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SOIL AND NUTRIENT LOSSES BY WATER EROSION UNDER MONO-CROPPING AND LEGUME INTER-CROPPING ON SLOPING LAND

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ABSTRACT: Nutrient and sediment losses from agricultural activities due to soil erosion have resulted in the loss of soil productivity and have become the dominant source of nutrient loads to fresh water. The experiment was conducted on slopping land in northern NWFP near Thana. Malakand Agency on permanent plots of mono-cropping and inter-cropping to assess soil and nutrient losses in surface runoff in comparison with bare plots. Runoff, soil and nutrient losses were monitored during both the seasons (*rabi* and *kharif*) for three years. During *rabi* season. the treatments maintained were wheat mono-cropping. barley-lentil inter-cropping and bare fallow while the treatments maintained during *kharif* season were maize mono-cropping. maize-mungbean inter-cropping and bare fallow. The results showed that runoff. soil loss. organic matter and nutrient losses were high from bare plots as compared to cropped plots. In comparison with bare fallow. inter-cropping reduced runoff and soil losses by more than 39% and 48%. respectively. Total runoff and soil loss showed good correlation with organic matter and plant nutrient losses. The order of sediment bound nutrient loss from all plots during the experimental period was: Organic matter (organic carbon) > K > N > P. While the order of nutrient loss in runoff from all plots was: K > P > N. Losses of all nutrients in surface runoff were higher as compared to the losses of nutrients in sediment. Organic matter and nutrient losses were largely governed by the amount of surface runoff and sediment lost. It can be concluded from the results that inter-cropping proved effective cropping system for controlling long term soil. runoff and nutrient losses on the slopping land. This experiment also generated data for the construction of conservation structures in the area.

Key Words: Legume: Slopping Land: Monocropping: Intercropping: Soil: Nutrient: Losses: Soil Erosion: Pakistan.

INTRODUCTION

Land degradation due to intensive agriculture has been much more detrimental in regions where croplands are established on sloping lands. Cultivation of sloping areas has been increasing for grain production during the past 50 years because of urban and suburban encroachment into prime agricultural land (Tiscareño-López et al., 2004). Annual cropping systems in steep slope conditions are very susceptible to losing soil. nutrient and OM to runoff and erosion. Nutrient loss is an important aspect of surface erosion. since nutrients are concentrated in the surface layer. The concentration of plant nutrients and organic matter is high in eroded sediments as they are closely associated with finer fractions of soils and substantially reduced by significant crop cover (Ghulam et al.. 1995). Nutrient losses to the extent of 0.7 kg N. 0.27 kg P. 9.8 kg K. 3.26 kg Ca and 4.7 kg C ha^{-1} through soil erosion were reported in sub tropical region of China (Kuhnt. 1988).

Various measures like crop and soil management practices can be adopted to control and conserve the fertility of the soil on sloping lands. Chaudhry and Shafiq (1986) concluded that crop management. being the easiest and most effective tool of soil conservation. can be accomplished by making an appropriate combination of crop selection. method of sowing. mulching, cover crops, strip cropping and application of fertilizers. The type of inter crop for a

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cropping system can be selected on account of their efficiency in controlling soil erosion and for their beneficial influence on the growth and yield of major crops. Almas and Jamal (1999) reported that inter-crop of banana-pineapple reduced soil and runoff losses by 75% and 43%, respectively, in comparison with bare fallow, while N P K losses were reduced by 74%, 50% and 26% under inter-cropping. Zobisch et al. (1995) showed that in comparison with bare fallow, P and K losses under the inter-cropped area were reduced to 9.3% and 10.7% respectively. Khisa et al. (2002) observed a highest plant cover and lowest soil losses from inter-cropping.

The purpose of this study was to estimate soil and nutrient losses in runoff from the cropping system of wheat and maize mono-cropping and barley-legume, and maize-legume inter-cropping in comparison with bare fallow. No study has been made in the past in this part of the country in an integrated sense; where the interaction between rainfall factors, cropping pattern and soil erosion can be analyzed to generate data for the development of conservation techniques. This study will provide enough data for erosion modeling and development of soil and moisture conservation techniques.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at village Thana, Malakand Agency, NWFP on an eroded field during 2000-02. The field is located on sloping land and is mainly used for rainfed agriculture. Erosion, shortage of moisture and traditional management are the main limitations of the area. Land is degraded due to past soil erosion and crop productivity is very low. A sloping land with 6% slope was selected. Composite soil samples from experimental site were collected from 0–20 cm depth before sowing. All the samples were analyzed for organic matter (Nelson and Sommers, 1982), pH (McLean, 1982), lime (Nelson, 1982), and AB-DTPA extractable P and K (Olsen and Sommers, 1982), and mineral nitrogen by semi-Kjeldahl digestion method (Jackson, 1982). Some physico-chemical properties of the experimental soil are shown in Table 1. Permanent plots of 2 m x 5 m size were established. Cemented sediment tanks, measuring 1.5m x 1m x 1m, were constructed at the bottom of each plot to collect total runoff and sediment from each respective plot.

Table 1. Some physico-chemical characteristics of the experimental site

Characteristics	Value
Sand (%)	18
Silt (%)	59
Clay (%)	23
Textural class	Silt Loam
Bulk Density (mg m^{-3})	1.28
Soil pH (1:5)	8.25
EC (1:5, dS m^{-1})	0.15
Organic matter (%)	0.87
Lime (%)	22.33
Mineral N (mg kg^{-1} soil)	23
ABDTPA Ext. P (mg kg^{-1} soil)	5.03
ABDTPA Ext. K (mg kg^{-1} soil)	131

Experimental Layout

The experimental design was RCB with three replications. The treatments maintained were, wheat (mono-cropping), barley+lentil (inter-cropping) and control (bare plot) in *rabi* season and maize (mono-cropping), maize+mungbeans (inter-cropping) and control (bare plot) in *kharif* season. A fertilizer rate of 120–90–60 kg N–P_2O_5–K_2O ha^{-1} was applied to cropped plots. All the recommended cultural practices were being followed during the growth period of the crops.

Calculations and Statistics

The incident rainfall amount was measured at the site. After every storm runoff was measured with volume depth ratio of each tank. Ten liters sample of runoff was collected from each tank for analyzing nutrient loss in sediment and surface runoff. Sediment in g L^{-1} was also calculated. Analysis for organic matter and plant nutrients was carried out after each storm. Total runoff, soil and nutrient losses were monitored for three years (*rabi* and *kharif* seasons).

Soil loss, nutrient lost in sediment and nutrient lost in runoff were calculated as follows:

Soil loss (kg ha^{-1}) = sediment wt. (g L^{-1}) × total runoff (m^3) × 10^3 [1]

Nutrient lost in sediment (kg ha^{-1}) = nutrient conc. (mg kg^{-1}) × Soil loss (kg ha^{-1}) × 10^{-6} [2]

Nutrient lost in runoff (kg ha^{-1}) = nutrient conc. in runoff (mg L^{-1}) × total runoff (m^3) [3]

All the data collected on runoff, soil and nutrient losses were statistically analyzed using standard analysis of variance through MSTATC statistical software. Treatment means were compared using least significant difference test. Linear regression and correlation analysis of different variables were also done.

RESULTS AND DISCUSSION

Runoff and Soil Losses

Runoff and soil losses from different treatments were in the order bare soil > mono-cropping > inter-cropping (Table 2). Within cropped plots, runoff was greater from mono-cropped plots than inter-cropped plots but comparable with each other, whereas, soil losses were significantly greater from mono-cropped plots than inter-cropped plots during both the seasons. In *rabi* season, inter-crop of barley+lentil reduced runoff and soil losses by 43% and 35%, respectively while mono-crop of wheat by 38% and 26%, respectively. In *kharif* season, runoff and soil losses were reduced by 39% and 50% by inter-crop of maize+mungbean respectively and 23% and 38% by mono-crop of maize, respectively. As a whole runoff and soil losses were reduced by 39% and 48% under inter-cropping and 24% and 37% under mono-cropping, respectively.

This may be attributed to surface cover which reduced soil loss under different treatments. The effectiveness of surface cover can be influenced by the amount and intensity of rainfall, but increase in surface cover effectively reduced soil loss (Figure 1). These trends indicate that adequate surface cover is necessary to protect soil from erosion. The canopy might have re-

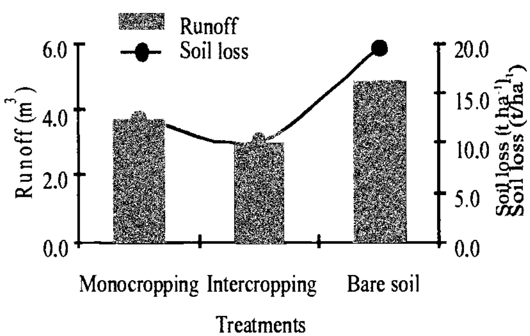

Figure 1: Effect of different cropping systems on runoff and soil loss

Table 2. Runoff, soil and nutrient losses from different cropping systems

Treatments	Runoff (m^3)	Soil Loss (t ha^{-1})	Nutrient losses in sediment OM kg ha^{-1}	N	P	K	Nutrient losses in runoff N	P	K
Average runoff, soil and nutrient losses during 3 *rabi* season									
Wheat	0.23a	1.97b	40b	0.11b	0.05b	0.48b	0.83a	2.75a	3.14a
Barley+Lentil	0.21a	1.72a	37a	0.08a	0.02a	0.39a	0.65a	2.71a	2.98a
Bare Soil	0.37b	2.65c	71c	0.18c	0.07c	0.60c	1.23b	5.06b	3.60b
LSD (0.05)	0.04	0.106	2.351	0.018	0.013	0.052	0.211	1.313	0.233
Average runoff, soil and nutrient losses during 3 *kharif* season									
Maize	3.44a	10.46b	128b	0.45b	0.22b	4.71b	5.96a	14.9a	113a
Maize+Mungbean	2.74a	8.52a	104a	0.30a	0.17a	3.66a	5.40a	12.1a	99a
Bare Soil	4.47b	16.99c	236c	0.77c	0.37c	7.30c	8.09c	23.5b	143b
LSD (0.05)	0.84	1.510	17.21	0.112	0.031	0.873	1.51	5.43	18.22
Average runoff, soil and nutrient losses for 3-years									
Monocropping	3.67a	12.44b	168b	0.56b	0.27b	5.18b	6.79a	17.7a	116a
Intercropping	2.95a	10.24a	141a	0.38a	0.19a	4.05a	6.05a	14.8a	102a
Bare Soil	4.83b	19.64c	307c	0.95c	0.44c	7.89c	9.32b	28.5b	147b
LSD (0.05)	0.78	1.458	15.34	0.113	0.035	0.792	1.36	4.83	20.31

Means followed by same letters in each column do not differ significantly from one another at 5% level of probability using LSD Test.

duced soil surface sealing by raindrop impact and thus maintained higher infiltration rates and low runoff (Almas and Jamal, 1999). Further, plant cover also has great effect on runoff velocity. This implies that a small reduction in runoff velocity will result in a major reduction in the quantity and size of materials that can be transported. These results are well in agreement with the findings of Gilley et al. (1986) and Almas and Jamal (1999) who demonstrated that maintenance of adequate surface cover may serve to conserve soil and water resources. In inter-cropping, reduction in soil losses can be due to high surface cover and thick barrier of legumes (lentil and mungbeans) in the inter-cropping, which reduced runoff velocity and provided much time for sediment to settle down and had a good filtration capacity for sediment to filter out from the surface runoff and ultimately less amount of sediment contributed significantly to the sediment tanks.

Relationship of Total Rainfall and Runoff with Soil Losses

The graphic relationship between rainfall and soil loss from each respective treatment showed that as rainfall increased. the amount of soil loss also increased (Figure 2). This relationship is linear for all the treatments i.e. mono-cropping (R^2 = 0.71), inter-cropping (R^2 = 0.72) and bare soil (R^2 = 0.74). To reduce the effect of plant cover and rainfall intensity, those rainfalls were selected for this graphic relation that occur after 50% crop cover gaining with close intensities.

Soil losses were also linearly increased with increase in runoff for all treatments (Figure 3). The co-efficients for this relationship were 0.85, 0.98 and 0.81 for mono-cropping, inter-cropping and bare soil, respectively. This indicates that surface overland flow represented the major deriving mechanism for sediment transport off the plot.

Organic Matter and Nutrient Loss in Sediment

Losses of organic matter, N, P and K through sediment were significantly different for all the treatments (Table 2). Losses of organic matter and all nutrients were in the order bare plots > mono-cropping > inter-cropping. Losses of organic matter, N, P and K from bare plots were 2.18, 2.50, 2.32 and 1.95 times higher respectively as compared to the losses from inter-cropping. In comparison with mono-cropping, these losses were 1.83, 1.70, 1.63 and 1.52 times higher from bare plots. The same trend for organic matter, N, P and K losses in sediment was observed during both the seasons individually. The order of nutrient losses through sediment from all plots during the experimental period was: organic matter (organic C) > K > N > P.

The loss of nutrients was closely related to the amount of sediment lost from

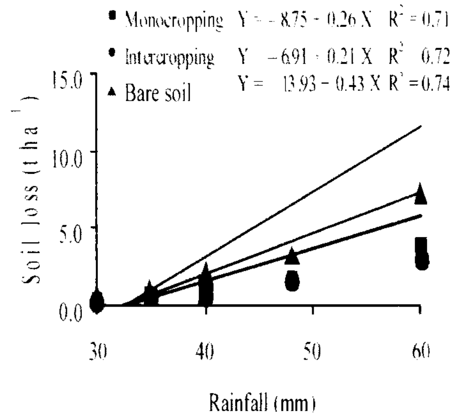

Figure 2: Relationship between rainfall and soil loss

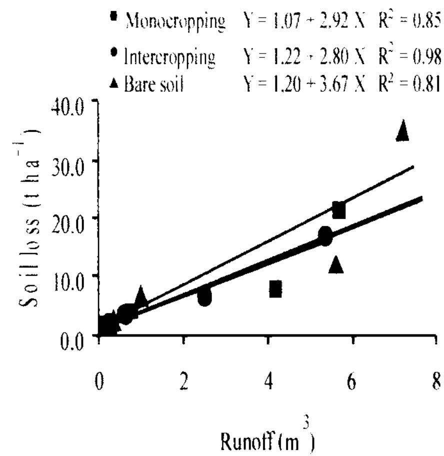

Figure3: Relationship between runoff and soil loss

the plots. Correlation coefficients (r) for soil losses with organic matter and nutrient losses were computed which ranged highly significantly from 0.84–0.96 indicating a highly significant correlation. T'..s highly significant correlation for soil loss with organic matter and plant nutrient losses may be due to the fact that soil fertility is mainly associated with the surface soil.

Nutrient Loss in Runoff

Losses of N, P and K in runoff were significantly higher from cropped plots (Table 2). Losses of all nutrients were in the order bare plots > mono-cropping > inter-cropping. Within cropped plots, losses of all nutrients from inter-cropping were lower than mono-cropping but statistically, were not different. Losses of N, P and K from bare plots were 1.54, 1.93 and 1.44 times higher, respectively, as compared to the losses from inter-cropping. In comparison with mono-cropping, these losses were 1.37, 1.61 and 1.27 times higher from bare plots. The same trend for N, P and K losses in runoff was observed during both the seasons individually. The order of nutrient losses in runoff from all plots during the experimental period was: K > P > N.

The loss of nutrients was closely related to the amount of runoff from the plots. Correlation coefficients (r) for runoff with nutrient losses were computed which ranged from 0.86 to 0.96 indicating a highly significant correlation. This highly significant correlation for runoff with plant nutrients losses may be due to the fact that soil fertility is mainly associated with the surface soil. Due to their higher concentration in the surface soil, plant nutrients can be easily removed and washed away by surface runoff.

Losses of all nutrients in runoff were also higher as compared to the losses of nutrients in sediment. This may be attributed to lower aggregate stability and dispersion of nutrient enriched clay particles in runoff.

Loss of N P K in Relation to Their Inputs and Original Status

The loss of nitrogen, phosphorus and potassium (N P K) in relation to their inputs of these nutrients by fertilizers is given in Table 3. The average original N, P and K content of all the plots is almost the same. Both the cropped plots also received N, P and K in fertilizers. The loss of N, P and K in sediment and runoff from bare plots were 10.27. 29 and 154 kg ha^{-1}, respectively. Whereas from mono-cropped plots. losses of N P K in sediment and runoff were 7.35, 18 and 121 kg ha^{-1}, respectfully. For the inter-cropped plot, losses of N P K in sediment and runoff were 6.43, 15 and 106 kg ha/1, respectively.

This comparison in relation to inputs and original status of N P K showed that from the bare soil where there was no application of fertilizers, the losses were even higher than those receiving fertilizer applications. These losses of nutrients from the bare soil have come from the nutrients present in the original soil. Since the loss of nutrients is mainly governed by the amount of surface runoff produced and sediment lost by each treatment (Tiscareño-López et al., 2004). Zobisch et al. (1999) reported that the total loss of N P K in the eroded soil as well as dissolved in surface runoff are not dependent on the nutrient concentrations of the eroded soil and water but rather on the total amount of runoff and eroded soil. So, more loss of nutrients from the bare soil is the result of high soil loss and runoff from the plots.

Table 3. Average loss of N P K in relation to their inputs and original soil status

(kg ha^{-1})

Treatments	Original Soil Status			Input from Fertilizers			Loss in Sediment + Runoff		
	N	P	K	N	P	K	N	P	K
Monocropping	53.96	12.5	255	120	90	60	7.35	18	121
Intercropping	52.27	11.71	261	120	90	60	6.43	15	106
Bare soil	44.77	10.48	238	0	0	0	10.27	29	154

loss and runoff from the plots.

This comparison, during both the seasons, shows that the inter-cropping is very effective in reducing nutrient losses, whereas the difference in nutrient losses of inter-cropping and mono-cropping was also comparable. The same results were reported by Almas and Jamal (1999) who showed the effectiveness of inter-cropping in reducing nutrient losses as compared to bare and banana plots, whereas the difference in nutrient losses of inter-crop and pineapple plots was very less.

Thus, a considerable amount of plant nutrients, organic matter and fine particles were lost through water erosion. There was positive correlation between runoff and soil loss. Surface cover reduced soil erosion by more than 37% and 48%, respectively. The treatment effect in reducing runoff, soil, organic matter, N, P and K were in the order inter-cropping > mono-cropping > bare soil. The loss of organic matter in sediment was higher from all the plots followed by the loss of K, N and P. Losses of all nutrients through runoff were higher as compared to the losses of nutrients through sediment. Highly significant correlation was observed for runoff and soil loss with organic matter and nutrient losses.

It can be concluded from this study that inter-cropping is an effective cropping system for controlling long term soil, runoff and nutrient losses from the slopping land. This also represents strong support for future research addressing crop management practices regarding soil and water conservation.

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