Research Article

Characterization of Eroded Lands of Pothwar Plateau, Punjab, Pakistan

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Abstract | Erosion is one of the complex and detrimental types of land degradation that deteriorates both soil quality and land productivity. Determination of soil characteristics and nutrient status of eroded lands is pre-requisite for restoring their productivity. The objective of present study was to quantify the selected soil properties and nutrient status of eroded soils. The study was undertaken on eight soil series (Missa, Pirsabak, Guliana, Rajar, Balkassar, Rawalpindi, Chakwal and Satwal) in tehsil Gujar Khan of Rawalpindi district. Amongst the soil characteristics of selected fields, pH ranged from 7.36-7.94 for surface soil (0-15 cm) and 7.49-7.94 for subsoil (30-45 cm), EC1:1 was 0.22-0.38 dSm^{-1} in surface soil and 0.21-0.28 dSm^{-1} in subsoil, $CaCO_3$ was 1.0-9.22% in top soil and 0.28-9.67% in the subsoil and soil organic matter (OM) was 0.89-1.25% in surface soil and 0.62-1.04% in subsoil. Among soil series, Missa soil series had higher OM (1.25% and 1.04% in surface and sub-surface soil, respectively) compared with other soil series. All soils were generally deficient in nutrients as NO_3-N was deficient in 97% surface soils (2.77-5.23 mg kg^{-1}) and 100% sub soils (1.03-4.14 mg kg^{-1}), P was deficient in 95% surface soils (0.76- 1.67 mg kg^{-1}) and 100% sub soils (0.22- 1.22 mg kg^{-1}), Zn was deficient in 100% both surface and subsoils and B was deficient in 85% surface soils and 90% subsoils. These results suggested that fertility status of these soils with respect to NO3-N, P, Zn and B was poor. The characterization of eroded lands provides a quantitative data and on the basis of this data application of integrated soil conservation practices could improve the soil sustainability and crop productivity of eroded lands. Furthermore, this data could also be helpful in developing policies, strategies and programs for the conservation of eroded lands.

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Introduction

Soil erosion is a complex process that depends on soil properties and erosion-induced loss in soil productivity is one of the major threats to global food and economic security. Erosion in excess of soil production would ultimately result in reduced agricultural potential. Crop yields in the Pothwar plateau (latitude 32° 10′ to 34° 9′ N and longitude 71° 10′ to 71° 55′ E) are low as compared to irrigated regions of Pakistan. Pothwar plateau is a large rain-fed tract of Pakistan which comprises of 1.8 m ha area (Nizami et al., 2004). Maize, sorghum and millet are the main crops during the summer season; and wheat is the predominant crop during the winter. Main causes of low production are; highly erratic, unevenly distributed rainfall, erosion, water runoff, and widespread deficiency of plant nutrients. Nutrient loss through erosion is among the most important factors in soil productivity decline (Moyo, 2003). Runoff water contributes substantially to the losses of P, K and Mn from the soil (Ruppenthal et al., 1997). Due to the loss of fine soil particles (along with nutrients) and centuries old crop production without adequate fertilization, the soils of Pothwar suffer with multiple nutrient deficiencies (Rashid et al., 1997). Analysis of nine soil series in Fatehjang tehsil showed that 100% of the soil samples were deficient in N, P, Zn and B for 0-15 cm and 30-45 cm soil depths (Shaheen et al., 2008). Erosion affects a number of soil properties as it reduces organic matter, fertility, tilth, rooting depth and water holding capacity, structure is deteriorated, and texture is changed. Collectively, these properties affect the soil's productivity potential. Soil fertility decline due to soil erosion and nutrients losses through runoff and leaching is a serious problem of hilly areas as in Nepal (Tripathi et al., 2000). Nitrogen and P are the main nutrients that restore soil fertility (Bertol et al., 2003). The correction of nutrient imbalances improved grain yield and reduced the impact of yield loss due to erosion (Izaurralde et al., 2006). There are some intrinsic and endogenous factors (Carpenter et al., 2001; Tobias et al., 2001) affecting restoration of soil fertility. An important external factor is soil management, e.g. nutrient deficiency can be overcome with the addition of fertilizers. Therefore, balanced use of fertilization with proper moisture conservation practices can be adopted in such soils. The objectives of present study were to investigate the plant nutrient status of the water eroded farmlands in Gujar Khan target areas, and to assess their potential for agricultural use. The results of this study will be useful to the farmer community and agriculture planners.

Materials and Methods

Selection of Study Sites

The study was conducted in Gujar Khan project areas during 2004-2006. The selection of areas was made on the basis of the degree of erosion. Eight soil series namely Missa, Pirsabak, Guliana, Rajar, Balkassar, Rawalpindi, Chakwal and Satwal were selected to study soil characteristics. These soil series belong to different erosion classes. Nizami et al. (2004) defined and identified the water erosion classes according to Soil Survey Manual (USDA Handbook No. 18). The Gujar Khan target area with 54,170 ha lies between latitude 33° 10′ to 33° 15′ N and longitude 73° 15′ to 73° -20′ E.

Soil Sampling

The soil sampling was undertaken during the month

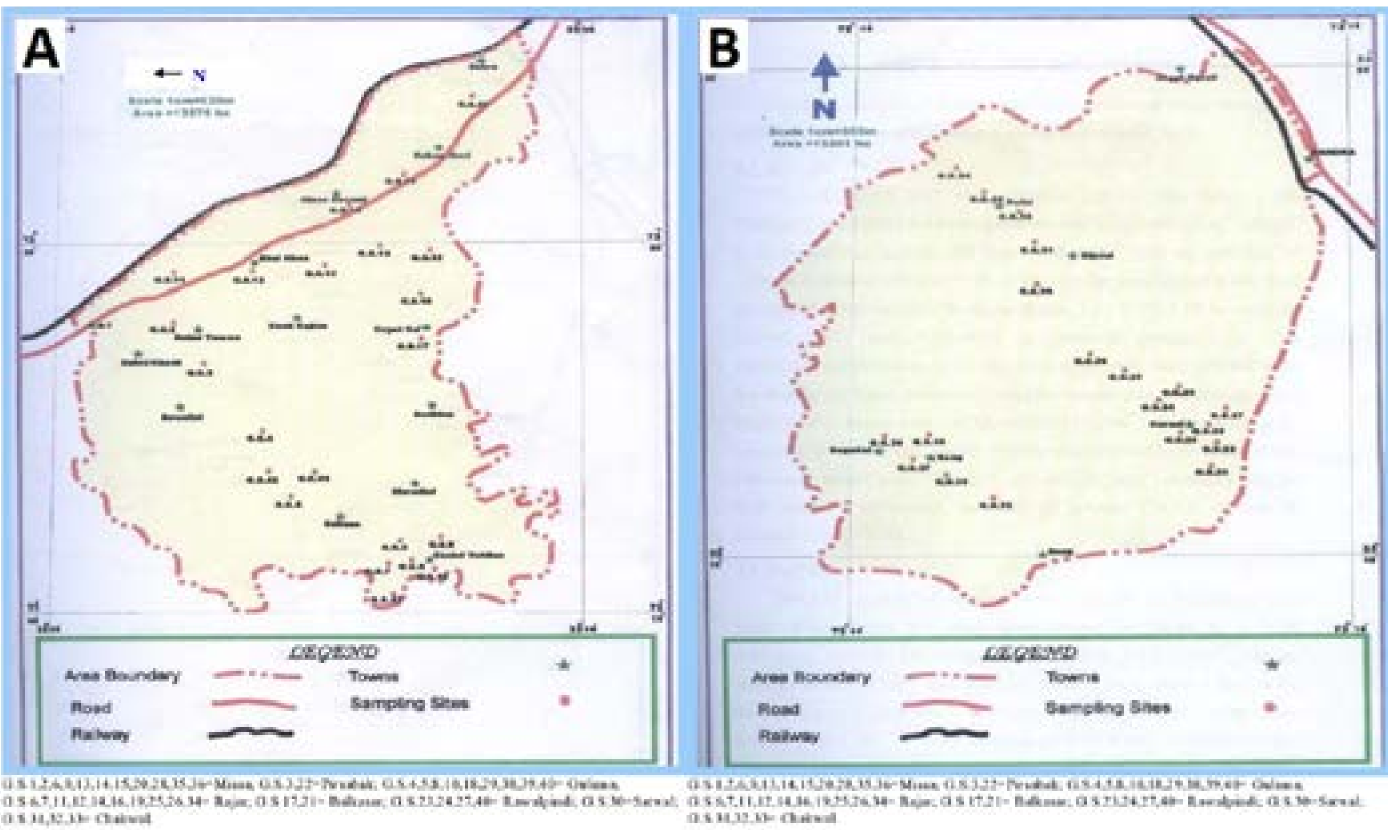

Figure 1: *Map showing sampling sites in Gujar Khan target area*

of September 2004. Some of the sampling sites were fallow in the previous summer and some were planted to *Kharif* crops (sorghum/maize) but harvested before sampling.

For the study of soil characteristics of various soil series, total 40 soil samples were collected from surface soil (0-15 cm) and 40 samples from sub soil (30-45 cm) to compare properties of surface and sub soil. Each soil series was sampled with different number of fields (ranging from 1-11), however, the number of soil samples from each field was three (3) to make a composite sample. Missa soil series was sampled from 11 fields, Pirsabak and Balkasar each from 2, Gulinana from 9, Rajar from 8, Rawalpindi from 4, Chakwal from 3 and Satwal from 1. The variation in no. of fields sampled for each soil series depend upon the presence of that particular series in study area. The map of sampling sites is given in Figure 1.

Soil Analysis

All the soil samples were analyzed for selected soil properties and nutrients. Soil $pH_{1:1}$ was determined by preparing a saturated soil suspension. In 250 ml conical flasks 40 g air-dry soil was taken and 40 ml distilled water was added. It was placed on reciprocating shaker and mixed for 30 minutes. Suspension was kept for 30 minutes to allow most of sediments to settle. Then pH was recorded with calibrated pH meter by immersing the electrode in to supernatant solution (Mclean, 1982). For determination of $EC_{1:1}$, 50 g of air-dry soil was taken in a 250 ml conical flask and 50 ml distilled water was added. It was mixed for 30 minutes by placing on reciprocating shaker and allowed to stand for 30 minutes. Then $EC_{1:1}$ was recorded with conductivity meter after standardizing conductivity meter with 0.01 M KCL solution (Mclean, 1982).

For determination of organic matter 1.0 g air dry soil was taken in a 500 ml Erlenmeyer flask, 10 ml of 1 N $K_2Cr_2O_7$ was added and mixed by swirling the flask. Then 20 ml of concentrated H_2SO_4 was added, and after gently mixing for 1 minute it was allowed to stand for 30 minutes. It was diluted by the addition of 175 ml deionized water and then 10 ml H_3PO_4 was added. After addition of 10-20 drops of indicator diphenylamine it was titrated against 0.5 N $FeSO_4$. $7H_2O$ to sharp green end point colour (Nelson and Sommers, 1982). For determination of $CaCO_3$ in a 250 ml Erlenmeyer flask 1 g soil was taken and 10 ml 1 N HCl was added. It was swirled and then heated the flask to 50-60 °C then let the contents cool. After addition of phenolphthalein indictor it was titrated against 1 N NaOH until a faint pink color developed (Soltanpour and Workman, 1981). To prepare AB-DTPA soil extract 10 g soil sample was taken in a 50 ml conical flask and 20 ml of AB-DTPA solution was added. The suspension was shaken for 15 minutes and filtered through Whattman No. 40. The extract was analyzed for NO_3-N, P, K, Cu, Fe, Mn and Zn (Soltanpour and Wrorkman, 1979). Nitrate–nitrogen and extractable P were determined with the help of spectrophotometer and K was measured on flame photometer. The concentrations of Zn, Cu, Fe and Mn in soil extract were measured on atomic absorption spectrophotometer. To determine HCl-extractable B, ten gram air-dried soil was taken in a polypropylene tube and 0.2 g activated charcoal (Boron-free) and 20 ml of 0.05 N HCl were added. It was shaken for 5 minutes and then filtered. One milliliter aliquot was transferred into a 10 ml polypropylene tube, and 2 ml buffer solution, 2 ml azomethine-H solution were added and mixed well. After 30 minutes light absorbance in the extract was recorded on spectrophotometer at 420-nm wavelength for boron determination (Rashid et al., 1994).

Data Analysis

The statistical analyses were performed according to Steel et al. (1997). For interpreting the status of plant nutrients in soil as deficient, marginal, adequate and high nutrient status a generalized guideline developed by Ryan et al. (2001) was followed.

Results and Discussion

Soil Characteristics

Among the selected soil series, Missa, Pirsabak and Rawalpindi belong to soil order Inceptisol, Guliana, Balkasar and Chakwal belongs to Alfisols, Rajar to Entisols and Satwal to Veritisols (Table 1).

These soil series fall in slightly (Pirsabak, Guliana, Balkasar, Rawalpindi and Chakwal), moderately (Missa) and severely eroded (Rajar) class except Satwal soil series that has accumulation of soil from eroded fields.

The data on soil characteristics are shown in Table 2. In surface soil, the highest soil pH of 7.94 was observed in Satwal soil series and the lowest pH of 7.36 in Rawalpindi soils. In subsoil, the highest pH was 7.94 for Chakwal soil series and the lowest was 7.47 for Rawalpindi soil series. The soil pH in subsoil was

Table 1: *Physical characteristics, classification and parent material of selected soil series at Gujar Khan area*

Soil series	Textural class	Parent material*	Soil order	Erosion class
Missa	Silt loam	Loess	Inceptisol	Moderately eroded
PirSabak	Silt loam	Loess	Inceptisol	Slightly eroded
Guliana	Silty clay Loam	Loess	Alfisol	Slightly eroded
Rajar	Silty clay loam	Loess	Entisol	Severely eroded
Balkasar	Sandy clay Loam	Sand stone	Alfisol	Slightly eroded
Rawalpindi	Loam	Loess	Inceptisol	Slightly eroded
Chakwal	Loam	Loess	Alfisol	Slightly eroded
Satwal	Sandy clay loam	Sand stone	Vertisol	Accumulation of soil from eroded soils

Source: *(Nizami et al., 2004)*

Table 2: *Soil characteristics of different soil series in Gujar Khan area*

Soil Characteristics	Soil depth (cm)	Missa (11)	Pirsabak (2)	Guliana (9)	Rajar (8)	Balkasar (2)	Rawalpindi (4)	Chakwal (3)	Satwal (1)
$pH_{1:1}$	0-15	7.58±0.16	7.43±0.06	7.64±0.21	7.74±0.24	7.58±0.04	7.36±0.11	7.86±0.04	7.94
	30-45	7.66±0.26	7.49±0.01	7.71±0.30	7.84±0.25	7.49±0.01	7.47±0.18	7.94±0.05	7.75
$EC_{1:1}$ (dSm^{-1})	0-15	0.35±0.12	0.36±0.01	0.29±0.10	0.35±0.25	0.28±0.00	0.22±0.08	0.38±0.05	0.43
	30-45	0.24±0.05	0.25±0.09	0.22±0.05	0.21±0.04	0.26±0.09	0.22±0.06	0.28±0.02	0.27
$CaCO_3$ (%)	0-15	7.59±6.34	1.00±1.41	1.17±0.95	9.22±5.48	2.75±3.18	1.11±1.51	2.57±0.93	1.50
	30-45	9.43±6.35	0.28±0.32	2.08±4.15	9.67±5.13	0.28±0.32	0.60±0.90	3.83±2.02	2.00
OM (%)	0-15	1.25±0.38	1.27±0.90	1.09±0.39	1.10±0.37	1.06±0.62	0.89±0.17	0.99±0.23	0.92
	30-45	1.04±0.53	0.93±0.94	0.74±0.32	0.67±0.38	0.93±0.94	0.62±0.15	0.75±0.09	0.57

Number of soil series sampled in parentheses; ± standard deviation of the mean

generally higher than in surface soil. The EC values in all soil samples were below 4 dS m^{-1} indicating that all these soils were free of salinity, in both the surface and sub soils. The highest (0.43 dS m^{-1}) and the lowest (0.22 dS m^{-1}) surface soil $EC_{1:1}$ was recorded for Satwal and Rawalpinid soil series, respectively. In subsoil the maximum value (0.28 dS m^{-1}) was recorded for Chakwal and minimum value (0.21 dS m^{-1}) was recorded for Chakwal and Rajar soil series. The average $EC_{1:1}$ was 0.32 dSm^{-1} for surface soil and 0.23 dS m^{-1} for subsoil. There was small difference between the $EC_{1:1}$ of surface soil and subsoil, it could be due to the reason that the surface soil had very little amount of salts to leach down in the sub surface soil.

The highest (9.22%) and the lowest (1.11%) surface soil free lime contents ($CaCO_3$) were obtained in Rajar and Rawalpinid soil series, respectively. Similarly, the highest (9.67%) and the lowest (0.28%) subsoil values were recorded for Rajar and Balkassar / Pirsabak soil series, respectively. The highest content of OM was 1.27% while the lowest were 0.89% in Pirsabak and Rawalpindi soil series, respectively. Whereas, in the subsoil, the highest (1.04%) and the lowest (0.57%) OM contents were observed for Missa and Satwal soil series, respectively. The mean OM contents were 1.11% in surface soil and 0.79% in subsoil. Subsoil contains less OM than surface soil at both areas.

Soils of Pothwar plataeu are calcareous in nature (Ali, 1967) causing a high pH that is further increased with erosion. These results are in conformity with the findings of Shafiq et al. (2005) and Ahmad and Rashid (2003) who reported alkaline pH of Pothwar soils. Severely and moderately eroded soil series had more free lime contents than slightly eroded soil series. Infact, the $CaCO_3$ contents increases with erosion (Miller et al., 1984; Cihacek and Swan., 1994). The soils of Pothwar plateau inherited $CaCO_3$ contents from their parent materials (Nizami et al., 2004). Shaheen et al. (2008) mentioned the deficiency of organic matter in Pothwar plateau soils as studied in tehsil Fatehjang area. The soil erosion is a major factor in land degradation, reduction of fertility and organic matter content of soils (Khan et al., 2003; Langdale et al., 1985). Atreya et al. (2005) stated that much of the soil OM loss from farm fields is associated with the eroded sediments. Thus, higher the soil loss higher will be the soil OM loss. Many studies have proved the importance of SOM to the physico-chemical properties of soil (Materechera, 2009; Wuddivira et al., 2009) and erosion susceptibility (Auerswald et al., 2003; Tejada and Gonzalez, 2007).

Surface soil loss with water erosion, no crop residue recycling and inadequate fertilizer use have led to the reduced content of soil OM throughout the Pothwar Plateau (Rashid et al., 1997).

Soil Macronutrients

The highest surface soil NO_3-N content was 5.23 mg kg^{-1} in Missa soil series while the lowest NO_3-N content obtained was 2.77 mg kg^{-1} in Satwal soils (Table 3).

The highest subsoil NO_3-N content recorded was 4.14 mg kg^{-1} in Rawalpindi soil series and the lowest value 1.03 mg kg^{-1} was observed in Balkassar series. All soil series had 100% deficiency of NO_3-N (Figure 2) except in Missa soil series, in which 9% of surface soil samples were recorded to have marginal soil NO_3-N status. On the overall, 97% of the surface soil samples and 100% of the subsoil samples were deficient in N contents. Subsoil has less NO_3-N than surface soil.

The soil P in the surface soil samples showed the highest P contents of 1.67 mg kg^{-1} in Balkassar soil series while the lowest P contents of 0.76 mg kg^{-1} were in Satwal soils (Table 3). In case of subsoil, the maximum P contents were 1.22 mg kg^{-1} and the minimum P content was 0.22 mg kg^{-1} in Missa and Satwal soil series, respectively. In study area only 9% surface soils of Missa soil series showed adequate P and rest of soils were having 100% deficiency of P contents (Figure 2). As a whole, 95% soil samples of surface soil and 100% of subsoil were deficient in Phosphorus.

The highest and the lowest surface soil K contents were 92 and 48 mg kg^{-1} in Rajar and Balkassar soil series, respectively (Table 3). In the subsoil, the maximum K (74 mg kg^{-1}) was found in Guliana soil series and the minimum K (42 mg kg^{-1}) was recorded for Balkassar soils. The deficiency of K contents in surface soil was not high however, 36% subsoil samples of Missa soil series and 100% of all other series were deficient in K contents (Figure 2). On overall basis, 32% surface soil samples were deficient, 63% were marginal and 5% were having adequate in K contents. In case of subsoil, 48% samples were deficient and 52% were having marginal amount of K contents.

Loss of OM cause impoverishment of soil resources of several elements essential for plant growth (Hadda and Arora 2006). The lower NO_3-N in subsoil could be due to more runoff losses with high intensity monsoon rainfalls and that NO_3-N was leached down in fewer amounts. The low NO_3-N in soils of Pothwar plateau is also because of imbalanced use of fertilizers. A considerable number of studies have also shown the deficiency of P in Pakistani soils (Nasir et al., 1990; Rashid, 1994). Xiaoyan et al. (2003) reported that P is often fixed on soil particles and also migrates with

Table 3: *Status of macro and micro-nutrients in different soil series of Gujar Khan area*

Nutrients (mg kg^{-1})	Soil depth (cm)	Missa (11)	Pirsabak (2)	Guliana (9)	Rajar (8)	Balkasar (2)	Rawalpindi (4)	Chakwal (3)	Satwal (1)
NO_3-N	0-15	5.23 ± 3.13	4.99 ± 1.20	4.39 ± 2.66	3.01 ± 1.09	3.19 ± 1.12	2.84 ± 0.96	3.04 ± 1.10	2.77
	30-45	2.90 ± 1.15	3.40 ± 3.37	2.58 ± 1.85	2.38 ± 1.77	1.03 ± 0.11	4.14 ± 1.03	1.85 ± 0.54	2.57
P	0-15	1.64 ± 1.71	1.27 ± 0.18	0.91 ± 0.55	0.95 ± 0.97	1.67 ± 0.79	0.82 ± 0.32	1.20 ± 1.31	0.76
	30-45	1.22 ± 1.17	1.03 ± 0.16	0.62 ± 0.97	0.46 ± 0.51	0.83 ± 0.05	0.88 ± 0.63	0.23 ± 0.21	0.22
K	0-15	76 ± 27.97	68 ± 31.11	78 ± 25.22	92 ± 36.78	48 ± 22.63	61 ± 5.51	61 ± 3.06	70
	30-45	63 ± 14.23	61 ± 15.56	74 ± 20.11	73 ± 18.30	42 ± 11.31	53 ± 4.12	49 ± 7.57	48
Zn	0-15	1.94 ± 0.35	0.59 ± 0.35	0.38 ± 0.33	0.22 ± 0.12	0.46 ± 0.55	0.33 ± 0.12	0.29 ± 0.14	0.43
	30-45	0.21 ± 0.22	0.15 ± 0.16	0.21 ± 0.13	0.13 ± 0.10	0.16 ± 0.21	0.18 ± 0.02	0.15 ± 0.07	0.35
Cu	0-15	1.94 ± 1.11	1.36 ± 0.03	2.88 ± 2.18	1.52 ± 0.73	1.28 ± 0.09	2.16 ± 0.27	2.32 ± 0.25	2.30
	30-45	2.41 ± 2.37	1.53 ± 0.32	2.03 ± 0.77	1.43 ± 0.95	0.87 ± 0.32	2.09 ± 0.47	2.14 ± 0.11	1.45
Fe	0-15	4.46 ± 1.21	4.05 ± 1.56	4.88 ± 1.53	4.23 ± 0.80	2.37 ± 0.06	4.44 ± 1.13	2.77 ± 0.28	3.59
	30-45	4.85 ± 2.78	3.98 ± 1.68	4.14 ± 0.99	4.62 ± 2.30	1.45 ± 0.18	4.38 ± 0.55	2.85 ± 0.49	3.78
Mn	0-15	4.42 ± 1.95	4.65 ± 0.04	4.27 ± 1.16	4.10 ± 1.28	3.94 ± 0.92	5.23 ± 0.83	2.71 ± 0.43	3.21
	30-45	3.48 ± 1.24	2.30 ± 0.21	3.15 ± 1.17	3.47 ± 2.42	2.86 ± 0.42	3.32 ± 0.55	2.08 ± 0.05	2.93
B	0-15	0.27 ± 0.13	0.44 ± 0.13	0.46 ± 0.24	0.22 ± 0.15	0.43 ± 0.33	0.58 ± 0.10	0.17 ± 0.12	0.12
	30-45	0.38 ± 0.27	0.58 ± 0.25	0.31 ± 0.19	0.16 ± 0.16	0.43 ± 0.37	0.57 ± 0.07	0.06 ± 0.03	0.07

Number of soil series sampled in parentheses; ± standard deviation of the mean

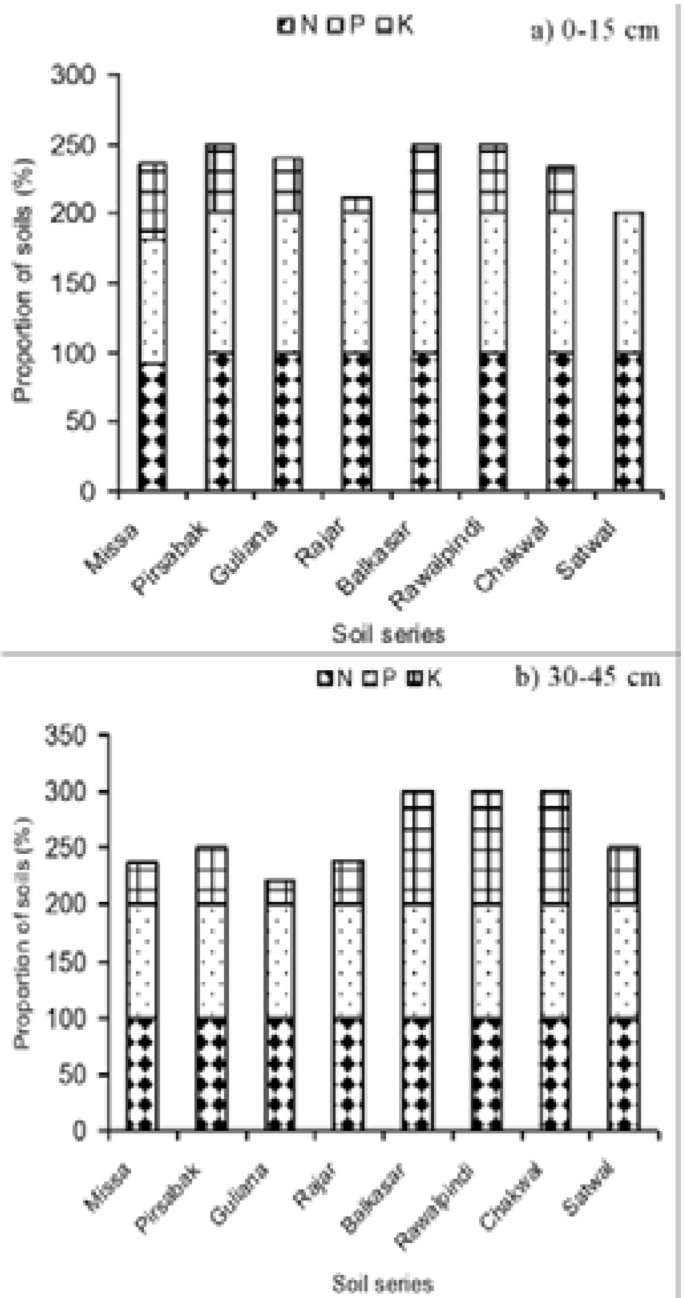

Figure 2: *Extent of macro-nutrient deficiencies in selected soil series of Gujar Khan area*

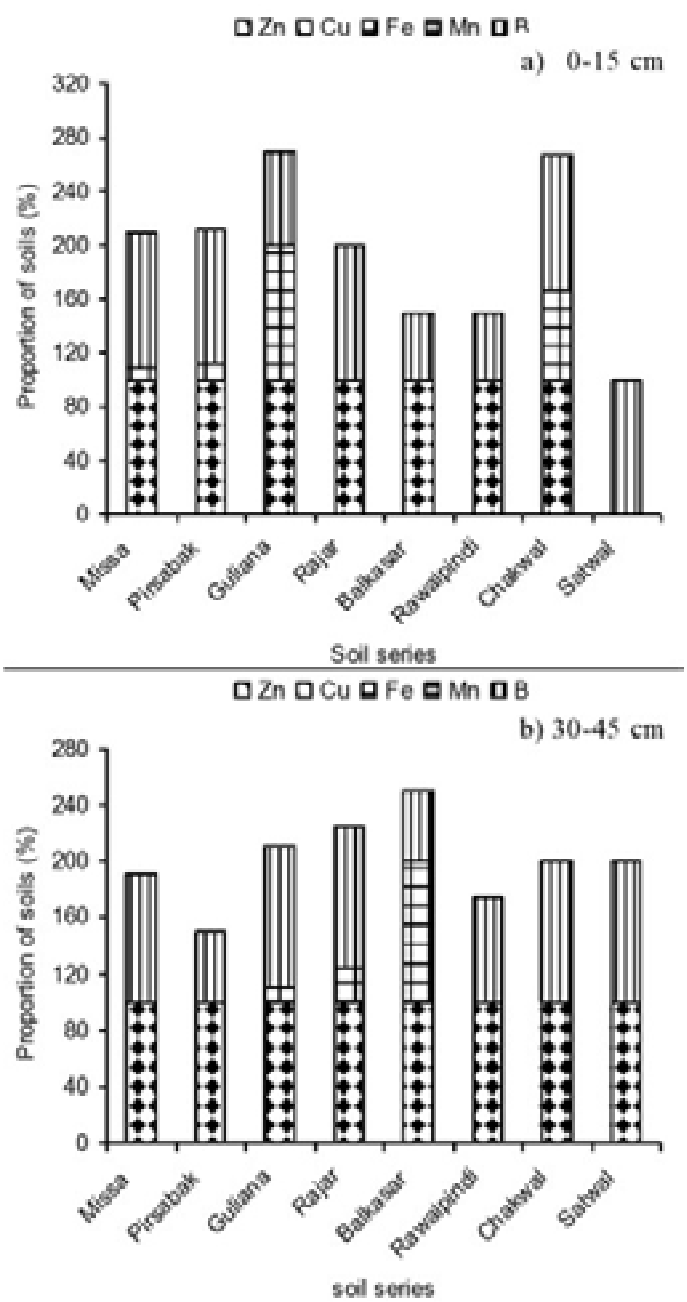

Figure 3: *Extent of micro-nutrient deficiencies in selected soil series of Gujar Khan area*

soil separates. Soil conservation can control the loss of P to some extent. In soils with pH 7-8, the soluble H_2PO_4 quickly reacts with calcium to form products of decreased solubility. The pH also affects the applied P fertilizer by changing it into extremely insoluble calcium phosphate form. This problem is common in calcareous soils (Ali et al., 2000). Our results are in agreement with those of Rashid and Shafiq (2002) and Rashid (1994) who reported 20% K deficiency in sorghum fields and 20% deficiency in wheat fields of Pothwar area. In all soil series K contents were more in surface soil than in subsoil. Soils of Pakistan are generally considered rich in mica minerals, which are the major source of natural potassium (Bajwa and Rehman., 1996). The total annual loss of N, P and K in the eroded soil was dependent on total amount of soil loss and generally, higher the soil loss higher will be the nutrient loss (Atreya et al., 2005). Abagale et al. (2012) reported higher nutrients status of non-eroded sites than eroded sites.

Soil Micronutrients

The greatest surface soil Zn contents was 4.30 mg kg^{-1} in Satwal and the lowest Zn contents recorded was 0.22 mg kg^{-1} in Rajar soil series (Table 3). Likewise, the maximum subsoil Zn contents recorded were 0.35 mg kg^{-1} in Satwal and the minimum was 0.13 mg kg^{-1} in Rajar soils. All soil series at both soil depths were deficient in Zn contents except 100% surface soil sample of Satwal that had adequate amount of Zn (Figure 3). However, on the average, 97% surface soil samples and 100% subsoil samples were deficient in Zn contents.

The highest Cu content of surface soil was 4.30 mg kg^{-1} in Satwal while the lowest was 1.28 mg kg^{-1} in Balkassar soil series (Table 3). The highest Cu content of subsoil obtained was 2.41 mg kg^{-1} for Missa and the lowest 0.35 mg kg^{-1} for Satwal soils. At both soil depths none of soil sample found deficient of Cu contents (Figure 3) and on an average, in both layers 92% soils were having adequate and 8% were having marginal amount of Cu contents.

The highest Fe recorded was 4.88 mg kg^{-1} in Guliana and the lowest was 2.37 mg kg^{-1} in Balkassar soils (Table 3). In subsoil the highest Fe observed was 4.85 mg kg^{-1} in Missa soil series and the lowest obtained was 1.45 mg kg^{-1} in Balkassar soil series. At both depths 100% of Balkassar were deficient in Fe contents (Figure 3). As a whole, Fe was deficient in 20%, marginal in 53% and adequate in 92% surface soils. Similarly, 22% subsoil samples were deficient, 52% marginal and 2% adequate in Fe contents.

The highest surface soil Mn of 5.23 mg kg^{-1} was observed in Rawalpindi soil series while the lowest Mn content of 2.71 mg kg^{-1} in Chakwal soils (Table 3). Similarly, at subsoil maximum Mn content was 3.48 mg kg^{-1} in Missa soil series and minimum Mn content was 2.08 mg kg^{-1} in Chakwal soils. None of soil series was Mn deficient (Figure 3). Manganese contents were adequate and higher concentration at surface soil than subsoil. The soils of Pothwar have sufficient Mn contents and its deficiency is not wide spread like Zn, B and Fe.

The maximum surface soil B contents was 0.58 mg kg^{-1} in Rawalpindi soil series, whereas, the minimum B content was 0.12 mg kg^{-1} in Satwal soils (Table 3). The highest subsoil B was 0.58 mg kg^{-1} in Pirsabak soil series while the lowest B was 0.06 mg kg^{-1} for Chakwal soils. Among soil series, 30% soil sample of Guliana soil series were recorded to have adequate amount of soil B contents while 50% soil samples of Rawalpindi soil series and 50% of Balkassar were having adequate amount of soil B contents. In subsoil samples, 9% of Missa, 50% of Pirsabak, 50% of Balkassar, 25% of Rawalpindi soil series were having adequate amount of B contents. On the average, 85% surface soil samples were deficient, and 15% were having adequate B contents. Likewise, 90% subsoil samples were deficient and 10% were having adequate amount of B contents. All other soil series at both depths were deficient in soil B contents.

In all soil series deficiency of Zn is due to erosion, high $CaCO_3$ that results alkaline pH and low organic matter (Rashid and Ryan, 2004). According to survey conducted by Rashid and Rafique (1996), 66% of rain-fed zone of Punjab had deficient Zn contents. Zia et al. (2004) reported that the information obtained from 329 soil samples collected from various depths of rain-fed areas during the period of seven months revealed widespread deficiencies of Zn. Zinc deficiency is most prevalent in intensively cropped light textured, alkaline soils (Takkar, 1996). Zinc solubility is highly pH dependent and decreases by a factor of 100 for each unit pH increases (Lindsay and Norwell, 1979). In soils of Pothwar plateau the nutrient removals far exceed than nutrient addition and it caused negative nutrient balances in the soil. On the overall, soils of Pothwar area do not have deficiency of Cu contents (Rashid, 1996) to a greater extent. Soil Cu availability is affected by sandy soils, high pH and low OM. Availability of Cu decreases with increasing pH because of greatly diminished solubility and increased sorption on soil colloids. Its availability decreases rapidly above pH 7 and Cu deficiency is believed to be a frequent problem in alkaline soils formed on a calcareous parent material (Katyal and Randhawa, 1983). In Pakistan Cu deficiency is less common than that of Zn, Fe and B. Copper is more strongly bound than Zn, Fe and B on organic matter so its deficiency is comparatively more on organic soils. In some soil series Fe contents were found greater in subsoil that might be due to leaching. Keren and Bingham (1985) also reported leaching of micronutrients with torrential monsoon rains. Most Pakistani soils contain adequate available Mn (Rashid, 1996) and crop response to Mn fertilizer is rare. Pakistani soils have deficiency of B (Rashid, 1993). The B availability decreases with increasing soil pH; thus it is often inadequately available in calcareous and sandy soils.

Present study shows higher variation of soil macro and micro nutrients even within same soil series that can be due to different rate of erosion and farmer practices. To recommend rate of fertilizers, it is required to know nature and severity of nutrients disorder. These soils are not homogeneous but variable in their nutrient status and, hence, in crop productivity.

Conclusions

The fertility of studied area was diverse in even same soil series belong to same soil erosion classes. This variation is attributed to different farmer's practices of farming and intensity of erosion. The NO_3-N, P, B and Zn were deficient while K, Cu, Fe and Mn were present in sufficient range. The deficiency of nutrients is attributed to high pH, calcareousness and less addition of inputs against their uptake by the crops. Soil erosion and its effect on productivity vary in their extent and seriousness. However, policies regarding soil and water conservation practices are needed to combat the severity of soil erosion, so that local communities may continue to rely on their soil resources in the future.

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