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Exploring Optimum Management Practices in Rainfed Areas to Reduce Soil erosion and Nutrient Losses

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ABSTRACT

The global sustainability of agroecosystems is severely hindered by soil erosion. Globally, agricultural production and the sustainability of natural ecosystems are at risk from soil erosion due to heavy rainfall, posing a severe threat to environmental conservation. Diverse nutrients, transferred along with sediments during detachment and transport by water, affect soil fertility and productivity. The effects of management practices and nutrient losses on soil erosion have remained undefined. A field experiment was conducted at University Research Farm, Koont Chakwal Road in the Pothwar Plateau, during the monsoon season from mid-July to mid-September, 2019 in which fallow-based cropping systems used in conservation tillage systems were compared to double cropping and green manuring systems. ***There were eight treatments and three replications with a split-plot arrangement design. The 900 m^2 plot having 3% slope was split into two major plots for the tillage treatments: conventional tillage and reduced tillage. Each main plot was then divided into four subplots for the summer crops: (i) fallow, (ii) soybean, (iii) maize fodder, and (iv) sesbania green manure. A plastic drum was installed at the bottom of each sub plot to collect runoff and sediment. The amount of sediment, nutrient concentration, and soil organic matter was collected and measured in runoff water. In contrast to cropped plots, the results showed that fallow plots had a higher rate of runoff water. Maize fodder and sesbania were among the cropping systems with the lowest sediment losses. Reduced tillage (chisel) showed less sediment loss than mouldboard plough. Overall, nutrient losses varied between crops and tillage systems. However, there was no significant difference in organic matter loss between tillage systems, but there was significant difference among crop systems with fallow plots showing the highest and maize plots having the lowest organic matter loss in different rainfall events. In conclusion, reduced tillage (chisel plough) in combination with summer crops, specifically maize fodder, can considerably reduce water erosion and soil losses in the Pothwar region.*

Key words: Runoff, erosion, sediment, nutrient loss, sustainability, agroecosystem

INTRODUCTION

Water-induced soil erosion is a major factor in global land degradation and productivity losses (Fang *et al.* 2017; Prosdocimi *et al.* 2017). Moderate to severe water erosion processes affect 751 million hectares of land worldwide. The layer of topsoil particles may become detached or redistributed, a result which could have a negative effect downstream (Dai *et al.* 2018). Water and sediments transported by water erosion contain nutrients lost from the soil such as nitrogen and phosphorus, which are considered the main nutrients causing eutrophication (Xu *et al.* 2013). Runoff and erosion responses differ under different soil management practices. Studies mostly focus on the effects of different management practices on runoff generation and erosion processes such as conservation tillage (Hösl and Strauss 2016), tied ridges (Ngetich *et al.* 2014), mulching (Grum *et al.* 2017) and hedgerow systems (Xia *et al.* 2013).

In Pakistan, water erosion of soil is a severe problem, considerably affecting rainfed agriculture. Country wide, 76% of total land mass is affected by erosion, of which 36% is affected by water erosion. In rainfed areas, the main causes of erosion are inappropriate land use, abandoned grazing, illicit tree cutting, and associated vegetation (Baig, Shahid, and Straquadine 2013) Reduced tillage, no-tillage, cover crops, and other sustainable land management (SLM) strategies have the potential to minimise organic carbon (OC) and nutrient losses from soil resulting from erosion (Martnez-Mena *et al.* 2020). For various types of soils and crops, it has been discovered that incorporating green manure into the soil improves the soil's hydraulic qualities by boosting macro-porosity and hydraulic conductivity (Haruna *et al.* 2018). The features and dynamics of many semi-arid plant communities are impacted by soil erosion, which may ultimately limit the land's ability to generate a variety of commodities and services. Ground cover of 20–30% is often the most effective way to mitigate water erosion, reducing erosion across a variety of soil types and land uses by 80–90% (Freebairn *et al.* 2009). Inadequate crop growth, excessive animal grazing on rangeland and loss of forest plant cover are the causes of severe soil degradation in rainfed environments (Irshad *et al.* 2007).

The 5.49 Mha Pothwar plateau has an irregular topography and is dependent on rainfall, 60–70% of which occurs from June to August. Due to the area's low precipitation and insufficient water supply, it is unsuitable for continuous farming. Nearly 50% of rainwater is lost as runoff in rainfed areas, which is one of the biggest challenges of the Pothwar region, along with soil erosion and decreased soil fertility (Anjum *et al.* 2010). Water erosion is a significant issue in the Pothwar region. Utilisation of stone walls, stubble mulching, cover crops, grass strips, field borders, and filter strips can minimise overflow by improving infiltration (Ali *et al.* 2018) while soil moisture can be conserved by the use of an intensive tillage system. Limited studies have been carried out to measure the effects of conservation tillage on soil erosion. Hence, this study was carried out to compare, conservation tillage systems with conventional tillage practices with each having a fallow-based cropping system compared with double cropping and green manuring. This research was based on the following objectives i.e., to compare soil, water and nutrient loss under reduced tillage and conventional tillage systems and to determine soil erosion under different summer crops compared with optimum management practices.

MATERIALS AND METHODS

Study Site

The field experiment was carried out at University Research Farm, Koont Chakwal Road in the Pothwar Plateau region. Climatically, this research field of Koont research station Chakwal, PMAS-Arid Agriculture University, Rawalpindi has a semi-arid to sub humid, sub-tropical continental climate and is located between 33° 1' N to 33° 6' N and longitude 73° 30' to 73° 45' E, Southeast of Rawalpindi. The bimodal rainfall occurs in late summer and winter season. Generally, about 60-70% of the rainfall is received in the monsoon season (15- June to 15- September). However, winter rainfall occurs as gentle showers of longer duration, and is therefore more productive for agriculture. The soil texture at the experimental site was sandy clay loam (56% sand, 22.8% silt, 21.2% clay) with a pH of 7.7.

Experimental Design

The field experiment was conducted in the monsoon season that occurs from July to mid-September 2019 with a split-plot design having tillage practices in main plots and summer crops in sub-plots. The experiment consisted of eight treatments with three replications. The treatment was arranged on total plot size of 900 m^2 with 3% slope, divided into two main plots for tillage treatments: (i) conventional tillage and (ii) reduced tillage. Each main plot was further divided into four subplots for summer crops: (i) fallow, (ii) soybean, (iii) maize fodder, and (iv) sesbania green manure. Sub-plot size was 35m^2. Seeds were sown at a rate of 1kg per plot. For sediments and runoff collection, a plastic drum was installed at the lower end of each sub-plot (Figure 1).

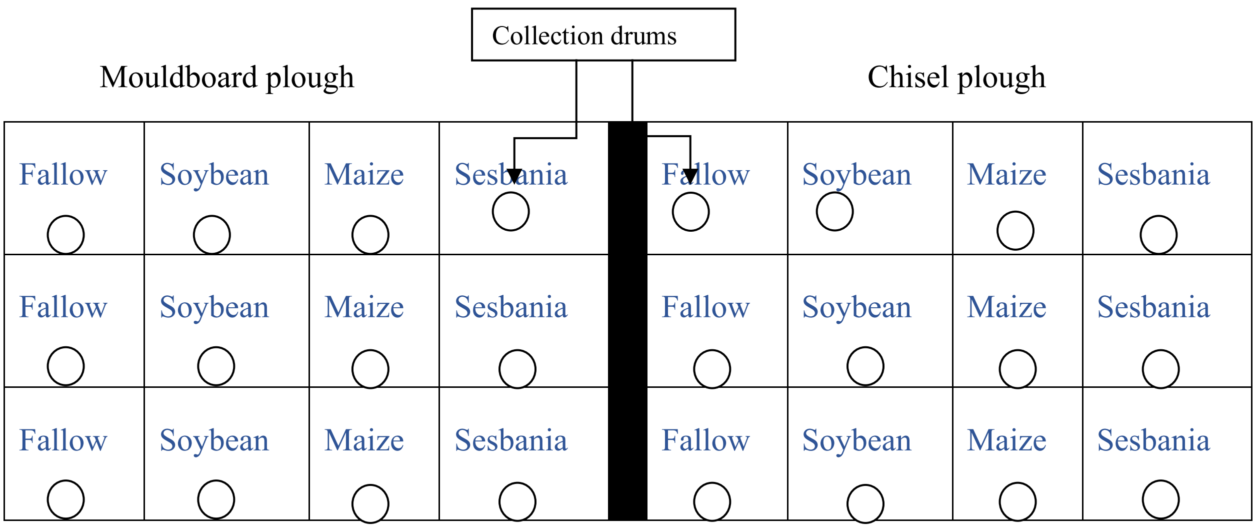

Figure 1. Schematic diagram of experimental layout and installation of containers

A pit (3 ft. vertical by1.5 ft. horizontal) was dug at the end of sub plots and collection drums were fixed for collection of runoff water. Soil around the pit was pressed and sealed for direct entry of runoff water. The collection drums were stirred and the sediment was collected in 1-L plastic bottles. Then the samples were transferred to enamel bowls to settle down for 24 h. The sediment was separated after being evaporated, dried and weighed. Ground samples were sieved and stored for further analysis of soil texture, soil loss, nutrient concentrations, and organic matter.

Soil Loss and Runoff

The ratio of the weight of the sediment to the area of the plot was calculated for soil loss (g m^{-2}). Runoff water was measured manually through 3L small buckets to remove the water from the drum. Soil texture was determined by hydrometer method (Gee and Bauder, 1986) and soil organic matter by Walkley-Black method by multiplying Soil organic carbon (SOC) with Van Bemmelen factor (1.724) (Nelson and Sommers, 1996). NO_3-N was determined by salicylic acid method (Vendrell and Zupancic 1990). AB-DTPA extractable phosphorous and potassium was measured by the method proposed by Soltanpour and Workman (1979).

Statistical Analysis

The collected data was analysed statistically using Statistix 8.1 software, through analysis of variance (ANOVA) technique. Differences between treatments were tested by using least significant difference Tukey HSD at 0.05 % probability level (Steel, Torrie and Boston, 1997).

RESULTS AND DISCUSSION

Pre-soil Physiochemical Attributes

The pre-physio chemical analysis of soil samples collected from different sites of the experimental field are given in Table 1.

Table 1: Soil characteristic of the experimental site

Characteristics	Value
Texture	Sandy loam
Sand (%)	54.7
Silt (%)	16.4
Clay (%)	28.9
Slope (%)	3.0
N-NO_3 (mg kg^{-1})	10.2
Available P (mg kg^{-1})	9.8
Extractable K (mg kg^{-1})	147.1
Organic matter (%)	0.99

Meteorological and Water Runoff Data

Meteorological data on rainfall during the experimental period was collected from Agro-met Centre Chakwal as shown in Table 2. Averaged over the events, there was no difference in runoff water between the tillage systems. However, cropped plots showed lower runoff than fallow plots (Figure 2).

Table 2: Daily precipitation data of 6 sampling events during monsoon in 2009 at University Research Farm, Koont

Dates	20 July	26 July	2 August	7 August	17 August	7 September
Rainfall (mm)	20.4	27.5	36.6	39.6	39.6	29.3

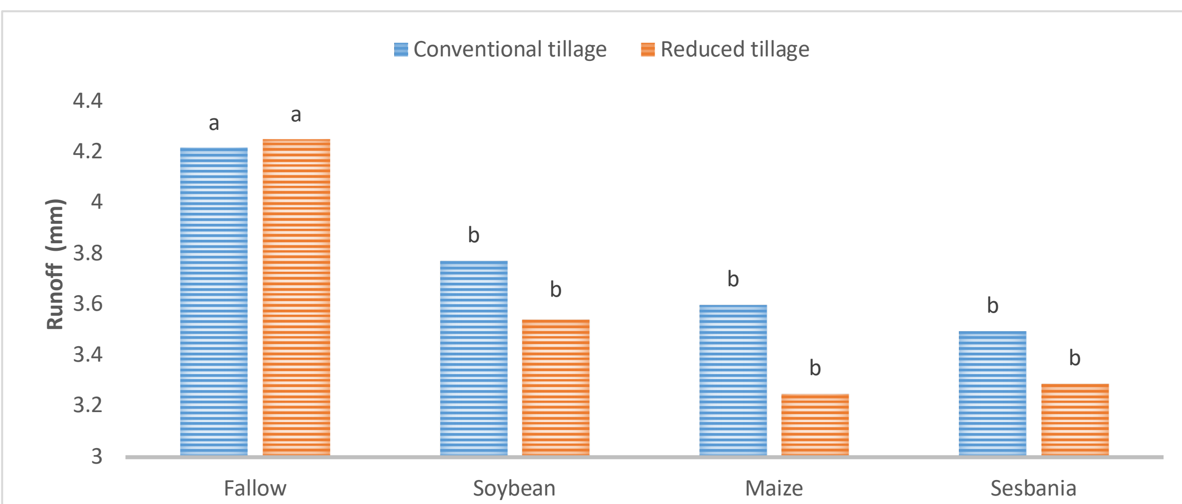

Figure 2. Comparison of average soil runoff water loss on events under different tillage and summer crops

Among crop systems, maize and sesbania plots showed lower runoff than soybean plots. Event-wise details are given in Table 3.

Table 3: Runoff water loss in six rainfall events under different tillage systems and crops

Treatments		Rainfall events 1	2	3	4	5	6
		---------Runoff loss (mm m^{-2}) ---------					
Conventional	Fallow	4.00a	4.47a	4.52a	4.33ab	3.80ab	4.19ab
Tillage	Soybean	3.90a	4.23a	3.52bc	4.00bc	3.19bc	3.80ab
	Maize	4.00a	3.85a	3.66b	3.57c	3.00c	3.85ab
	Sesbania	3.90a	3.90a	3.52c	3.52	3.00c	3.14cd
Reduced	Fallow	4.09a	4.20a	4.52a	4.28a	4.00a	4.23a
Tillage	Soybean	3.71ab	4.04a	3.14bc	3.71c	3.14c	3.50bc
	Maize	3.76ab	4.19a	3.00c	3.38c	2.71c	2.61d
	Sesbania	3.42b	3.80a	3.00bc	3.57c	2.71c	3.66abc

Note: Differences among values with similar letters in each column are statistically non-significant.

In the first rainfall event, there was no difference in runoff between the tillage systems but differences were significant among the crop systems with sesbania showing least runoff and fallow plots, the highest. In the second rainfall event, all the tillage systems and crops had equal runoff. In the third rainfall event, there was no difference in runoff between the tillage systems but among crop systems, fallow plots showed significantly higher runoff than cropped plots. In the fourth rainfall event, runoff was equal in tillage systems but differences were significant among crop systems. Among crop systems, the lowest runoff was from maize fodder and sesbania while the highest runoff was from fallow plots. In the fifth rainfall event, both tillage systems produced equal runoff but among crop systems, fallow plots produced significantly higher runoff than cropped plots. In the sixth rainfall event, there was no difference in runoff between tillage systems. However, differences were significant among crop systems with sesbania showing least runoff followed by maize fodder and lastly by soybean.

Soil Loss

Due to topography and high rainfall intensity, soil loss and runoff are the main problems in the Pothwar region especially during the monsoon periods. To overcome the risk of soil erosion, different tillage systems and crops are used. Overall, there were significant differences among tillage systems and crops in the six rainfall events (Figure 3).

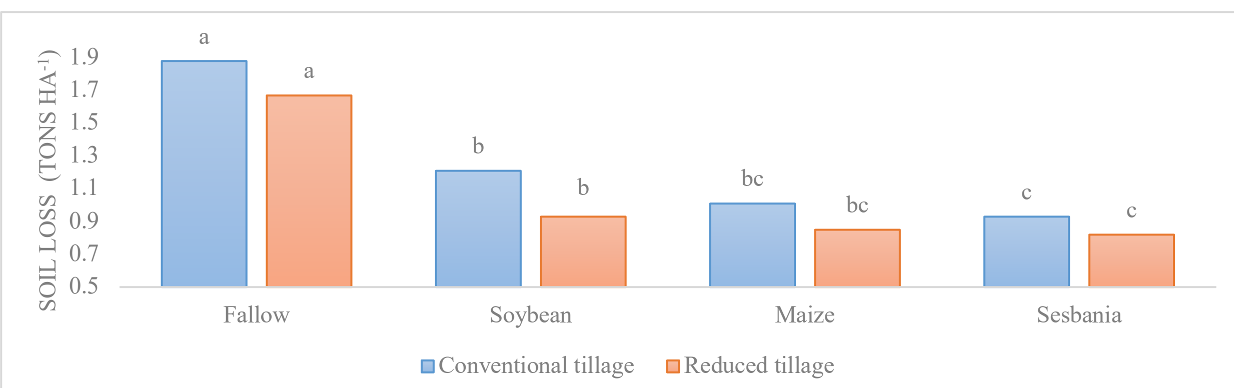

Figure 3. Comparison of average soil runoff water loss in six rainfall events under different tillage and summer crops

Between the tillage systems, a lower sediment loss was observed in reduced (chisel) than conventional (mouldboard) tillage. Among the summer crops, maize fodder resulted in lowest sediment loss, while the highest sediment loss was from fallow plots. Among the six rainfall events, the highest soil loss was in the 2nd event followed by 3rd and lowest in the 5th event followed by the 1st event (Table 4).

Table 4: Soil loss during six rainfall events under different tillage and crops

Treatments		Rainfall events 1	2	3	4	5	6
		---------Soil loss (tons ha^{-1}) ---------					
Conventional	Fallow	1.49a	2.44a	2.30a	1.84a	1.25a	1.98a
Tillage	Soybean	1.11a	1.68a	1.07b	0.97b	0.87a	1.56ab
	Maize	1.10a	1.26a	0.94b	1.21b	0.58a	0.99c
	Sesbania	0.90a	1.24a	0.91b	0.92b	0.63a	1.03bc
Reduced	Fallow	1.21a	1.73a	2.37a	1.73a	1.01a	1.98a
Tillage	Soybean	0.97a	1.32a	0.79b	0.83b	0.71a	1.00bc
	Maize	1.10a	1.26a	0.99b	1.03b	0.58a	0.75c
	Sesbania	0.86a	1.18a	0.78b	0.83b	0.64a	0.67c

Note: Difference among values with similar letters in each column are statistically non-significant

There was no difference in sediment loss between crops and tillage systems in the first rainfall event. A significantly higher sediment loss in follow plots among crop systems and equal sediment loss in both tillage systems were observed in the second, third and fourth rainfall events. In the fifth rainfall event, there was an equal amount of sediment loss in tillage systems but the difference was significant among crop systems. In the sixth rainfall event, among crop systems the least sediment loss was in sesbania plots followed by maize fodder and then soybean.

Soil Nitrate-Nitrogen Loss with Sediment

Nutrient losses are directly associated with sediment loss and runoff water. Soil nitrate nitrogen losses were compared under different tillage systems and crops. There was a significant difference in nitrate-N loss in tillage systems and crops systems. Between tillage systems and reduced tillage (chisel plough) plots showed lower loss of nitrogen. compared to conventional tillage plots (mouldboard plough). Nitrogen loss was highest in fallow plots, decreasing in cropped plots. Overall, more nitrate-N loss was observed in the second rainfall event followed by the lowest loss in the first rainfall event. Rainfall event details are given in Table 5.

Table 5: Mean loss of $N\text{-}NO_3$, available P, extractable K and organic matter in sediment in rainfall events under different tillage and crops

Conventional	Fallow	12.12a	10.67a	144.08a	0.77a
Tillage	Soybean	10.66b	8.83b	123.01b	0.64ab
	Maize	10.44b	7.85b	123.23b	0.56b
	Sesbania	10.22b	7.25b	114.39c	0.58b
Reduced	Fallow	11.21a	9.58a	126.25a	0.57a
Tillage	Soybean	9.40b	6.96b	110.32b	0.54ab
	Maize	9.53b	5.32b	119.34b	0.47b
	Sesbania	9.55b	6.27b	104.15c	0.49b

Note: Difference among values with similar letters in each column are statistically non-significant

There was no difference in nitrate nitrogen loss between the first and second rainfall events in both tillage and crop systems. In the third rainfall event, a significant difference was observed between tillage and crop systems. Among the crops, the least loss of N was from sesbania crop compared to other summer crops. In the fourth rainfall event, a significant difference was found among the crop systems while an equal amount of nutrient loss was found in both tillage systems. In the fifth rainfall event, no significant difference was observed between tillage systems; however, a significant difference of nutrient loss was found among the crop systems. In the sixth rainfall event, there was no difference between tillage systems and crop systems but the same amount of nitrogen loss was found in both tillage and crop systems. The highest nitrogen loss was in the second rainfall event followed by the first rainfall event. The high nitrogen loss in the second rainfall event could be explained by the effect of tillage practices that affected soil pores after the first rainfall event, which could have led to greater runoff than infiltration into the soil.

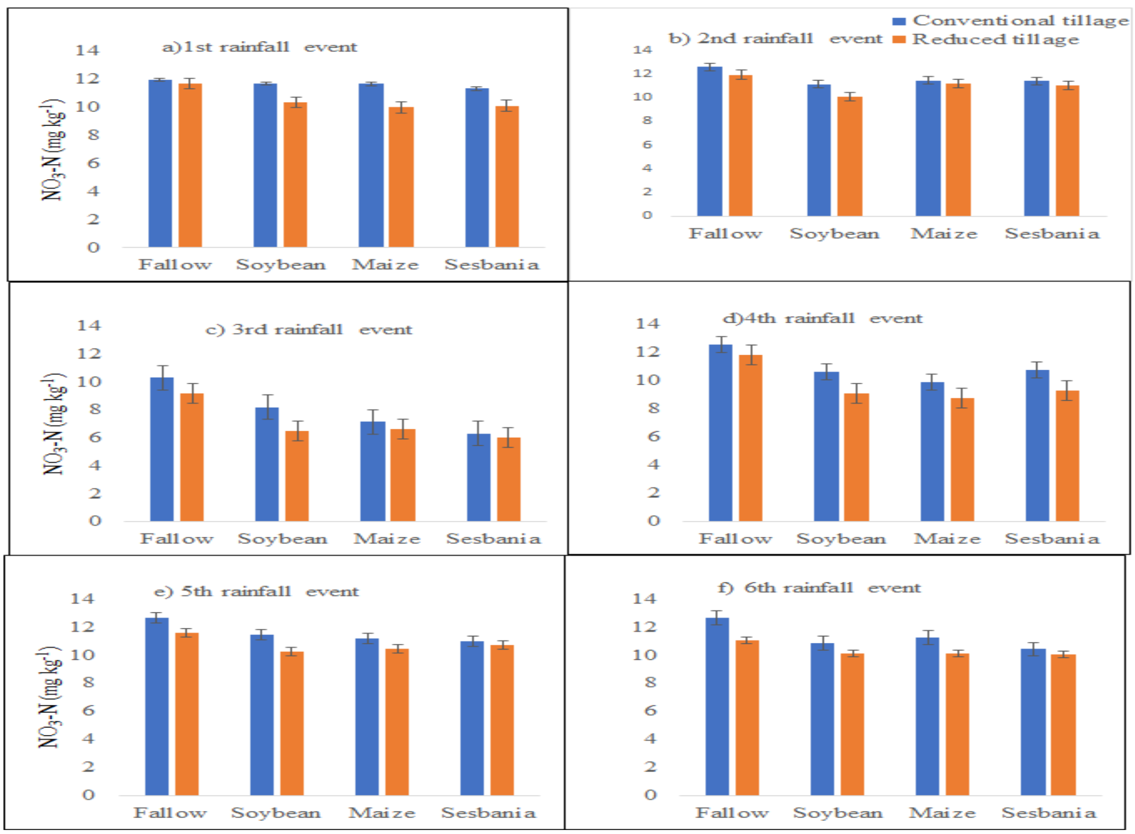

Figure 4. Comparison of soil nitrate nitrogen loss in rainfall events under different tillage and crops

Available Phosphorus Loss with Sediments

Soil phosphorus loss was measured during the monsoon rainfall in the field under different tillage and crops. There were significant differences in phosphorus loss between tillage systems and crop systems in overall events of monsoon rainfall. The highest P loss among crop systems was in fallow plots which gradually decreased in cropped plots (Figure 5). Between tillage systems, lower P loss was observed in reduced tillage (chisel plough) than in mouldboard plough. Overall, the highest phosphorus loss was in the second rainfall event followed by the sixth rainfall event and lowest in the fifth rainfall event. Further event-wise details are given in (Table 5). In the first event, there was significant difference among crop systems and tillage systems. In the second event, there was equal amounts of soil P loss in both tillage systems and crop systems. In the third event, no difference was observed between tillage systems but a significant difference among crop systems was recorded. In the fourth event, there was difference in P loss among crop systems with the lowest loss being in maize fodder followed by sesbania and then soybean. All crops showed lower P loss than in fallow plots. In the fifth event, both tillage systems had an equal loss of P but significant differences were observed among crop systems with the highest loss of P being in fallow than in cropped plots. Equal P loss occurred in tillage system while differences among crop systems were observed in the in the sixth event.

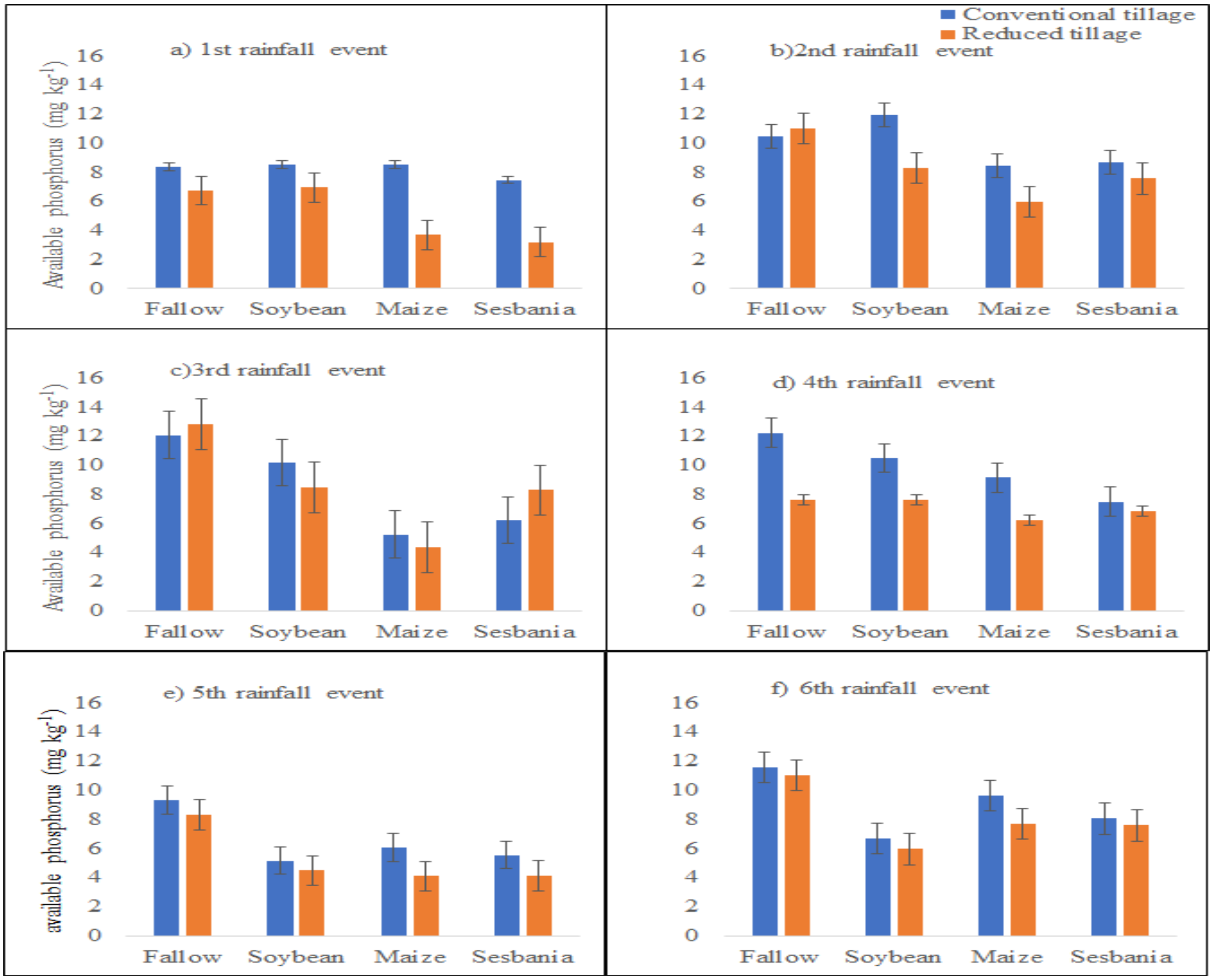

Figure 5. Comparison of soil phosphorus loss in rainfall events under different tillage and crops

The highest phosphorus loss was found in the second rainfall event and lowest in the fifth event as phosphorus is highly soluble in runoff water and soil loss. The fifth event recorded the lowest runoff because the crops were then at maturity stage, with a canopy and deep root system which led to decreased runoff water and sediment loss. Meanwhile in the second event, crop seeds had not germinated with less infiltration of water, resulting in higher nutrient losses.

Extractable Potassium Loss with Sediments

There was a difference in the amount of potassium loss between tillage systems and crop systems (Table 5). In the crop system, overall, the highest loss was observed in fallow plots with lowest potassium loss seen in sesbania compared to other crops. Comparing potassium loss in different rainfall events, the highest loss was in the second event and lowest in the fifth event. Potassium loss in event-wise details is given in (Figure 6). An equal amount of soil K loss was seen in all crops and tillage systems in the first rainfall event. In the second event, no significant difference in soil K loss was seen among crop systems and tillage systems. In the third event, significantly different K loss was seen among crop systems with sesbania having the lowest K loss. However, equal K loss was found in both the tillage systems.

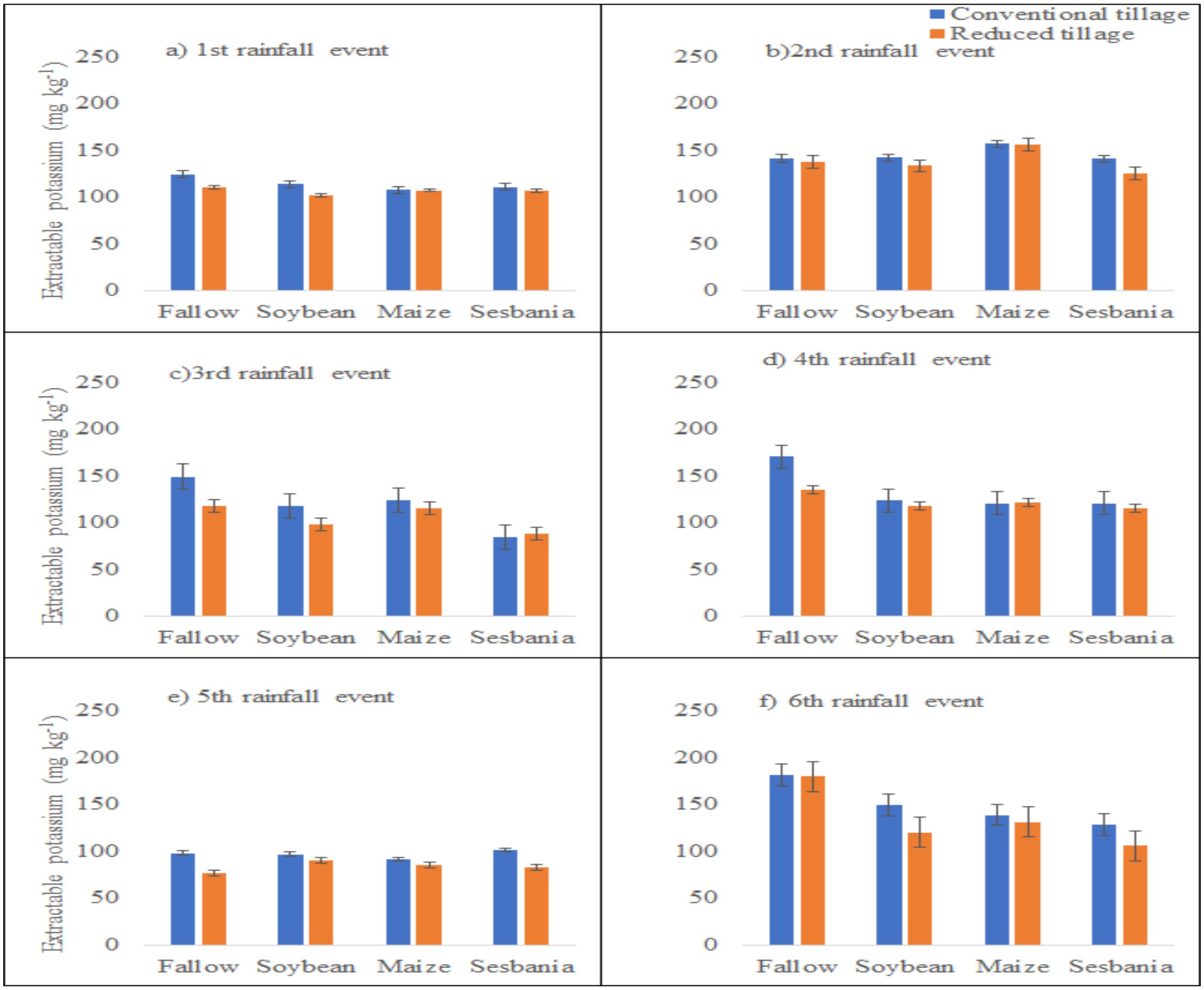

Figure 6. Comparison of soil potassium loss in rainfall events under different tillage and crops

In fourth event, the highest K loss was in follow plots with no significant difference observed in the tillage systems. All plots showed equal loss of K among the summer crops and tillage systems in the fifth event. Among crop systems, a significant difference was observed with less K loss being shown by sesbania followed by soybean and then by maize fodder. The highest K loss was found in fallow plots in the sixth rainfall event.

Soil Organic Matter Loss with Sediment

Soil organic matter (OM) loss was found to be dependent upon sediment loss. In this study there was no difference in OM loss among tillage systems while significant differences were found among crop systems when averaged over all events (Figure 7). The highest OM loss was observed in the first and second rainfall events and the lowest in fifth and sixth rainfall events (Table 5). In the first and second rainfall events, all treatments showed equal OM loss among crop systems and tillage systems. In the third event, significant difference in OM loss occurred among crop systems. All cropped plots showed lower OM loss than in fallow plots while no significant difference was found in OM loss between tillage systems. In the fourth event, among crops systems, less OM loss was found in maize fodder than in sesbania and soybean. No significant difference in OM loss occurred among tillage systems. In the fifth event, there was significant difference in OM loss among the crop and tillage systems while in the sixth event, all plots showed an equal amount of organic matter loss.

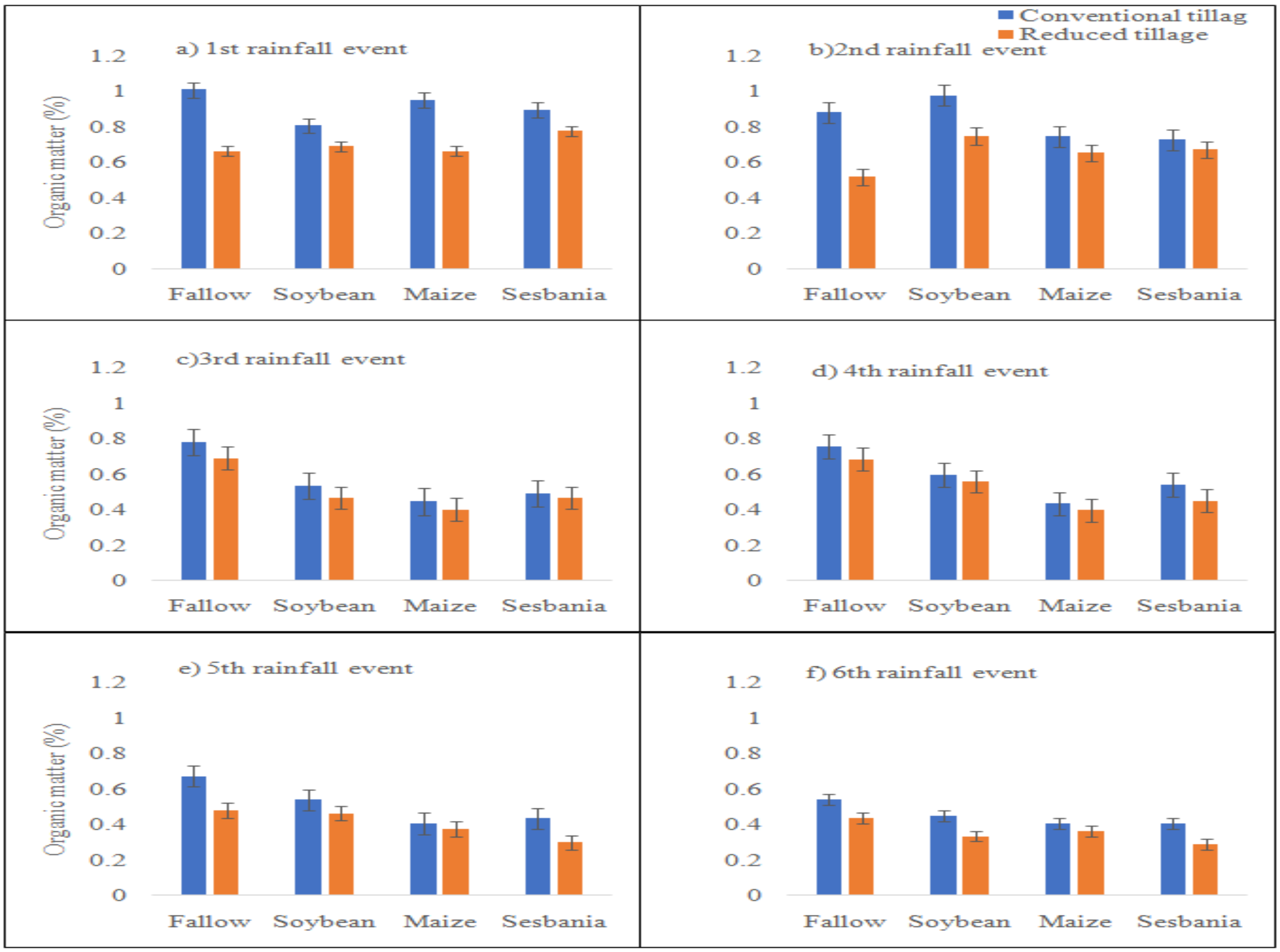

Figure 7. Comparison of soil organic matter loss in rainfall events under different tillage and crop systems

DISCUSSION

Runoff Water

Runoff water loss in both tillage systems was found to be equal. This shows equal infiltration in both the tillage systems. The ability of the reduced tillage system to infiltrate equal amounts of water without intensive tillage (as required by mouldboard plough) is very useful because it does not need to physically crush the soil and break the aggregates and accelerate the decomposition of organic matter. Tang *et al.* (2015) studied three tillage practices in the purple soil region of China. They examined the scaled plots over four years: bare land with minimum tillage (BL), conventional tillage (CT) and seasonal no-tillage ridges (SNTR) which was initially designed to stop erosion of soil by contoured ridges and no-tillage techniques. Their findings showed no differences in the surface runoff and soil erosion between the three practices: BL caused a comparative increase in surface runoff and soil erosion, followed by CT and SNTR. The plots with vegetation coverage had much lower runoff than fallow plots. In fact, vegetation coverage is assumed to be the main factor affecting rainfall interception, other than bulk density and topography. Runoff speed surges and rate of infiltration decline as the soil vegetation cover declines, bulk density increases and topography or gradient of the slope rises (El Kateb *et al.* 2013). In a study by Kirk *et al.* (1995) the rainfall threshold for runoff water production in different land use types showed this trend: Crop Land<Crop Land-Simple Grass<Crop Land-Abandoned Land< Abandoned Land. The increase in runoff during the second rainfall event could be due to lesser infiltration caused by closing of soil pores opened with tillage before the first rainfall event. This also could be linked to lower vegetation coverage during the initial stages of crops. On the other hand, the lowest runoff in the fifth event could be attributed to relatively higher vegetation coverage due to the highest vegetative stage of the crop.

Soil Loss

Varying soil loss in tillage systems (conventional and reduced) occurs because much soil disturbance results from conventional tillage (mouldboard plough) in comparison to reduced tillage (chisel plough). Due to increased soil aeration and disruption of soil aggregates, very high soil losses under conventional tillage are caused by the deteriorated soil structure (Moyo 1998). Since soil loss is a consequence of runoff, the lack of impediments to slow down runoff is also a contributing factor (Munodawafa 2007). Surface and subsurface drainage contribute similar amounts of suspended sediments from conservation tillage treatments while in conventional tillage, sediment loss in subsurface drainage exceeds surface runoff loss. Subsurface drainage contributes significantly to soil erosion, probably because of preferential flow of surface sediments to the drains through extensive cracking of the soil (McKeague *et al.* 1987). Soil erosion is reduced significantly by cover crops but conventional tillage systems are least effective to prevent soil sediment loss (Novara *et al.* 2011). Runoff and soil erosion have been found to increase with an increase in maize strover harvest. Reduced tillage with crop residue, straw removal, crop stubble and maintaining the ridges and deep tillage year to year increases soil fertility (Zhang *et al.* 2011). These measures increase water infiltration and storage thus offering less opportunities for soil erosion (Adekalu *et al.* 2006).

Nutrient Loss with Sediments

Increased rainfall leads to greater runoff resulting in higher sediment loss. The lowest nitrogen loss observed in the third rainfall event was due to less sediment loss from a thicker vegetation cover. High nutrient loss is a result of poor management of soil (Bashagaluke *et al.* 2018) as reflected in high N-NO_3 loss in the control plots where there was no alley cropping compared to contour alley cropping (Wang *et al.* 2010) highest nitrogen loss occurs in bare soil in comparison to vegetation covered soil. A higher phosphorus loss due to maximum runoff and soil loss was observed in conventional tillage (CT) than in reduced tillage. The differences in runoff, soil loss and subsequent nutrient losses between bare follow (BF) and CT are mainly due to soil protection offered by the crops under CT (e.g., crop cover, addition of organic matter, soil binding through roots) (Munodawafa 2007). In terms of various soil management approaches, the highest level of phosphorus (P) losses through soil runoff occurred in a no-till system with surface residues intact, compared to a conventional system with desiccated surface residues. (Bertol *et al.* 2007). Minimum soil erosion and P nutrient loss were seen in chisel and coulter tillage systems. Conventional tillage had also maximum soil P nutrient loss (Romkens *et al.* 1973). Maximum P loss was seen in bare fallow, beans and intercrop at 24.4%, 15% and 9.3% respectively. The concentration of P loss was in the following order: bare fallow < single crop < intercrop. In comparing tillage systems, there was significant difference in K loss with a lower K loss in reduced tillage (chisel plough) than in conventional tillage (mouldboard plough). Potassium loss was found to be equal in both conventional tillage and reduced tillage systems. Mulch ripping (MR) and tied ridging (TR) were efficient in reducing soil erosion and consequently nutrient losses through run-off and sediments (Munodawafa 2007). A difference in potassium loss was also seen among crops, an indication that with increased vegetation growth, sediment loss is reduced and ultimately less potassium loss. This explains why in fallow plots which had no vegetation, potassium loss was higher. The effect of aggregate sediment loss on soil properties under mono-cropping of wheat and corn, barely-legume intercropping and corn legume in comparison with fallow found maximum sediment and runoff in fallow, which was even higher compared to other practices (Ali *et al.* 2006). K was found to be significantly associated with a collective soil loss. OM, N, P, and K losses were maximum with increased rainfall intensity (Tejada *et al.* 2008).

Soil Organic Matter Loss with Sediments

When there was a general increase in the concentrations of Organic Carbon, N, and P in soil under Reduce Tillage total losses in both crops were lower. This was a direct consequence of the reduction in runoff and erosion, as well as of the size of material transported (Napoli *et al.* 2017). Vegetative barriers may improve soil quality through organic matter input and N-fixation depending on species composition, but appropriate soil management is required to minimise competition with adjacent crops (Guto *et al.* 2012).

CONCLUSION

The mountainous and sub mountainous areas of Pakistan experience significant soil erosion due to undulating topography, torrential rainfall, conventional agriculture and other anthropogenic activities. It is necessary to explore and identify the land use practices that can reduce soil erosion and achieve a certain level of agricultural production. The rate of runoff water was higher in fallow plots than in cropped plots. Among the crop systems, the lowest sediment loss was found in maize fodder and sesbania compared to other crops. Comparing the tillage systems, a lower sediment loss was found in reduced tillage (chisel) than in mouldboard plough. Overall, nutrient losses differed between crops and tillage systems, and the amount of organic matter loss between tillage systems also differed. However, a significant difference was found in crop systems with fallow plots showing the highest and maize plots the lowest organic matter loss collectively over the rainfall events.

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CONFLICT OF INTEREST

We declare no any conflict of interest.

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