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Slope Steepness And Crop Vegetative Cover Impact On Soil And Water Losses Under High Rainfall Zone Of Pothowar

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Abstract

The sloping lands are considered to be challenging one in terms of cultivating field crops. The undulated slopes pose hindrances in field operations and aggravate soil and water losses. A study was carried out to demonstrate feasible measures in improving cultivation at sloppy lands of Sohawa, district Jhelum, Pakistan. The objectives were to evaluate, under different vegetative covers and slope gradients, the runoff water and soil sediment loss in comparison to bare land on each slope gradient. Three summer crops Mung bean, Mash bean and Millet were grown on 1 %, 5 % and 10 % slope gradient. Slope steepness induced soil and runoff losses were gauged against each summer crop. Overall soil losses were reduced by 6.3, 8.3 and 4.5 % from mung, mash and millet respectively against bare soil. While water losses were lowered by 11.9, 12.5, 9.8 % from mung, mash and millet respectively as compared to bare soil. The sediment and runoff losses were at the maximum with 10 %, then by 5 % and the least with 1 % slope gradients.

Key words: Soil erosion; runoff; slope gradient; vegetation cover; pothowar

1. INTRODUCTION

The Pothowar region of Pakistan suffers a lot at the hands of limiting factors such as water depreciation and soil erosion for its sustainable agricultural growth and development. Soil erosion by water is governed by multiple factors as topography, drainage, amount and intensity of rainfall and land use patterns. The raindrop impacts the most as the driving force behind soil erosion is the striking strength of raindrops which disintegrates soil and carries it away on sloppy lands. Soil erosion inflicts serious hazard to ecosystems like forests, crops and pastures[1]. The soil losses in turn lead to severe degradation of soil fertility causing reduced crop production and climate change[2]. Surface runoff is the phenomenon associated with heavy precipitation making the soil saturated quickly and flowing unabsorbed excess water down the slope[3]. The kinetic energy of raindrops plays pivotal role for initiating soil erosion, enhanced by intensity and severity of runoff under rainy conditions[4]. The amount of runoff is typically impacted upon by rainfall characteristics (amount and intensity), vegetation cover, slope gradient and other soil characteristics[5]. The generated runoff causes sediment loss, albeit irrigating crop grown on down the slope. Erosion is deemed to be aggravated by steep slopes, lengthy slopes and enhanced runoff. The vegetation covers are deemed to be an effective approach to get reduce water induced soil erosion[6]. Vegetation operates bimodal in controlling soil erosion (i) leaves and stems intercept raindrops lowering their KE (ii) underground roots and litter can augment physi-co- chemical properties of soil, reducing erosive force of rainfall and runoff acting on the soil[7]. Vegetation cover is the main agent for protecting soil due to water induced erosion[8] . Both the vegetative cover and its varying nature lower the frequency of surface runoff[9]. Nutrient removal is yet another very important perspective of runoff and soil erosion, the vegetation not only reduces it by minimizing erosion but also improves fertility of soil by addition of organic matter. Soil erosion and water loss has become menace especially in rainfed areas. It is matter of the fact that about 76% of the total area of Pakistan is suffering at the hands of erosion problem with 36% water and 40% wind erosion[10]. The Pothowar region falls in north-west of Pakistan suffering badly due to water erosion. The high rainfall zone areas are especially under threat of water erosion. The present study was specifically designed to evaluate the impact of slope gradient and different crops grown in high rainfall kharif season on sediment losses and productivity of summer crops.

2. MATERIALS AND METHODS

2.1 Agro-ecology of Experimental Site

The experiment was carried out at farmer's field located in Sohawa, District , Jhelum (lat. 33.06° N, long. 73.17° E and height at 1452 m), from 2015-19 to supervise the sediment losses at three slope gradient for summer crops. Keeping in mind, the variable sloppy lands of this high rainfall tract of Pothowar, on designated slopes (1%, 5% and 10%). Four plots ($10m^2$ each) were kept on each slope gradient. Each of the experimental unit plot was linked to a plastic tank having 200 litters capacity through a pipe (5 inch dia). Cemented raised banks were made of every plot to channelize all runoff water to storing tank. Runoffs were got measured throughout the year. The water stand, measured in tanks, were converted to m^3ha^{-1}. Eroding soil along with runoff water was measured and converted to t ha^{-1} in same way. The data were recorded for each rainfall event having intensity ≥ 20mm. The Kharif crops (Mung, Mash and Millet) were cultured on the established sloppy plots. Recommended fertilizer doses of NPK were applied at the base as Urea, Diammonium phosphate and Sulphate of potash. One of the plots was left uncultivated or fallow as per farmer practice prevailing in the area under study.

2.2 Climate and soil

The climate of experimental area lies in semi arid with mean yearly temperature (20.3°C) while monthly ranging from 10°C to 31°C during January-June. Annual rainfall is about 1000 mm of which 70% occurring during July to September. The soils are at the most are silt 24-41% and clay varying from 20-33%.

2.3 Soil loss and runoff data

Soil and water losses were estimated following every rainstorm ≥ 20mm. To determine runoff, container depth has been measured by which runoff volume was calculated, one L runoff water was collected from every container after thorough mixing. The sampled water was filtered, remaining material was dried at

45°C temperature for 12h to gauge soil loss. The dried material was shifted to the Soil and Water Conservation Research Station for laboratory analysis. The accumulative soil and water losses were estimated using the recorded data generated due to slope gradient under vegetation and fallow[11]. Rainfall (mm) data were recorded at study site (Fig. 1).

2.4 Crop data

To estimate grain yield per hectare, 01 m^2 of plants sample were harvested from each repeat.

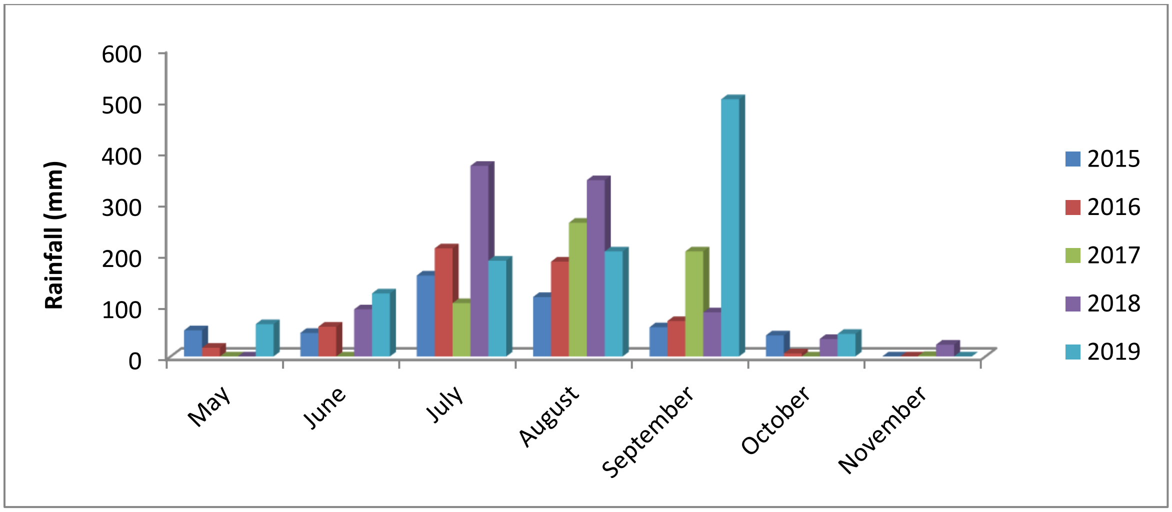

Fig. 1. Rainfall pattern at study site (Kharif season)

2.5 Statistical Analysis

The data were subjected to statistical analysis employing SPSS-16 version (SPSS for Windows, Version 16.0. Chicago, SPSS Inc., 2007).

3. RESULTS AND DISCUSSIONS

3.1 Soil and sediment losses

In sloppy lands the most detrimental factors effecting soil loss is slope gradient. The slope gradient affects on intensity regarding soil and water loss along downward the slopes. The soil loss occurred due to runoff by rainfall during summer 2015 to 2019 is tabulated in Table 1 and it is evidence of maximum runoff occurred in rainy period of monsoon (July and August), which is in alliance with rainfall pattern during 2015 to 2019 (Fig 1). Crop cover significantly reduced soil loss as compared to fallow ranging maximum to minimum in slope gradients from 1, 5 and 10% slope. The highest soil loss quantity (0.530 t ha^{-1}) was generated from non-crop area (control with 10% slope gradient) while, the minimum soil loss was recorded (0.227 t ha^{-1}) from the plot covered with mung bean at 1% slope gradient. The soil loss intensity was significantly increased with increasing slope gradient from different plots under cultivation of various legume-cereal summer crops. Thus, the steepness of slope is striking force behind the soil erosion[12]. Already many researchers have reported significant effect of soil slope steepness on sediment losses[13, 14]. The slope gradient is proportional to surface runoff and soil losses in a sloppy land[15]. Lenka et al. (2017) observed in long term experiments in Northeast India that the crop cover can reduce soil erosion by more than 50%. Vegetation distribution significantly reduced soil loss[17]. In order to compare crop vegetative growth covers, the mash resisted the most against soil erosion, followed by mung and millet. The results are in accordance with[18] who reported that vegetation cover reduced surface runoff. Panomtaranichagul and Nareuban (2005) found out that soil loss rate significantly lowered with developed root architecture and enhanced crop canopy during rainy season.

3.2 Water loss

Runoff generates on slopes due to storm water that does not infiltrate and moves down the slope. So, runoff initiates when rainfall intensiveness empowers capacity of infiltration. Varying crops grown in present experiment at designed slope gradients influenced the erosion. The results regarding runoff (water loss) are tabulated in Table 2, showing a remarkable difference at three designed slope gradients and crop vegetation covers. In comparison with fallow (573 m^3 ha^{-1}), minimum water loss was observed with Mash crop (360 m^3ha^{-1}) followed by Mung (370 m^3ha^{-1}) and Millet (405 m^3ha^{-1}). Among factors affecting soil erosion, the slope steepness is very crucial for soil erosion under constant precipitation. Slope gradient affected runoff under all the three crops in a similar pattern i.e. 1% > 5% > 10%, enhanced with incremented slope gradient. There was found a sustained link between sediment concentration and runoff like soil loss. Ai et al., (2015) reported that increased runoff resulted in more sediment yield. Khan and Bhatti (2000) apprehended that maintaining ample vegetation may protect wastage of precious soil and water resources. It was found out that rainfall occurrence in monsoon every year tend to cause most of the runoff. It was apparent that water loss intensity was affected by both, crop type and slope gradient. A negatively correlated crop vegetative cover and erosion were reported by[21]. The crop cover hinders water runoff and soil erosion effectively and efficiently[22]. High rainfal1 intensity could result in enhanced erosion rate[23]. Chen et al., (2012) reported that heavy precipitation caused incremented runoff. Vegetation can influence runoff by improving soil texture and hydrophilic characteristics by root growth activity on one hand and canopy cover intercepts rainfall lowering its kinetic energy, on the other,[25]. In accordance with the observations by[26], the present effort also ascertained that various crop species had variable effect on controlling runoff.

Table 1. Impact of cover crops and slope gradient on soil loss (t ha^{-1}) with rainfall

Cover Crop	Slope gradient (%)	2015	2016	2017	2018	2019	Mean
	1	0.381	0.248	0.306	0.396	0.44	0.354
Fallow	5	0.441	0.328	0.399	0.489	0.541	0.440
	10	0.522	0.408	0.493	0.583	0.644	0.530
	1	0.225	0.144	0.184	0.274	0.307	0.227
Mung	5	0.223	0.234	0.289	0.379	0.421	0.309

	10	0.289	0.351	0.426	0.516	0.571	0.431
	1	0.229	0.144	0.184	0.274	0.307	0.228
Mash	5	0.239	0.261	0.321	0.411	0.456	0.338
	10	0.229	0.324	0.394	0.484	0.536	0.393
	1	0.253	0.207	0.257	0.347	0.386	0.290
Millet	5	0.275	0.279	0.342	0.432	0.479	0.361
	10	0.382	0.378	0.458	0.548	0.605	0.474

p-values for cover crop = 0.001 and slope gradient = 0.000 @ 5% probability level

3.3 Crop grain yields

Planting different crop species on experimental site changed the simulation data of yield with varying slope gradient. It was found that different crop yields differ significantly. Decreasing trend was observed in the entire three crops grain yield with increasing slope steepness (Table 3). It is apparent from the experimental results that the slope steepness significantly affected grain yields of all the three crops, Mung, Mash and Millet. Yields were declined with increasing steepness. It was observed that erosive force of raindrops exponentially reduced by canopies of various crops[27]. Consequently, energy with which it strikes the earth surface depending on raindrop's size and its velocity becomes negligible and hence minimizing soil and water loss on a sloppy track[28]. In addition, crop root system holds soil particles strongly making it more resistant against erosion. Rhizosphere soil becomes compacted by roots penetration and growth, tend to resist against erosion[29]. Various studies have confirmed the efficacy of crop cover in reducing discharge and sediment loss[30, 31].

Table 2. Impact of cover crops and slope gradient on water loss ($m^3\ ha^{-1}$) with rainfall

Cover Crop	Slope gradient (%)	2015	2016	2017	2018	2019	Mean
	1	211	310	101	80	87	158
Fallow	5	238	334	132	117	127	190
	10	265	380	164	153	167	226
	1	166	182	85	61	66	112
Mung	5	147	171	117	99	108	129
	10	121	157	130	114	125	129
	1	142	167	88	73	80	110
Mash	5	113	152	114	106	116	120
	10	104	134	127	136	148	130
	1	171	180	99	78	85	123
Millet	5	152	174	128	111	121	137
	10	139	163	146	132	144	145

p-values for cover crop = 0.000 and slope gradient = 0.000 @ 5% probability level

Table 3. Impact of slope gradient on grain yield ($t\ ha^{-1}$) of crops

Cover Crop	Slope gradient (%)	2015	2016	2017	2018	2019	Mean

	1	0.000	0.000	0.000	0.000	0.000	0.000
Fallow	5	0.000	0.000	0.000	0.000	0.000	0.000
	10	0.000	0.000	0.000	0.000	0.000	0.000
	1	0.453	0.404	0.472	0.469	0.511	0.462
Mung	5	0.450	0.342	0.469	0.466	0.508	0.447
	10	0.397	0.354	0.415	0.411	0.448	0.405
	1	0.565	0.813	0.731	0.838	0.813	0.752
Mash	5	0.515	0.642	0.549	0.877	0.846	0.686
	10	0.433	0.468	0.586	0.583	0.765	0.567
	1	0.902	0.702	0.950	0.948	1.034	0.907
Millet	5	0.785	0.706	0.826	0.825	0.899	0.808
	10	0.687	0.619	0.724	0.722	0.787	0.708

p-value for slope gradient= o.o4 @ 5% probability level

4. CONCLUSION

Topographic gradient impacted the crop yield, more the gradient lower was the crop economic yield. The mash (Vigna mungo L.) is the appropriate summer crop for sloppy areas of high rainfall zone of Pothowar, which was appeared as a major obstacle against soil erosion. Millet (Pennisetum glaucum L.) did not show satisfactory results in the same zone (high rainfall zone of Pothowar) due to meager contribution towards controlling soil and water losses.

CONFLICT OF INTEREST

No conflict of interest among authors.

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