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# Soil water variation under different cropping patterns on sloppy lands in Punjab, Pakistan

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## Abstract

Soil water variations are due to topographic characteristics of soil and land uses on the sloppy lands. The objective of this study was to monitor the soil water variation in relation to three cropping patterns and three different terraces at Khairimurat area during 2007-08. Three cropping patterns were Wheat (*Triticum asetivum* L.) – Millet (*Pennisetum glaucum)* – Fallow, Wheat – Millet – Lentil (*Lens caulinaris)* and *Wheat* – Fallow and terraces were low height terrace (5 feet high from the leveled field), medium height terrace (3 feet high from the low terrace) and high height terrace (2.5 feet high from medium terrace). Soil water measurements were performed monthly from above mentioned cropping patterns under different terraces and measured by adopting gravimetric method at six depths of the soil profile at an interval of 15 cm (0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm). The soil water was available maximum on high height and low height terraces but it was observed minimum in medium terrace. Thus, the low delta crops on medium terrace should be planted instead of growing high delta crops. Actually, the medium terrace contains relatively low clay contents which resulted low retention of soil water. The soil water contents within all terraces down to the depth increased linearly. The rainfall distribution was almost same on the study site during the rainy season. However, the temperature variation trend at all the locations was season dependent. This study provides an idea for crop management under arid environment and to introduce the suitable crop in their cropping pattern. Hence, the high delta crop in the existing cropping patterns could be replaced by the new cropping patterns depending upon the findings of soil water availability.

**Keywords:** Soil water variation, cropping patterns, terraces, sloppy lands, Khairimurat

## *Introduction*

Soil water has a variable impact under different soil environment such as different catchments (Fu *et al.,* 2000, 2003), bench terraces (Sang-Arun *et al.,* 2005), topography (Wesemael *et al.*, 2003), groundnut fields (Gardner and Gerard, 2003), hedgerow and ceral crop plots (Agus *et al.*, 1997). Soil water heterogeneity gives the best understanding in utilizing the terraced lands under suitable crops to reduce the soil erosion (Gardner and Gerard, 2003). Various scientists have studied the variability of soil water in different ecosystems and their effect on crop growth on the terraced and sloppy lands (Fu *et al.,* 2000; Qiu *et al.*, 2001, 2003).

In Pakistan, the Pothowar Plateau covers an area of 5.49 mha having uneven topography and is directly or indirectly dependent on rainfall (Figure 1). Almost 60-70 percent rainfall occurs in months of June to August. The areas receiving rainfall less than 500 mm are not suited to continuous cropping due to shortage of water supply (Yousaf, 2007). This tract has lot of potential for raising crops which can significantly play an important role in the economy of the country. The main soil problems of Pothowar include soil erosion, loss of soil water and low soil fertility due to uneven sloping topography.

In order to prevent soil erosion and depletion of soil fertility, the farmers have converted sloppy lands into terraces and among them bench terraces are common. In Pothwar, such types of terraces are present at Khairimurat. These existing terraces viz. low height terrace (5 feet high from the leveled field), medium height terrace (3 feet high from the low height terrace) and high height terrace (2.5 feet high from medium height terrace) are adopted by the farming community. Currently, cropping patterns on these terraces including Wheat-Millet-Fallow, Wheat-Millet-Lentil and Wheat-Fallow are grown in this site by the farmers. These lands were investigated for the soil water variation. The fallow lands slowly came into existence during 2 and 3 years when cultivated plots were abandoned. The objective of this study was to monitor the soil water

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variation on these terraces under different cropping patterns and its effect on crop growth.

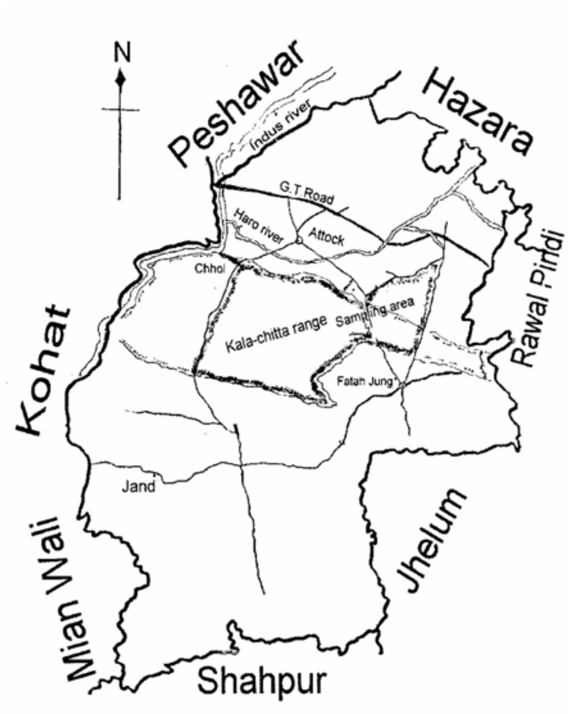


**Figure 1. Map of Pathowar Plateau**

## Material and Methods

### *Description of Site*

The Khairimurat area in Pothowar Plateau is situated at 33° 34' 12" N and 72° 39' 0" E. The experimental sites are located 65 kilometer from Rawalpindi. The climate is arid with an average annual temperature of 22.2 $^{o}$C. The monthly mean temperature ranges from about 11 $^{o}$C in January to 31 $^{o}$C in June. The total annual precipitation is 988 mm and 70 percent rainfall falls in between June to August. The most common soil types have silt 20-40 % and clay varying from 18-23 % (Table 1, 2 and 3). The soil has less resistance to the erosion.

Soil terraces viz. low height terrace (5 feet high from the leveled field), medium height terrace (3 feet high from the low height terrace) and high height terrace (2.5 feet high from medium height terrace) were selected for the soil water monitoring purpose. The cropping patterns at the sloppy (terraced) lands were 1) Wheat-Millet-Fallow, 2) Wheat-Millet-Lentil and 3) Fallow Lands. Soil water data were obtained on monthly basis interval from April 2007 to March 2008. The soil samples were taken from 18 points of terraced lands at six depths of 15 cm interval: 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm. The mean water contents for three locations were computed as the soil water level of each sample site. Rainfall and temperature data during the study period was obtained from the meteorological department, Islamabad, Pakistan (Figure 2).

Under Wheat-Millet-Lentil cropping pattern, the wheat was planted in the first week of November and harvested in the last week of April. The millet was sown in the second week of May and harvested in last week of August. The lentil was grown in the second week of September and harvested in the last week of October, 2007. Under Wheat-Millet-Fallow cropping pattern, the Rabi wheat was grown in the first week of November, 2006 and harvested in the first week of May, 2007. The millet crop was sown in the first week of June, 2007 and harvested in last week of August, 2008 for fodder purpose on these terraces. For rest of the period, the soil was kept fallow (uncultivated). Under Wheat-Fallow cropping patterns, the Rabi wheat crop was sown in the second week of November, 2007 and harvested in the last week of April 2008. After harvesting of wheat crop, the terraced land was kept fallow.

### *Soil analyses*

Soil particle size distribution was determined by using Bouyoucos Hydrometer method (Black, 1965). Soil textural grade was determined by using Triangle from USDA (Gee and Bauder, 1986) and soil water contents were measured by gravimetric method (Hess, 1971). The data obtained were analyzed statistically using SPSS program (Norusis and SPSS, 1993).

## Results and Discussion

### *Soil water variation under wheat-millet-lentil cropping pattern*

The data on soil water variation under wheat-millet-lentil cropping pattern is given in Figure 3. The data showed that in general the average soil profile water variation pattern from April to December was similar on all terraces except in the September and October whereas the low terraces have significantly less water as compared to medium and high terraces. Further more, on all terraces, the soil water content was significantly higher in April as compared to May, June, July and August. It increased non-significantly in high and medium terraces in September but it was significantly lower in low terraces in the same month. Soil profile water decreased in October and November. In December, it was significantly higher in all terraces as compared to October and November.

The millet crop as high delta crop extracted more water from low terrace. Whereas, the other two terraces had enough water to meet the crop water requirement of millet.

**Table 1. Soil particle size distribution under wheat-millet-lentil cropping pattern**

| Terrace | Soil Depth (cm) | Soil Particles (%) | | | Textural Class |
|---|---|---|---|---|---|
| | | **Sand** | **Silt** | **Clay** | |
| | | 2-0.05 mm | 0.05-0.002 mm | < 0.002 mm | |
| High | 0-15 | 65 | 16 | 19 | Sandy Loam |
| | 15-30 | 63 | 19 | 18 | Sandy Loam |
| Medium | 0-15 | 41 | 40 | 19 | Loam |
| | 15-30 | 39 | 40 | 21 | Loam |
| Low | 0-15 | 36 | 41 | 23 | Loam |
| | 15-30 | 35 | 42 | 23 | Loam |

**Table 2. Soil particle size distribution under wheat-millet-fallow cropping pattern**

| Terrace | Soil Depth (cm) | Soil Particles (%) | | | Textural Class |
|---|---|---|---|---|---|
| | | **Sand** | **Silt** | **Clay** | |
| | | 2-0.05 mm | 0.05-0.002 mm | <0.002 mm | |
| High | 0-15 | 38 | 36 | 26 | Loam |
| | 15-30 | 36 | 38 | 25 | Loam |
| Medium | 0-15 | 40 | 39 | 22 | Loam |
| | 15-30 | 40 | 39 | 21 | Loam |
| Low | 0-15 | 35 | 40 | 24 | Loam |
| | 15-30 | 36 | 39 | 25 | Loam |

**Table 3. Soil particle size distribution of Khairimurat Site under Fallow Land**

| | | Soil Particles (%) | | | |
|---|---|---|---|---|---|

This might be the reason that there was less water on low terraces. Moreover, the soil of the high and medium terrace had bed rocks and stored water while the low terraces have deeper soil. Vegetation also competed for soil water contents on low terrace that caused low soil water content during the month of October and November. Wang *et al.* (2008) also observed that the soil water contents on sloppy lands showed a negative impact with heavy weed infestation which lowered the availability of soil water contents to the prevailing crop. Rockstriim and Valentin (1997) also reported that on sloppy lands, the millet crop utilized the maximum soil water on sloppy land under arid environment and their findings match to our observations. Similar results were reported by Kizito *et al.* (2006).

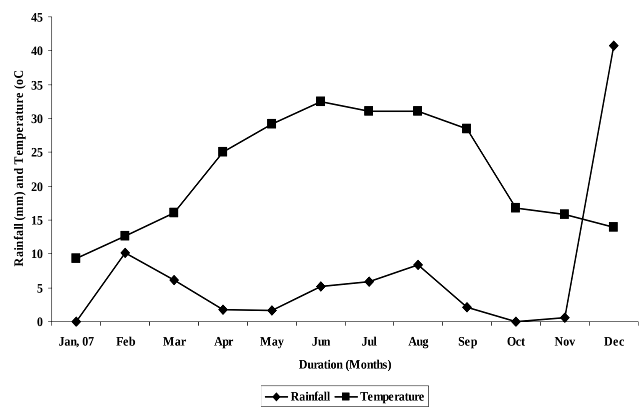


**Figure 2. Annual Rainfall and Temperature on the experimental area**

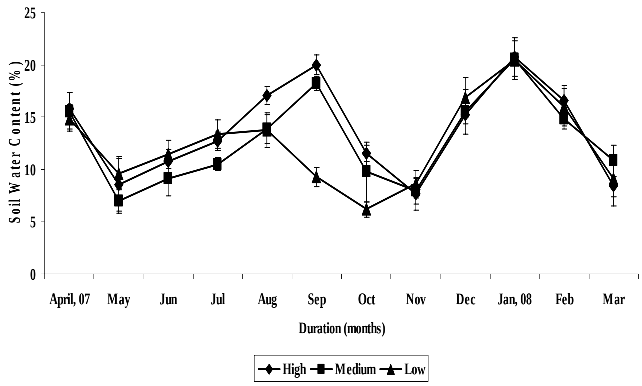


**Figure 3. Soil Water Variation under Wheat-Millet-Lentil Cropping Pattern**

### *Soil water variation under wheat-millet-fallow cropping pattern*

The data on soil water variation under wheat-millet-fallow cropping pattern is given in Figure 4. On all the three terraces, the soil water contents were significantly higher in April as compared to May to November except July, September and December and less in July, September and December. The high soil water contents in April, July, September and December could be attributed to high rainfall.

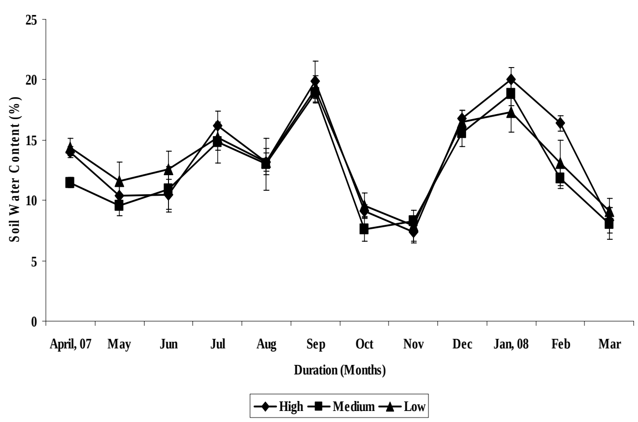


**Figure 4. Soil Water Variation under Wheat-Millet-Fallow Cropping Pattern**

The soil water contents did not differ significantly from each other during May and June but differed significantly from other months on high, medium and low terraces. The soil water increased significantly during the month of July on all terraces. It showed slight decrease in August on all terraces. A significant increase in soil water variation was observed in the month of September. Such trend was attributed due to heavy rains on all terraces. Soil water availability significantly decreased during the months of October and November and did not differ statistically from each other on high, medium and low terraces. During December, a significant increase in soil water availability was observed on all terraces. Overall, the maximum soil water variation was available in September and it was deficit in October and November on all the terraces. It is concluded from the results that high terraces stored maximum soil water contents while medium terraces had minimum soil water variation.

The reason for low soil water variation on medium terrace might be due to variation in soil texture, growing of high delta crop (millet), poor drainage, poor establishment of embankments and vegetation (weeds). It also might be due to exhaustive and long proliferation of root system of millet on medium terraces.

These results coincide with the finding of various scientists (Fu *et al.*, 2000; Gomez-Plaz *et al.*, 2000; Wang *et al.*, 2001; Dijk *et al.*, 2003; Fu *et al.*, 2003; Gardner and Gerrard. 2003; Mileham *et al.*, 2008).

### *Soil water variation of wheat-fallow cropping pattern*

The soil water variation measurements under wheat-fallow cropping pattern are elucidated in Figure 5 and 6. The results revealed that the soil water variation in general showed a heterogenic impact during the Rabi and Kharief season. The soil water contents did not differ significantly from all terraces during April. In May, the soil water variation showed a greater difference among high, medium and low terraces. It was available maximum in high terraces as compared to other terraces but the medium and low terraces had uniform soil water availability. Similar trend was observed in June for soil water variation on all terraces. The soil water contents slightly increased during July. A significant decrease in soil water variation was observed in August. It increased linearly in September due to heavy rains on all terraces. A greater soil water variation was observed in October for soil water contents on high, medium and low terraces. The order for soil water contents as high terraces> low terraces >medium terraces prevailed under wheat-fallow cropping system in November. A significant decrease in soil water contents was observed in November on all terraces especially at medium terraces. During December, it showed a significant increase and heterogenic impact among the terraces. The soil water content trend as high terraces >low terraces >medium terraces was found under wheat-fallow cropping pattern.

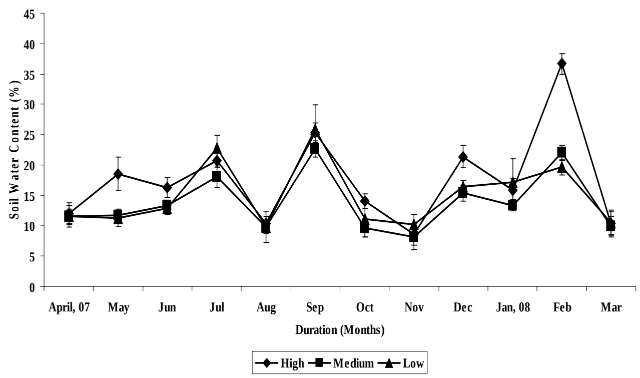


**Figure 5. Soil Water Variation under Wheat-Fallow Cropping Pattern**

Overall, the maximum soil water was available in September and it was minimum in April on all the terraces. It means that high terraces stored maximum soil water content while medium terraces had minimum soil water variation. The reason for low soil water variation on medium terrace might be due to variation in soil texture, growing of high delta crop (millet), poor drainage, poor establishment of embankments and vegetation (weeds). It might also be due to exhaustive and long proliferation root system of millet on medium terraces.

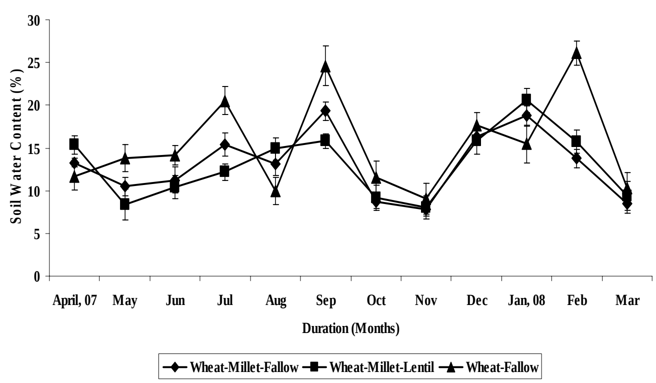


**Figure 6. Comparison of soil water variation under various cropping patterns on all terraces**

These results coincide with the finding of various scientists (Gomez-Plaz *et al.,* 2000; Wang *et al.,* 2001; Dijk *et al.,* 2003; Fu *et al.,* 2003; Gardner and Gerrard, 2003; Fu *et al.,* 2000, Mileham *et al.,* 2008).

The data clearly indicated less average soil profile water contents under wheat-millet-lentil cropping pattern as compared to wheat-millet-fallow and wheat-fallow cropping patterns. This was expected as the crop water requirement of millet, wheat and lentil is comparatively more as compared with wheat-millet-fallow and wheat-fallow cropping patterns.

The experimental area falls under arid climate having rainfall less than 250 mm but it is very erratic as it has been shown in Figure 2 along with the temperature. Although farmers are practicing this pattern but the expected climate change and if drought prevails then these crops will be affected badly. The other possibility needs to be tested. Experiments are being conducted by replacing the low delta crops with high delta crop in the existing cropping patterns at this site.

### *Correlation between temporal variation and rainfall distribution on three cropping pattern under different terraces*

The correlation between temperature variation and rainfall distribution of study area under various cropping patterns on sloppy lands (terraced) is shown in the Figure 2. The temporal variation and rainfall distribution correlated significantly ($r^2$ = 0.87) among each other. The Figure 2 reflects that maximum rainfall was observed in monsoon seasons at the month of June, July and August while it was found minimum in the month of November and December. Heavy rains appeared in the month of June, July and August and dry spell was found in the winter season and prolonged up to the beginning of February. So, rainfall exhibits two peaks and three troughs throughout the year. Overall the temperature was found maximum in the summer season. On one side, temperature caused maximum evapotranspiration to maintain the growth and development of crops but on the other side, it reduced the amount of water stored in the deeper profile. Such conditions prevailed throughout the year on fallow and cropped lands under different cropping patterns on sloppy lands (terraced). Similar results were also reported by various scientists (Qiu *et al.,* 2001; Dercon *et al.,* 2003; Zougmore *et al.,* 2003) for correlation among the temperature and rainfall distribution.

## Conclusion

The trend of soil water variation on bench terraces under different cropping pattern showed that the medium height terraces had minimum amount of soil water content under wheat-millet-lentil, wheat-millet-fallow and wheat-fallow cropping pattern compared to high height and low height terraces under wheat-millet-lentil, wheat-millet-fallow and wheat-fallow cropping patterns. It is therefore proposed that the crops with less water requirement may be grown on the medium height terraces whereas the high delta crops can safely be grown on high height and low height terraces.

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