

Research Article

Characterization and distribution of rainfed soils of district Chakwal for sustainable agricultural production

Rizwan Latif¹, Abdul Latif^{2*}, Muhammad Arsalan², Madeeha Khan³, Rehmat Ullah⁴, Muhammad Bilal⁴, Azhar Mahmood Aulakh³, Sabir Hussain Shah⁵ and Muhammad Abdullah⁶

1. Soil and Water Testing Laboratory, Talagang Road, Chakwal, Pakistan

2. Barani Agricultural Research Institute Chakwal, Pakistan

3. Soil and Water Conservation Research Institute, Chakwal, Pakistan

4. Soil and Water Testing Laboratory, Dera Ghazi Khan, Pakistan

5. Department of Agricultural Sciences, The Allama Iqbal Open University, Islamabad, Pakistan

6. Department of Soil Science, Arid Agriculture University Rawalpindi, Pakistan

*Corresponding author's email: farhanqais@gmail.com

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Abstract

A study aimed to improve agricultural productivity and soil management by offering consulting services. From 2018 to 2020, 5008 soil samples were collected from Chakwal villages. Standard testing techniques were used to assess soil characterization and distribution, including EC, pH, organic matter, phosphorus, extractable potassium, and texture. Soil analysis revealed 99.18% of soils were normal, with a pH between 7.5 and 8.5, low organic matter, and inadequate phosphorus. Soil texture was medium, and farmers were advised to improve production through crop rotation, organic manuring, balanced fertilizer use, and integrated plant nutrition management.

Keywords: Chakwal; Characterization; Recommendations; Soil; Sustainable agricultural

Introduction

The northern region of Punjab has the rainfed district of Chakwal. Winter temperatures range from 4 to 25 degrees Celsius, while summer temperatures typically range from 20 to 45 degrees. The district receives 500 mm to 1000 mm of rain on average each year. Its topography varies, ranging from relatively level terrain to undulating terrain with exposed rocks or heavily eroded areas with intricate cuts and

enormous gullies [1]. Agriculture is primarily dependent on rainfall, and insufficient rainfall can lead to drought [2]. Only 8% of the agricultural area is irrigated by canals, tube wells, and wells. The district's primary crops are wheat and groundnuts, but there are also patches of maize, chickpea, sorghum, millet, canola, and guar. The majority of the soils in the Chakwal district are light-textured (sandy loam) to medium-textured (loam) [3, 4]. Due

to unpredictable rainfall patterns, soil erosion, tiny land holdings, and dispersed fields, farmers are hesitant to pursue agriculture as a full-time career. The country's population is growing at a very rapid pace, hence improving agricultural productivity per acre is urgently needed. Maintaining soil health through balanced fertilizer use, integrated nutrient management, etc., is crucial for this. A study was designed with the following goals in mind, taking into account the significance of soils for agricultural production: (1) to give farmers site-specific advice or suggestions based on soil analysis for improved agricultural output, and (2) to give researchers a summary of the soil properties in district Chakwal.

Materials and Methods

Study area description

In Pakistan's northern Punjab, the Chakwal district is located in Potohar (32.8322° N, 72.6151° E). District Chakwal's water quality varies due to the presence of hills, variations in slope and geography, and variations in rainfall patterns. For the sake of farmers, the Punjabi government set up various laboratories in each district. By analyzing soil and water samples, the Soil and Water Testing Laboratory in Chakwal also helps farmers. In this case, underground water samples were gathered from five tehsils in the district of Chakwal (Choa Saidan Shah, Kallar Kahar, Talagang, Lawa, and Chakwal). These samples were then examined for suitability in order to assess their quality, and recommendations were made in light of the findings. The map of Chakwal is presented in (Fig. 1).

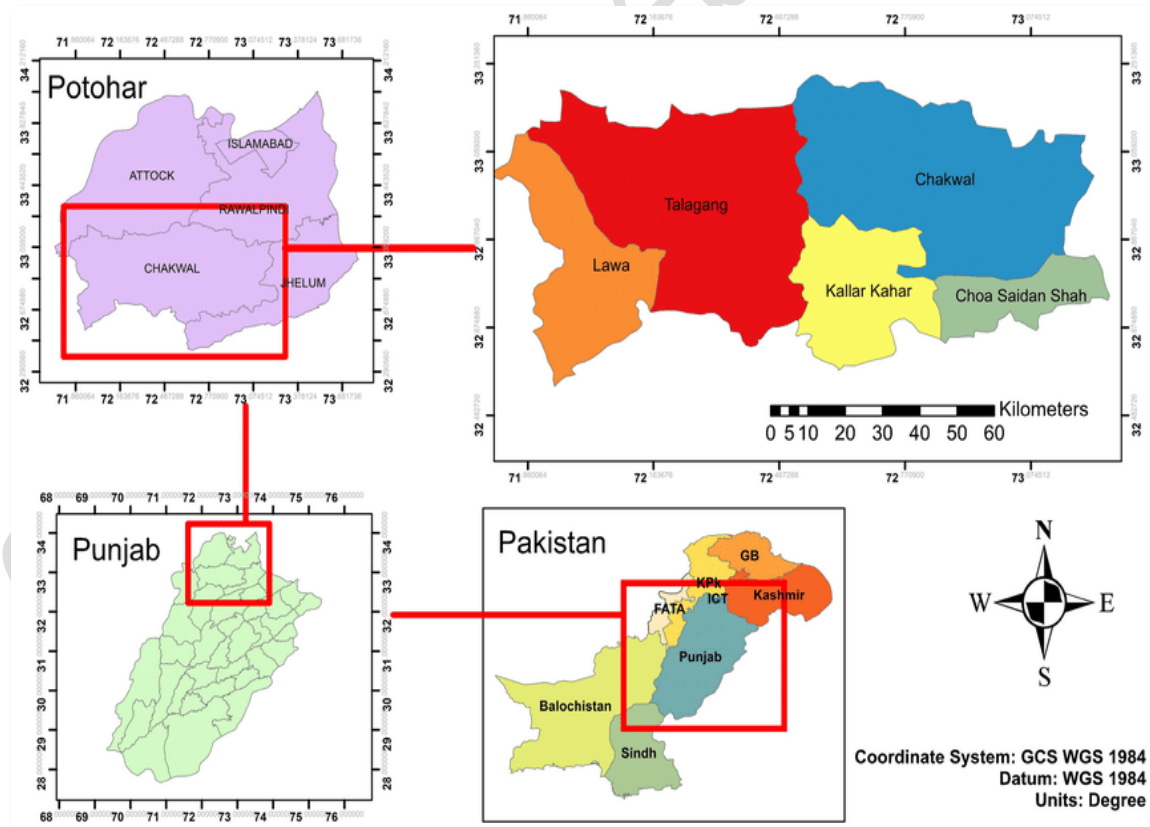


Figure 1: Map of Chakwal showing its tehsils Collection and analysis of soil samples

The farmer's field provided the 5008 soil samples that were gathered. The samples were held in airtight plastic jars at the Soil and Water Testing Laboratory in Chakwal for additional soil analysis after being air dried, crushed, and sieved through a 2 mm mesh sieve. All sites's soil samples were subjected to chemical analysis using standard procedures, as advised by the Punjab Agriculture Research Board. Microsoft Excel 2007 was used to statistically analyze the data. The following formula was used to calculate the Nutrient Index (NI) [5].

$$\text{Nutrient Index (NI)} = ((N_i \times 1) + (N_m \times 2) + (N_h \times 3)) / N_t$$

Where N_t = Total number of samples analyzed in a given area N_i = Number of samples falling in low category of given nutrient, N_m = Number of samples falling in medium category of given nutrient, N_h = Number of samples falling in high category of given nutrient.

The criteria used to categorize the soil samples for various classes of texture, salinity/ sodicity and nutrients are given in (Table 1 & 2) [6].

Table 1: The criteria used to categorize the soil samples for various classes of texture

Saturation % age	Textural Class
0-20 %	Sand
21-30 %	Sandy Loam
31-45 %	Loam
46-65 %	Clay Loam
66-100 %	Clay

Table 2: The criteria used to categorize the soil samples for various classes of salinity/sodicity

Status	E.C (d Sm ⁻¹)	Soil pH
Normal	< 4.0	< 8.5
Saline	> 4.0	< 8.5
Saline Sodic	> 4.0	>8.5
Sodic	< 4.0	> 8.5

Results and Discussion

Overall 5008 Number of soil samples were analyzed for all above mentioned parameters. Based upon the soil analysis and critical limits according to standard testing methods (STMs) for various characteristics the distribution / categorization of soil samples is given as under:

Tehsil Chakwal

A) Soil physico-chemical analysis

The electrical conductivity (EC) furnished in the (Table 3). The EC of the soil samples

varied from 0.12 to 7.6 dSm⁻¹ with an average value of 0.99 dS m⁻¹. The soil pH ranged from 7.6 to 9.4 and average value was found to be 7.96. Chakwal soils have an alkaline pH of 7.7–7.8, according to [7] Latif et al. The region appears to be immune from the threat of salinity and sodicity when average values are taken into account. Organic matter (OM) ranged from 0.41 to 1.54 and average value 0.85 Pakistan's soils are quite deficient in organic matter. Generally, Punjab soils had less than 1%

organic carbon [8]. P ranged from 3.70 to 31.19 and average value 7.58. Similarly, K ranged from 60 to 280 and average value 122. In Chakwal soils, the researchers [9] found that K was within a reasonable range (80–180 mg kg⁻¹). However, Rashid and co-workers [10] reported low K contents in 30% surface soils of groundnut growing areas of Chakwal.

B) Soil nutrient index (NI)

Soil fertility level was measured in terms of NI values. The NI values (Table 4) in present study indicated that SOM and P levels were low and K level (1.87) was found in medium range. Nutrient index value of <1.5 is taken as low, values between 1.5 -2.5 indicates medium and >2.5 as higher fertility status of the given area [11].

Table 3: Minimum, maximum and mean values of different soil parameters of tehsil Chakwal

Parameters	Average	SD	MAX	MIN
EC (dS m ⁻¹)	0.994123	0.433586	7.6	0.12
pH	7.952368	1.805157	9.4	7.6
O.M (%)	0.84395	0.680825	1.54	0.41
Av. P (mg kg ⁻¹)	7.571921	6.758125	31.19	3.7
Av. K (mg kg ⁻¹)	122.9019	56.1699	280	60
Saturation %	33.12075	4.267049	64	24

Table 4: Soil fertility index of soils in Tehsil Chakwal

Parameters	Total samples	Low	Med	high	NI
Organic matter (%)	1498	1168	305	25	1.23
Av P (mg kg ⁻¹)	1498	958	495	45	1.39
Av K (mg kg ⁻¹)	1498	325	948	225	1.26

Tehsil Talagang

A) Soil physico-chemical analysis

The Electrical Conductivity (EC) furnished in the (Table 5). The EC of the soil samples varied from 0.1 to 1.6 dSm⁻¹ with an average value of 0.97 dS m⁻¹. The soil pH ranged from 7 to 9.6 and average value was found to be 7.91. OM ranged from 0.14 to 1.82 and average value 0.85. According to Kalpana et al [12], the decrease in SOM is caused by crops that are farmed with little or no addition of plant and animal wastes. P

ranged from 1.30 to 17.3 and average value 6.38. Similarly, K ranged from 100 to 430 and average value 110.36.

Soil nutrient index (NI)

Soil fertility level was measured in terms of NI values. The NI values (Table 6) in present study indicated that SOM and P levels were low and K level (1.) was found in medium range. Nutrient index value of <1.5 is taken as low, values between 1.5 -2.5 indicates medium and >2.5 as higher fertility status of the given area [11].

Table 5: Minimum, maximum and mean values of different soil parameters of tehsil Talagang

Parameters	Average	SD	MAX	MIN
EC (dS m ⁻¹)	0.972281	0.139226	1.6	0.1
pH	7.913905	0.203482	9.6	7
O.M (%)	0.734851	1.714863	1.82	0.14
Av. P (mg kg ⁻¹)	6.379632	2.920114	17.3	1.3
Av. K (mg kg ⁻¹)	110.3618	5.643447	430	100
Saturation %	31.87786	5.146095	68	21

Table 6: Soil fertility index of soils in tehsil Talagang

Parameters	Total samples	Low	Med	high	NI
Organic matter (%)	1441	963	450	28	1.35
Av P (mg kg ⁻¹)	1441	1012	397	32	1.31
Av K (mg kg ⁻¹)	1441	140	1236	78	1.95

Tehsil Kalar Kahar

Soil physico-chemical analysis

The Electrical Conductivity (EC) furnished in the (Table 7). The EC of the soil samples varied from 0.36 to 1.4 dSm⁻¹ with an average value of 0.96 dS m⁻¹. The low status of EC may be due to leaching of salts to lower horizons as suggested by kalpana et al. [12]. The soil pH ranged from 7.1 to 8.4 and average value was found to be 7.89. OM ranged from 0.20 to 2.51 and average value 0.74. P ranged from 1.30 to 19.8 and

average value 6.38. Similarly, K ranged from 18 to 300 and average value 102.

Soil nutrient index (NI)

Soil fertility level was measured in terms of NI values. The NI values (Table 8) in present study indicated that SOM and P levels were low and K level (1.93) was found in medium range. Nutrient index value of <1.5 is taken as low, values between 1.5 -2.5 indicates medium and >2.5 as higher fertility status of the given area [11].

Table 7: Minimum, maximum and mean values of different soil parameters of tehsil Kalar Kahar

Parameters	Average	SD	MAX	MIN
EC (dS m ⁻¹)	0.96	0.137352	1.4	0.36
pH	7.89	0.186528	8.4	7.1
O.M (%)	0.74	0.383522	2.51	0.2
Av. P (mg kg ⁻¹)	6.13	2.656713	19.8	1.3
Av. K (mg kg ⁻¹)	102	46.78368	300	18
Saturation %	34.14	4.185757	42	24

Table 8: Soil fertility index of soils in tehsil Kalar Kahar

Parameters	Total samples	Low	Med	high	NI
Organic matter (%)	450	355	63	32	1.28
Av P (mg kg ⁻¹)	450	359	80	11	1.22
Av K (mg kg ⁻¹)	450	42	306	72	1.93

Tehsil Choa Saiden Shah**A) Soil physico-chemical analysis**

The electrical Conductivity (EC) furnished in the (Table 9). The EC of the soil samples varied from 0.74 to 6.9 dSm⁻¹ with an average value of 1.46 dS m⁻¹. The soil pH ranged from 7.89 to 9.86 and average value was found to be 7.91. OM ranged from 0.48 to 1.87 and average value 1.10. P ranged from 4.30 to 18.3 and average value 10.59. The reasons for poor available phosphorus is that farmers do not apply phosphatic fertilizers to crops according to recommendations and only nitrogenous

fertilizers are applied due to price hike of phosphatic fertilizers [13]. Similarly, K ranged from 80 to 380 and average value 168.95.

Soil nutrient index (NI)

Soil fertility level was measured in terms of NI values. The NI values (Table 10) in present study indicated that SOM (1.78), P (2.08) K (2.38) level were found in medium range. Nutrient index value of <1.5 is taken as low, values between 1.5 -2.5 indicates medium and >2.5 as higher fertility status of the given area [11].

Table 9: Minimum, maximum and mean values of different soil parameters of tehsil Choa Saiden Shah

Parameters	Average	SD	MAX	MIN
EC (dS m ⁻¹)	1.467742	1.283108	6.9	0.74
pH	7.912581	0.615483	9.86	1.89
O.M (%)	1.100968	0.30781	1.87	0.48
Av. P (mg kg ⁻¹)	10.59524	3.30765	18.3	4.3
Av. K (mg kg ⁻¹)	168.9516	7.428102	380	80
Saturation %	36.83871	3.621048	45	30

Table 10: Soil fertility Index of soils in tehsil Choa S Shah

Parameters	Total samples	Low	Med	high	NI
Organic matter (%)	123	79	21	32	1.78
Av P (mg kg ⁻¹)	123	13	89	21	2.08
Av K (mg kg ⁻¹)	123	0	84	39	2.31

Tehsil Lawa**Soil physico-chemical analysis**

The Electrical Conductivity (EC) furnished in the (Table 11). The EC of the soil samples varied from 0.74 to 1.40 dSm⁻¹ with an average value of 0.96 dS m⁻¹. The soil pH

ranged from 7.35 to 8.28 and average value was found to be 7.89. OM ranged from 0.27 to 0.85 and average value 0.61. The low Om content could be due to the OM degradation and removal taken place at faster rate coupled with low vegetation cover thereby,

leaving less changes of accumulation of organic matter in the soil as reported by Kalpana et al. [12]. P ranged from 2.50 to 7.90 and average value 5.64. Similarly, K ranged from 10 to 140 and average value 91.40.

Soil nutrient index (NI)

Soil fertility level was measured in terms of NI values. The NI values (Table 12) in present study indicated that SOM (1.07), P (1.11) K (1.68) level were found in low range. Nutrient index value of <1.5 is taken as low, values between 1.5 -2.5 indicates medium and >2.5 as higher fertility status of the given area [11].

Table 11: Minimum, maximum and mean values of different soil parameters of tehsil Lawa

Parameters	Average	SD	MAX	MIN
EC (dS m ⁻¹)	1.467742	1.283108	6.9	0.74
pH	7.912581	0.615483	9.86	1.89
O.M (%)	1.100968	0.30781	1.87	0.48
Av. P (mg kg ⁻¹)	10.59524	3.30765	18.3	4.3
Av. K (mg kg ⁻¹)	168.9516	7.428102	380	80
Saturation %	36.83871	3.621048	45	30

Table 12: Soil fertility index of soils in tehsil Lawa

Parameters	Total samples	Low	Med	high	NI
Organic matter (%)	136	129	5	2	1.07
Av P (mg Kg ⁻¹)	136	124	9	3	1.11
Av K (mg Kg ⁻¹)	136	64	72	7	1.68

Fertilizer Recommendations for Major Crops in Chakwal District

The soil fertility analysis of Chakwal district revealed distinct fertilizer requirements for various crops based on soil fertility levels (low, medium, and high). The primary rabi crops in the region include wheat and canola, while the main kharif crops are groundnut, mung, and mash. Fertilizer recommendations for these crops, based on soil health, are detailed in Table 13. For example, wheat requires N-P-K levels of 35-23-25 kg/acre for low fertility soils, 28-23-0 kg/acre for medium fertility soils, and 23-23-0 kg/acre for highly fertile soils. Groundnut, a key cash crop, showed N-P-K recommendations of 12-23-25 kg/acre for low fertility soils, 09-18-18 kg/acre for medium fertility soils, and 07-12-12 kg/acre for high fertility soils. Similarly, lentil crops

required 14-27-0 kg/acre for low fertility soils, 10-23-0 kg/acre for medium fertility soils, and 10-14-0 kg/acre for high fertility soils. Mung and mash, the predominant kharif crops, had N-P-K recommendations of 14-23-12 kg/acre for low fertility soils, 9-23-12 kg/acre for medium fertility soils, and 9-23-0 kg/acre for high fertility soils. These recommendations were formulated after extensive soil testing and categorization, taking into account indigenous soil fertility and rainfall patterns. The results highlight the importance of site-specific fertilizer application, balanced nutrient management, and the integration of organic manures for sustainable agricultural production. This data provides a valuable resource for farmers and researchers to optimize crop yields while maintaining long-term soil health.

Table 13: Fertilizer recommendations for various crops grown in district Chakwal

Sr No.	Major Crops of Chakwal district	Nitrogen (Kg/acre)			Phosphorus (Kg/acre)			Potash (Kg/acre)		
		Weak	Medium	Strong	Weak	Medium	Strong	Weak	Medium	Strong
2	Wheat (Barani)	35	28	23	23	23	23	25	0	0
4	Canola	46	35	23	23	23	23	0	0	0
5	Chickpea	14	10	10	27	23	14	0	0	0
6	Red Lentil	14	10	10	27	23	14	0	0	0
8	Groundnut	12	9	7	23	18	12	25	18	12
9	Mung/ Mash	14	9	7	23	18	12	0	0	0
12	Onion	57	46	35	35	23	23	25	25	25
14	Chili, cucumber ,Lady's Finger ,bitter gourd	35	23	23	35	23	23	0	0	0
15	Melon	65	46	35	35	23	23	25	25	25
16	Cauli Flower, Garlic	46	35	23	23	23	23	0	0	0
17	Radish , carrot , Turnip	23	23	14	23	18	14	0	0	0
18	Peas	10	7	7	35	23	18	0	0	0

Conclusion

This study also provides an overview of the soil properties of the Chakwal district, which will help researchers plan future experiments. The study shows the importance of fertilizer recommendations based on soil fertility levels and agroecological zones. The findings emphasize the need for balanced nutrient management and integrated approaches to enhance agricultural productivity in Chakwal district.

Authors' contributions

Conceived and designed the experiments: Rizwan Latif, performed the experiments: Rizwan Latif, Analyzed the data: Abdul Latif, contributed reagents/materials/analysis tools: M Arsalan, M Khan, R Ullah, M, Bilal, AM Aulakh, SH Shah & M Abdullah, wrote the paper: Abdul Latif

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