend of low magnitude in soil loss reduction was observed for cultivation across the slope with subsurface tillage (T₃) and cultivation across the slope (T₂). This is due to the effect of tillage practices applied to the field. It maintains the infiltration rate, reduces the velocity of flowing water and soil particles got longer period to settle on the ground surface. From the discussion related to the treatment wise rainfall, runoff and soil loss for the kharif season 2013-2014, reflected the superiority of cultivation across slope with alternate furrow with subsurface tillage of *in situ* soil and water conservation.

Nutrient loss

During each runoff event a certain amount of nutrients such as Nitrogen (N), Phosphorous (P) and Potassium (K) are also lost. The total amount of nutrient loss for each treatment is illustrated in Figure 3. It reveals that there is a decreasing tendency in nutrient loss as the effectiveness of cultivation practices increases, which is similar as in the case of

surface runoff and soil loss. Treatment wise details nutrient loss occurred in each storm is tabulated in Table 5. It was observed that in treatment T₂ (cultivation across slope) Nitrogen (N) loss reduced from 0.878 Kg ha⁻¹ to 0.796 Kg ha⁻¹ (i.e. 9.34 percent over T₁), while in treatment T₃ (cultivation across the slope with subsurface tillage) it was reduced up to 0.702 Kg ha⁻¹ (i.e. 20.05 percent over T₁). In treatment T₄ (cultivation across the slope with alternate furrow with subsurface tillage) it was reduced up to 0.492 Kg ha⁻¹ (43.96 percent over T₁). Same trend was observed for Phosphorous (P) and Potassium (K). It is clearly visible that T₄ (cultivation across the slope with alternate furrow with subsurface tillage) retains more soil nutrients than others, which is followed by T₃.

In conclusion, cultivation across the slope with alternate furrow with subsurface tillage (T₄) and Cultivation across the slope with subsurface tillage (T₃) followed by Cultivation across the slope (T₂) over treatment cultivation along the slope (T₁), were seen effective in reducing runoff, soil loss and nutrient loss.

Cultivation across the slope with alternate furrow with subsurface tillage (T₄) reduced the peak discharge rate and cumulative runoff over treatments T₃, T₂ and treatment T₁.

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How to cite this article:

Pundlik, A.D. and Tathod, D.V. 2019. Effect of Tillage Practices on Runoff, Soil Loss, and Nutrient Loss. *Int.J.Curr.Microbiol.App.Sci.* 8(06): 1381-1389.

doi: <https://doi.org/10.20546/ijcmas.2019.806.167>