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VARIATIONS IN SOIL CHARACTERISTICS ALONG SLOPE POSITIONS OF ERODED SLOPPY LANDS OF TEHSIL SOHAWA, DISTRICT JHELUM

[a]Zahid Hassan Tarar, [b]Adnan Umair, [b]Hafeez-U-Rehman, [c]Hafiz Abdul Rauf, [d]Muhammad Qaisar Nawaz, [d]Ghulam Qadir, [d]Muhammad Faisal Nawaz, [e]Maryam Sarfraz, [e]Muhammad Zaigham Mushtaq, [f]Muhammad Nadeem, [g]Muhammad Arif, [h]Shah Faisal

[a] *Soil and Water Testing Laboratory Mandi Bahauddin, Pakistan.*
[b] *Soil and Water Testing Laboratory Sialkot, Pakistan.*
[c] *Cotton Research Institute, Khanpur, Pakistan.*
[d] *Soil Salinity Research Institute Pindi Bhattian, Pakistan.*
[e] *Biochemistry Section, PHRC, Ayub Agricultural Research Institute, Faisalabad, Pakistan.*
[f] *Soil and Water Testing Laboratory Hafizabad, Pakistan.*
[g] *Soil and Water Testing Laboratory Multan, Pakistan.*
[h] *Directorate of Agriculture Research Cotton Nal at Khuzdar, Pakistan.*

ABSTRACT

The management of eroded, sloppy soils is somewhat different from leveled lands due to variation in soil physical and chemical properties. To evaluate these properties the research work was planned on the eroded sloppy lands of Sohawa, District Jhelum (also known as Potohar). Collection of Soil samples were done from Top-slope (TS), Mid-Slope (MS) and Bottom-Slope (BS) gradients at two depths. Two catchments were selected for data collection viz. Khallabut catchment and Mohra Pari catchment. Results demonstrated a substantial difference among the physicochemical properties of top, mid and bottom slope soils. The finding of this study depicted that, electrical conductivity EC 0.0.48 dS m^{-1}, observed at Top Slope compared to 0.63 dSm^{-1} at the Bottom Slope gradient. Furthermore phosphorus (5.40 mg kg^{-1} at TS compared to 6.39 mg kg^{-1} at BS), Potassium (167 mg kg^{-1} at TS compared to 215 mg kg^{-1} at BS), and Organic matter content (0.47 % at TS compared to 0.70 % at BS at Both sites). The silt was highest at bottom slope i.e., 31 % mainly due to siltation process transported by water erosion. As far as the middle of the slope is concerned the values for all the variables are in between the Top and bottom of the slope. The soil moisture observed 11 % and 9.2 % at Top slope at Khallbut and Mohra Pari Catchment respectively. There was significant effect of slope position on water content as it showed 44 % increase at Bottom of the slope compared to Top slope. Deterioration in physico-chemical attributes of top slope as compared to mid and bottom slopes were assumed to be due to past soil erosion effect that removed the finer soil particles including soil organic matter and other plant nutrients. This study concluded that increasing extent of erosion due to slope effect can further deteriorate soil properties. This study also suggests that the top of the slope need more care and intention of the farmer for better productivity and profit. The slope position had affected water movement from the upper to the lower slope position and this process caused variation of soil chemical characteristic formation.

Keywords: Eroded soil; Nutrient deficiencies; Soil fertility; Slope gradient; Water erosion

Corresponding Author: Adnan Umair
Email: adnanumair@gmail.com

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INTRODUCTION

Soil is an important natural resource for growing plants, food and fiber. The suitability of soil for crop production is based on the quality of the soil's physical, chemical and biological properties. One of the naturally occurring processes that affect detrimentally these soil properties and subsequent crop production is soil slope position. Slope is one of the important factors of universal soil loss equation. Its geometry, such as slope angle, length and curvature influence runoff, drainage, and soil erosion (Aandahl, 1949) causing a significant difference in soil physico-chemical properties (Brubaker et al., 1993). Erosion would normally be expected to increase with increase in slope length and slope steepness, as a result of respective increase in velocity and volume of surface runoff. As a major topographical parameter, the slope position, i.e., the relative height position along the hill's side slope, could also significantly change the soil physico-chemical properties by controlling the movement of water and material in a hillslope and contributing to the spatial differences of soil properties (Begum et al., 2010).

Chaudhry and Rasul (2004) described that the Potohar region comprised of Attock, Jhelum, Rawalpindi and Chakwal. Total area of Potohar region is 28488.9 sq Km. The best suited area is mainly located between 33.0º N and 35.0ºN latitude where the food crop production is possible under rainfed conditions. While, Tongde et al. (2021) concluded that in the Potohar region due to overgrazing, gravity erosion and gully erosion also occurred in some natural hillsides, the range of soil erosion of the 15 investigation units was about 5.14~133.89 t ha^{-1} $year^{-1}$.

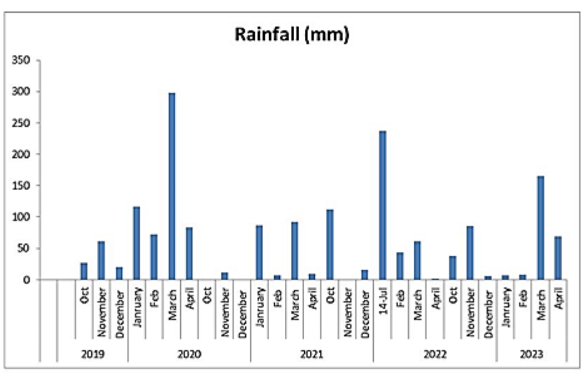
In order to maintain soil fertility under rainfed condition of sloppy Potohar lands, farmers have to care of the characteristics and constraints of their soils and use sustainable management practices to conserve and improve soil fertility. Slope is one of such characteristics of farmland that farmers have to take into consideration. Though slope is an inherent geographic condition of lands that is beyond the control of farmers. However, through management practices, farmers can manage their farmlands for greater crop productivity (Okorie et al., 2022).

In the area under study, water erosion takes place in which slope steepness is the dominant factor where the accumulating water removes the finer soil particles including soil organic matter and plant nutrients thus adversely affecting the soil properties and crop productivity. The study aimed to inquire the effect of slope position on properties of soil in order to provide the basic information about the fertility status of the eroded land of the area. Such information would be helpful in recommending the type and amount of fertilizer and other soil management practices in future crop production strategies on such soils.

MATERIALS AND METHODS

Study Area

The experiment was carried out at eroded soil of Sohawa District Jhelum (Longitude:73.42308°; Latitude: 33.12775°) during 2017 to 2021. The climate is sub-humid, sub-tropical continental type with an annual rainfall of about 1000 mm, occurring in bi-model pattern mostly in late summer and winter spring periods. For this study two locations were selected viz., Mohra Pari and Khalllabut catchment. The weather data i.e., rainfall and temperature of the experimental sites was given in Figure 1.



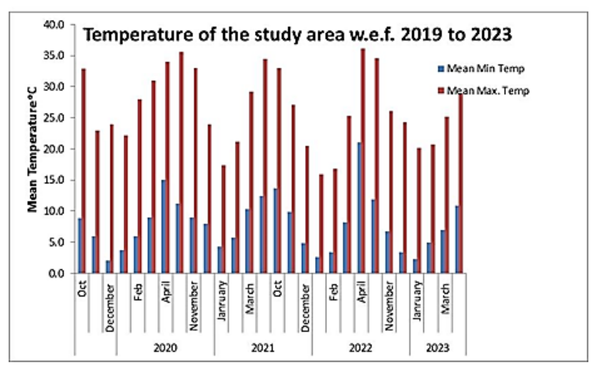


Figure 1: Shows the met data (Rainfall and Temperature regime) of five years for the study site.

Soil Sampling and Analysis

Soil sampling was done from two depths on top, mid and Bottom slope gradient and were analyzed for the soil properties. Meanwhile, soil moisture content was measured by using gravimetric method at the same location where the soil samples were taken.

The air dried, crushed and sieved (2 mm) soil samples were analyzed for different physico-chemical properties using processes as; soil texture (Tagar and Bhatti, 1996), bulk density (Blake and Hartage, 1984), electrical conductivity (Rhoads, 1996), organic matter (Nelson and Sommers, 1982), pH (McLean, 1982) and Olsen extractable P and K

(Soltanpour and Schwab, 1977).

Statistical Analysis

All data were tested for normality of distributions and homogeneity of variances prior to analysis. When data were not normally distributed, they were logarithmically transformed before analysis. The main statistical parameters (minimum, maximum, mean, median, variance, standard deviation, and coefficient of variance (CV)) of soil physico-chemical properties at three different slope positions were calculated through the Statistix 10 software. Differences in soil physico-chemical properties across the three different slope positions were compared by using the one-way analysis of variance (one-way ANOVA) method. Furthermore, the Tukey–Kramer honestly significant difference (HSD) test of the means was used when statistically significant differences ($p < 0.05$) were observed among slope positions.

RESULTS AND DISCUSSION

Soil Organic Matter %

Soil organic matter was significantly affected by soil position and varies from 0.28 % to 0.89 % from top to bottom of the slope respectively. The data depicts that the highest soil organic matter was observed at bottom slope of both the catchments. The highest Organic matter percentage was observed at Bottom slope at Mohra Pari catchment which was 0.89% (Table 1). The top slope shows 0.28 % at Khallabut and 0.66 % at Mohra Pari. The low soil organic matter at top slope may be due to direct contact with the sunlight and erosion. Due to water erosion the top soil moves to the lower side leaves the top slope with low fertile soil contents. The results are in confirmity with the findings of Liu et al. (2020).

Electrical Conductivity (EC)

The positioning of the slope gradient at sloppy lands of Sohawa District Jhelum demonstrated a notable impact ($p<0.05$) on soil electrical conductivity (EC) (Table 1). The EC levels were highest at the bottom slope (0.74 dS m^{-1}), followed by the mid slope (0.44 dSm-1) and the top slope (0.36 dS m^{-1}). Notably, the EC values at the bottom slope were approximately double those observed at the mid and top slope positions. The higher electrical conductivity at the bottom of the slope seems due to water erosion and the effective rainfall contributes soil erosion (Figure 1). The results are at par with the findings of Liu et al. (2020). The work of other researchers (Ahmad and Khan, 2009) also confirmed the increase in EC with depth which they have presumed to be due to the downward movement of soluble ions (Na^+, K^+, Mg^{2+} Cl^-, HCO^{3-}) with percolating water during the erosion processes and its accumulation in the compact subsoil.

Table 1: Effect of Slope position on Soil OM% and pH and EC (dSm^{-1}) at Khallabut and Mohra Pari Catchment.

Treatment	Location	OM %	pH	EC dSm^{-1}
Top Slope	Khallabut Catchment	0.28	7.89	0.36
	Mohra Pari Catchment	0.66	8.18	0.60
	Mean	0.47 b	8.05 a	0.48 b
Mid Slope	Khallabut Catchment	0.40	7.92	0.44
	Mohra Pari Catchment	0.76	8.16	0.64
	Mean	0.58 ab	8.04 a	0.54 a
Bottom Slope	Khallabut Catchment	0.50	7.88	0.53
	Mohra Pari Catchment	0.89	8.18	0.74
	Mean	0.70 a	8.03 a	0.63 a
	CVC*	0.075	0.123	0.081

The numbers followed by the same letter are not significantly different based on the Tukey HSD test at the 0.05 level. CVC* is Critical Value for Comparison

Soil pH

Soil pH did not show significant variation down the slope (Table 1). However, bottom slope had the highest pH. The pH levels were highest at the bottom slope (8.18), followed by the mid slope (7.92) and the top slope (7.89). The statistical analysis showed that there was not any effect of slope gradient on the pH value at top mid and bottom of the study area. These results are at par with the findings of Khan (2013). Furthermore, as one of the most important physico-chemical properties of soil, soil pH directly affects plant growth and microbial activities, and most plants are suitable for growth in an environment where pH is neutral (Šimek and Cooper, 2002). Data regarding soil pH showed a non-significant effect of slope position on soil pH; however, the increase in soil pH at the bottom slope position could be attributed to the accumulation of bases. This accumulation was presumed to have been eroded from the top and bottom slope positions, as evidenced by the work of Garcia et al. (1990), who reported the highest Na+ concentration at the bottom slope position of 30 eroded sites.

Ammonium Acetate Extractable Potassium (K)

Extractable Potassium (K) was significantly ($p<0.05$) different at different slope positions down the slope (Table 2). The bottom slope had the highest K (230 mg kg^{-1}) which was 15 and 35% higher than the mid and top slope positions, respectively. The data showed that the lowest Ext. K was at top slope i.e, 155 mg kg^{-1}. The low potash at top of the slope might be due to the water erosion along the slope gradient. These results are at par with the findings of Khan et al. (2013). Our present study found that levels of extractable Phosphorous, Potash, and Soil Organic Matter (SOM) increased from the top (upper slope) to the bottom slope (foot slope), likely due to their movement downward with runoff water. Despite this pattern, the concentration of these soil fertility parameters remained below the optimum range across all slope positions. Previous research has suggested that soil organic matter plays a crucial role in controlling Phosphorous and other soil fertility parameters in semi-arid regions. Therefore, the decrease in soil organic matter content at the top slope, caused by erosion, may have led to reduced availability of Phosphorous and Potash in the soil at that position (Prüeß et al., 1992).

Table 2: Effect of Slope position on Soil Soil Moisture%, Ext. K and Available P at Khallabut and Mohra Pari Catchment.

Treatment	Location	Soil Moisture %	Ext. K	Available P
Top Slope	Khallabut Catchment	11	178	5.26
	Mohra Pari Catchment	9.2	155	5.53
	Mean	10.1 b	167 b	5.40 c
Mid Slope	Khallabut Catchment	11.3	223	5.82
	Mohra Pari Catchment	9.4	194	6.02
	Mean	10.4 b	208 a	5.92 b
Bottom Slope	Khallabut Catchment	17.9	230	6.32
	Mohra Pari Catchment	14.9	200	6.46
	Mean	16.4 a	215 a	6.39 a
	CVC	1.97	24.17	0.483

The numbers followed by the same letter are not significantly different based on the Tukey HSD test at the 0.05 level. CVC* is Critical Value for Comparison

Olsen Ext. Phosphorus

The findings indicate a notable influence ($p<0.05$) of slope positioning on extractable phosphorus (P), with the bottom slope exhibiting the highest levels (6.39 mg kg-1), trailed by the mid slope (5.92 mg kg-1) and top slope (5.40 mg kg-1) positions, correspondingly (Table 2). The increase in extractable P at bottom slope was 17 and 37% higher than the mid and top slopes positions, respectively. The range of physico-chemical properties varied across slope positions, as indicated by descriptive statistics. The middle slope position showed a relatively small range, indicating more consistent conditions. This stability may be due to the relatively favorable environmental conditions at this position, resulting in lower variation in soil properties. Conversely, the upper slope position endured harsher environmental conditions, such as stronger winds, higher surface evapotranspiration rates, and shallower soil layers, leading to a wider range of soil physico-chemical properties (Horta and Torrent, 2007; Liu et al., 2020).

Soil Moisture Content %

The data obtained from our study showed that there was significant effect of slope position on the soil moisture or water content 5. The data depicts that there was 11 % and 9.2 % of moisture found at top of the slope at both Khallabut and Mohra Pari Catchment area. Furthermore it is found that the soil moisture content were 17.9 % and 14.9 % at both of the sites respectively. There was an increase of 35% observed at bottom of the slope compared to top or upper slope gradient (Table 2).

The study observed that soil water content at the top or upper slope was greatly lower compared to the foot slope or bottom slope and middle slope or mid slope positions. This difference is likely determined by the lower altitude of the foot slope (bottom slope), which gets weaker solar radiation and thus holds relatively higher soil water content. Conversely, the Top slope with 6 to 7 % slope gradient, and its higher altitude, receives stronger surface evapotranspiration due to vivid solar radiation. Additionally, the steeper slope contributes to surface runoff, which is transported downhill, accumulating at the footslope (Bottom slope) position. The determinations of Liu et al. (2020) and Magdić et al. (2022) in a similar research study are in line with our research findings.

Soil Texture Analysis (Sand, Silt and Clay %)

The soil texture analysis showed that there was significant effect of slope position (Upper, Middle and foot slope) on the sand, silt and clay content at both catchments i.e., khallabut and Mohra pari. The data showed that there is 50 % and 45 % sand contant at Khallabut and Mohra Pari catchment respectively. Whereas the mean value of both sites was 46% at the foot or bottom slope position (Table 3). As far as the silt fraction is concerned the data showed that silt content are slightly higher at the bottom of both catchment i.e., 27 % and 35% respectively compared to 25% and 31% at the top or upper slope of both the catchments (Table 3). Silt contents are upto 25% higher at the bottom compared to the top slope position. These results indicate that due to water erosion the silt percentage is more at the bottom of the slope. These results are also at par with the findings of Khan et al. (2013).

Table 3: Effect of Slope position on Soil Soil Sand, Silt and Clay%, at Khallabut and Mohra Pari Catchment.

Treatment	Location	Sand %	Silt %	Clay %
Top Slope	Khallabut Catchment	50	25	24
	Mohra Pari Catchment	45	31	24
	Mean	48 a	28 b	24 a
Mid Slope	Khallabut Catchment	50	27	23
	Mohra Pari Catchment	45	33	22
	Mean	48 a	30 a	22 b
Bottom Slope	Khallabut Catchment	50	27	23
	Mohra Pari Catchment	43	35	22
	Mean	46 b	31 a	22 b
	CVC*	1.26	1.52	1.75

The numbers followed by the same letter are not significantly different based on the Tukey HSD test at the 0.05 level. CVC* is Critical Value for Comparison

During the erosion processes, likewise, the suspended clay particles also move downward the profile along with downward movement of water and conglomerate there in the B and C horizons thus choking the existing soil pores and raising soil bulk density down the profile.

CONCLUSION

Our present study affirmed that slope position has more pronounced negative effects on soil physic-chemical properties of the top slope compared to the mid and foot (Bottom) slopes. The increasing slope gradient from3 to 7 percent influence the soil fertility status of different slope position finally impacting soil productivity mainly because of water erosion. The impairment in physico-chemical properties of the soils of top slope at both catchments i.e., Khallabut and Mohra Pari, was assigned to past soil erosion removing finer soil particles like clay and silt, including organic matter and essential plant nutrients. For the top slope position, exceptional care is recommended due to deteriorating or lower fertility levels and exposure to direct sun light. This could demand implementing soil conservation schemes such as chemical, physical and biological approaches for conservation of the top slope. Our study concluded that the upper slope need more care/ management compared to lower slope positions.

CONFLICT OF INTEREST

The authors declare that there is no conflict in the publication of this article.

AUTHOR’S CONTRIBUTION

All the authors contributed equally in the study.

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