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REVEALING THE FERTILITY STATUS OF KHANEWAL DISTRICT'S LANDS THROUGH GIS-BASED STUDY

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ABSTRACT

A rapid increase in industrialization and urbanization and population growth requires expansion of agricultural area for food security and raise the importance of soil health assessment to ensure protection and sustainable use of agricultural lands according to their potential. For this purpose, use of digital soil mapping for the analysis of key physicochemical characteristics has been widely used. The GIS enabled the mapping of extensive areas. The purpose of this study is the spatial analysis of soil fertility indicators i.e., soil reaction (pH), Electrical Conductivity (EC), organic matter (OM), micro-macro {Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn), Boron (B)} nutrients in Khanewal districts using GIS-approaches. The result of study shows that soil pH and EC are normal for crop production while almost 95% of samples show low OM, 100% have low available phosphorous content, 33.3% have low K content, 71% have low Fe and 83% have low B content. Therefore, it was recommended that, to continuously incorporate farmyard manure, green manure, and crop residues into the soil over an extended period to address the organic matter deficiency. P, K, Fe and B deficient area should be fertilized with variable rate of respective fertilizer and soil should be periodically tested. It was recommended that the central parts of Khanewal district lands are cultivable as compared to boarder areas.

Keywords: Soil analysis, GIS, soil reaction, micro-macro nutrients, soil organic carbon,

INTRODUCTION

Earth is the first natural wealth that provides food to millions of people. However, rapid increased of population, urbanization and limited land resources constitutes to acute scarcity of land for food commodities. Globally, there are more than 800 million people who are chronically undernourished (Abdellatif *et al.,* 2021). Pakistan suffers from severe degree of hunger and malnutrition. 20.3% of the population is undernourished and large population face acute malnutrition. According to global hunger index 2019, Pakistan ranked 94th out of 117th countries (Hameed *et al.,* 2021; von Grebmer *et al.,* 2019). In order to fulfill the food demand of extensive population global world require strategic direction in agricultural expansion which highlight the importance of assessing soil fertility for optimal agricultural production (AbdelRahman *et al.,* 2021). Soil fertility, a critical factor for soil productivity refers to the ability of soil to support life and supply plant with essential nutrients (Nie *et al.,* 2016) it's a tool that help to determine the seasonal or annual requirement level of different fertilizers, along with forecasting potential increases or decreases on the basis of cropping pattern and intensity of specific area (Jamil *et al.,* 2021). Soil fertility evaluation, is foremost principle for land management. It not only aid in evaluating land productivity level but also facilitate the rationale development and utilization (Elnaggar *et al.,* 2016). Soil fertility can be considered in several ways, depending on type of land use but in all context, it mainly depends on numerous physico-chemical characteristics of soil includes, acidity, organic matter content, soil texture water holding capacity (Elnaggar *et al.,* 2016). In Pakistan, most of agricultural lands are nutrient deficient, 75-92% of Pakistan soils lack sufficient OM, 70-95% are deficient in P and 20-60% are low in K. Additionally micro-nutrient like Zn, Cu, Fe, Mn, and B deficiencies are becoming increasingly common in Pakistan soils particularly in orchard soils. (Akram *et al.,* 2014). Despite the inherently low soil fertility, crop yields can still be increased by 30-50% through the use of balanced fertilization (Akram *et al.,* 2014). On the basis of soil fertility status, fertilizer recommendations can be made to enhance the macro and micro nutrient content and for profitable production. For sustainable production it is a crucial requirement that inputs must be used according to fertility status of particular region (Jamil *et al.,* 2021). Multan division (Pakistan) is facing a severe deficiency of some mineral nutrients, which results in the low yield of crops particularly mango fruits. Mainly, most of the farmers are practicing intercropping in mango orchards with fodder crops, further exacerbating the nutrient supply to mango trees. For improved quality and better mango growth, application of macronutrients is not sufficient. In plants, micronutrients are required for different physiological and metabolic processes, and their deficiency affects a number of processes including hindered plant growth, productivity, and quality (Ahmad *et al.,* 2020). Multan division comprising of four districts, including Multan, Vehari, Khanewal, and Lodhran. The area of Khanewal lies between longitude 71° 56′41′′ E to 72° 50′ 17′′ E and latitude 29° 89′ 30′′ N to 30°72 ’85′′ N. District Khanewal boundary lies on the east by Sahiwal, on the west by Multan and Muzaffargarh, on the south by Vehari and Lodhran and the north by districts of Jhang and Toba tek singh. District Khanewal has the second largest railway station in the country, the Khanewal Junction. The area of district Khanewal is an alluvial plain and flat, which is an ideal area for agricultural activities. The district. Khanewal has a total area of 4,290.41 square kilo-meters divided into four tehsils, namely Jahanian, Mian Channu, Kabirwala, and Khanewal. Many canals are present here that irrigate this district. This irrigation network of canals makes the land very fertile. In the monsoon season, the land area close to the Chenab River is usually flooded. All areas with sweltering summers and mild winter’s features are an arid climate. The average rain-fall is roughly 186 millimeters (Hussain *et al.,* 2023). Therefore, it is imperative to evaluate soil fertility by using precise and sophisticated methods, which help the farmers to make informed decisions to optimize cultivated land resource and maximize soil productivity. As for the researches about soil fertility assessment, selecting appropriate evaluation mean is the emphasis (Li *et al.,* 2011). Especially, the use of quantitative mathematical approaches has become increasingly important in this field. Numerous researchers have conducted studies on quantitative mathematical methods for soil fertility evaluation and have put forward many valuable evaluation (Li *et al.,* 2011) includes, integrated fertility index method (WANG *et al.,* 2001), integrated grading evaluation method (Xu *et al.,* 2005). Mainly index indicators have been used for assessing soil quality and fertility while developing, the soil quality index require selecting particular indicator, scoring and then integration, and in recent era, GIS based approaches have been established to introduced quantified procedures for soil fertility assessment such as Agricultural Land Evaluation System, combined with GIS software that assess the land capability and provide a sensible solution, accuracy and ease of application (Abdellatif *et al.,* 2021). GIS technology has made possible to compute spatial variability of soil phenomena and properties. Integrating GIS can be promising in evaluating spatial variation of soil properties. Soil fertility maps minimize the need for detailed plot by plot soil testing and contribute to reduce excessive use of fertilizers (Elnaggar *et al.,* 2016). Therefore, a key aspect of this study is to evaluate soil fertility using GIS-based approach. Soil fertility of specific area vary on the basis of particular type of land, climate, and agricultural present and past practices. Previously soil fertility has analyzed for different districts of Pakistan include Muzaffargarh (Akram *et al.,* 2014), Attock (Ahmad & Afzal, 2010) and Sahiwal (Jamil *et al.,* 2021) while this study is particularly focusing on the district Khanewal.

Study area: Khanewal is an important district of Punjab, Pakistan famous for cotton growing industry, located 29° 51’ to 30° 43 north latitudes and 71°30’ to 72 ° 28’ east longitudes. It is located in the center of the country at an almost equal distance from Karachi and Peshawar having the total area of 281035 acre, in which 232017 acre is cultivated area and 49018 acre is uncultivated. Climate of the district is hot and dry with the highest temperature recorded at 37°C and the lowest temperature at 29 °C and average precipitation of 201.4 millimeters. Wheat, sugarcane and cotton are the main crops grown, rice, sugar beet, linseed, jawar, bajra, moong, mash, masoor, maize and oil seeds (rape seeds and sunflower) being grown at a much lower scale. Mangoes, dates, citrus and pomegranate, guavas, jamun, peaches, dates, are the main fruits trees grown whereas dates, banana, phalsa melon, musk melon occupy a limited area *(District Gazette 2021)* (Figure 1.).

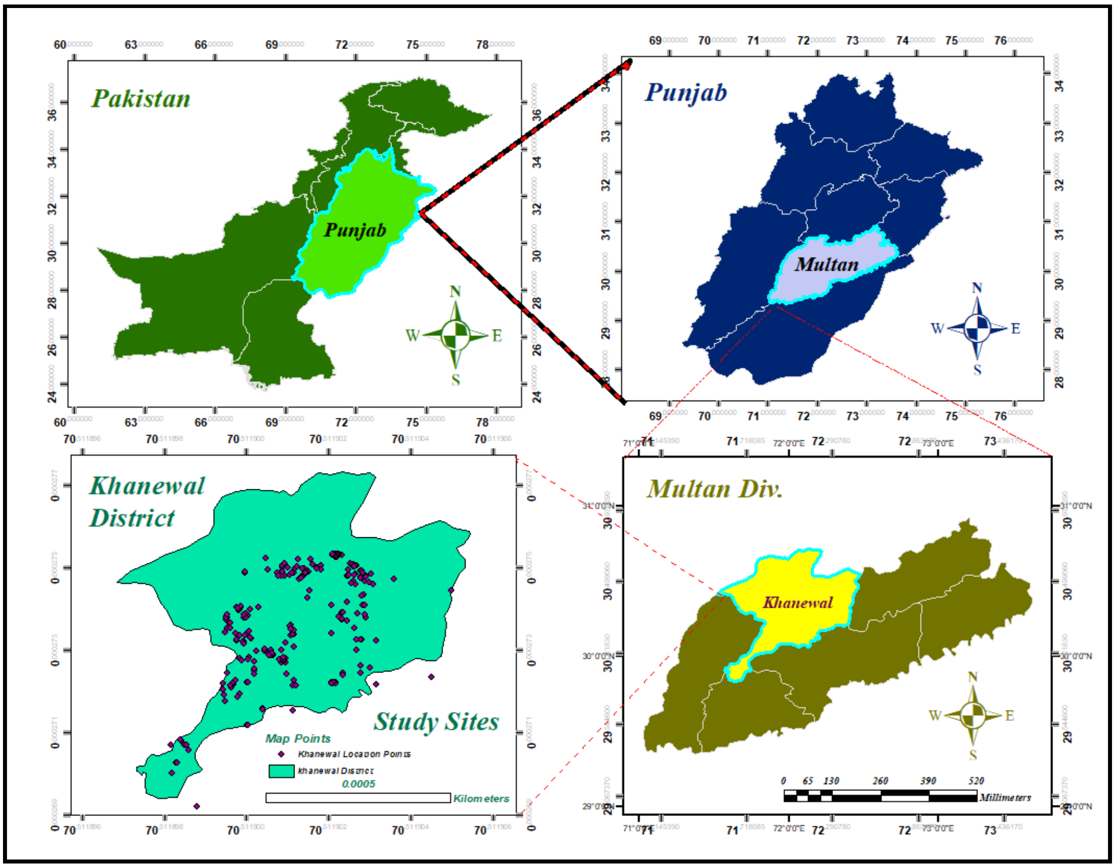

Figure. 1. Geographic overview of the study area

MATERIAL AND METHODS

Sample collection: Soil samples were collected as a random sampling technique from tehsil Khanewal, Mianchanu, Kabirwala and Jahanian covering the main area of cultivation of crops in whole district from the depth of 0-15 cm. The main crops of these areas are sugarcane, wheat and maize. A total of three hundred samples were collected, during the sampling process, a composite sampling method was employed, where each sample was formed by combining several individual samples.

Samples were air-dried, ground, sieved with 2 mm sieve and were stored in airtight polyethylene zipper bag for further analysis.

Soil physico-chemical parameters: Soil pH was measured using pH meter by preparing a 1:5, sample water suspension (Mclean, 1982). Soil electrical conductivity was measured using EC meter by making 1:10 sample water suspensions (Richards, 1954). Soil saturation percentage was determined by method (Wilcox, 1951) and saturation percentage was determined by using the given equation.

Saturation percentage= (Loss in weight of soil/weight of wet soil) ×100 (Kargas *et al.*, 2018) (1)

Organic matter was analyzed by Walkely and Black method briefly, 1.00 g air-dried soil was weighed in 500 ml beaker and 10 ml 1.00 N potassium dichromate solution using a pipette was added, afterward 20 mL concentrated H_2SO_4 was added, and beaker was swirled to mix the suspension. Suspension was allowed to stand for 30 minutes. Then 200 ml deionized water and 10 ml phosphoric was added. Mixture was allowed to cool, later on 10-15 drops diphenylamine indicator was added and suspension was titrated using a 0.5 M ferrous ammonium sulfate solution, until the color change from violet-blue to green and reading was calculated using the following equation (Walkley, 1947).

$M=10/V_b$ (2)

OOC (%) = Vb-Vs × 0.3 × M/W (3)

TOC (%) = 1.334 × OOC (%) (4)

OM (%) = 1.724 × TOC (%) (5)

Determination of soil nutrient status: Soil available phosphorous (AP) content was determined using Olsen method, briefly 5g of soil sample was taken in a 0.25 L flask. 0.5 M solution of sodium bicarbonate ($NaHCO_3$) was added. Mechanical shaker was used for shaking the solution for 30 minutes at 200-300 rpm. Afterward, suspension was filter by using Whatman filter paper. Color developing reagent of 8 ml was added and made final volume up to the mark. After 10 minutes reading was noted on spectrophotometer at wavelength of 880 nm (Olsen *et al.*, 1954). Available potassium (AK) was extracted in 1M ammonium acetate at normal pH i.e., 7.0 and was measured using flame photometer. Zinc (Zn), copper (Cu), iron (Fe), manganese (Mn) and boron (B) concentration was determined using atomic absorption spectrophotometer, following the ammonium bicarbonate diethylene triamine Penta acetic acid (ABDTPA) method briefly the soil sample of 10 g was extracted by using DTPA extracting solution, extracting solution was prepared by adding 1.97 g DTPA to 800 ml DI water and then 2 ml of ammonium hydroxide in 1:1 was added to facilitate the dissolution, later on when most of the DTPA get dissolved, 79.06 g ammonium bicarbonate was added and stirred gently, pH of the solution was adjusted to 7.6 using ammonium hydroxide. Adding extracting solution, sample is kept placed for 2 hours at room temperature and later on centrifuged for 10 minutes at 3500 rpm and filtered (Estefan, 2013).

Quality Assurance: All chemicals used in this study were chromatographically pure. All laboratory consumables and centrifuge tubes were dipped in 20% nitric acid solution which was prepared with double de-ionized water overnight. Determination in atomic absorption spectrophotometer was carried out in three replicates, and the reported results were the average of three replicated along with the standard deviation. All determinations were performed at room temperature. The chemicals and standards used in the study were traceable to National Institute of Standards and Technology (NIST) manufactured under ISO 17025 laboratory. The limit of detection for trace elements was 0.001 mg kg^{-1} and limit of quantification was 0.01 mg kg^{-1}.

Statistical Analysis: Statistical analysis was performed with Statistic 8.1. Statistical difference between groups were determined by ANOVA (one-way analysis of variation). Differences were considered significant for $p \leq 0.05$. Graphs were plotted using ARC-GIS version 10.9.1.

RESULTS AND DISCUSSION

Soil physico-chemical parameters: Lowest electrical conductivity was observed as 1.18 dS m^{-1} and highest was 2.94 dS m^{-1}. Soil analysis exhibit that 20% of the samples analyzed in the district have EC range between 1.0-1.5 dS m^{-1}, while 24% of samples have EC range between 1.5-2.0 dS m^{-1}, 33.3% of samples have EC range between 2.0-2.5 dS m^{-1} and 22.7% of the samples have EC greater than 2.5 dS m^{-1}. Overall district soil is not saline as EC<4 dS m^{-1} and have low content of soluble salt (Figure 2.).

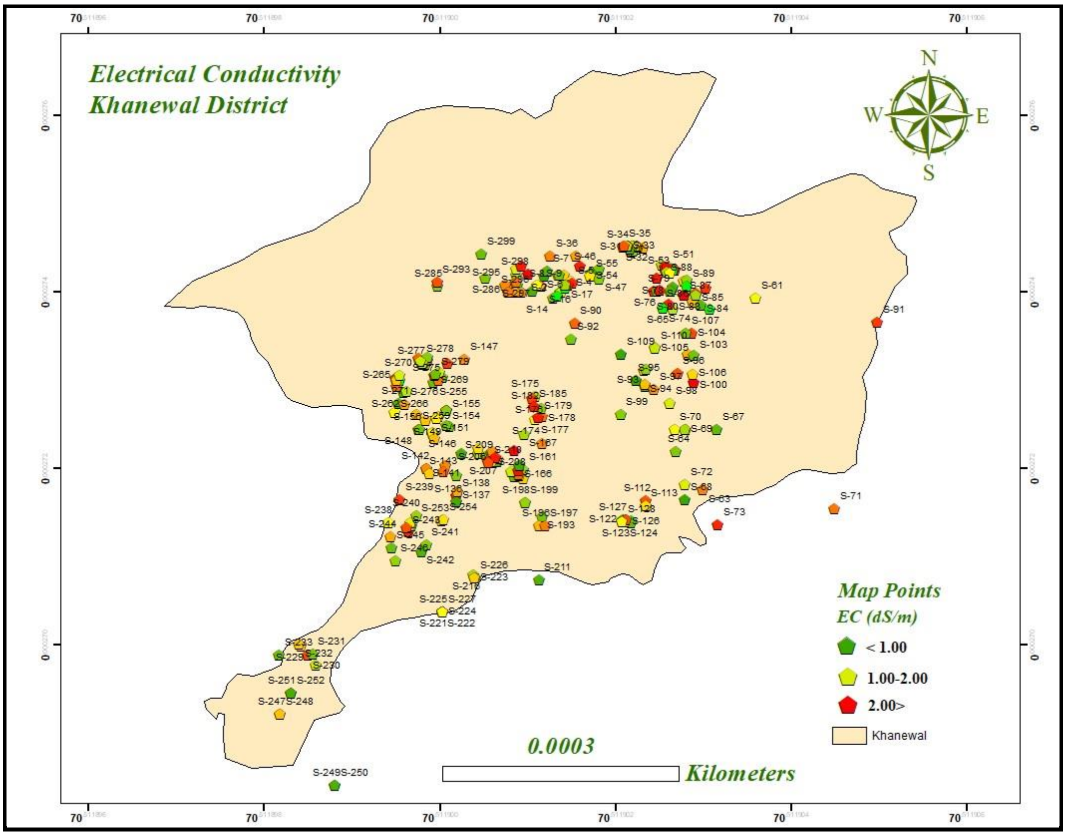

Figure 2. Spatial analysis of electrical conductivity of Khanewal district

The pH (soil reaction) is an important factor to support the plants, it should be in the range of 6-8 at which most of the nutrients become available to plants (Yuvaraj & Rajeswari, 2020). The pH of the sample analyzed was observed between 7.9-8.1, representing that district have alkaline soils. Overall, 27.67% of the samples have pH less than 8.0 and 72.33% of samples have pH greater than or equal to 8.0 (Figure. 3), similar results were reported earlier (Akram *et al.,* 2014).

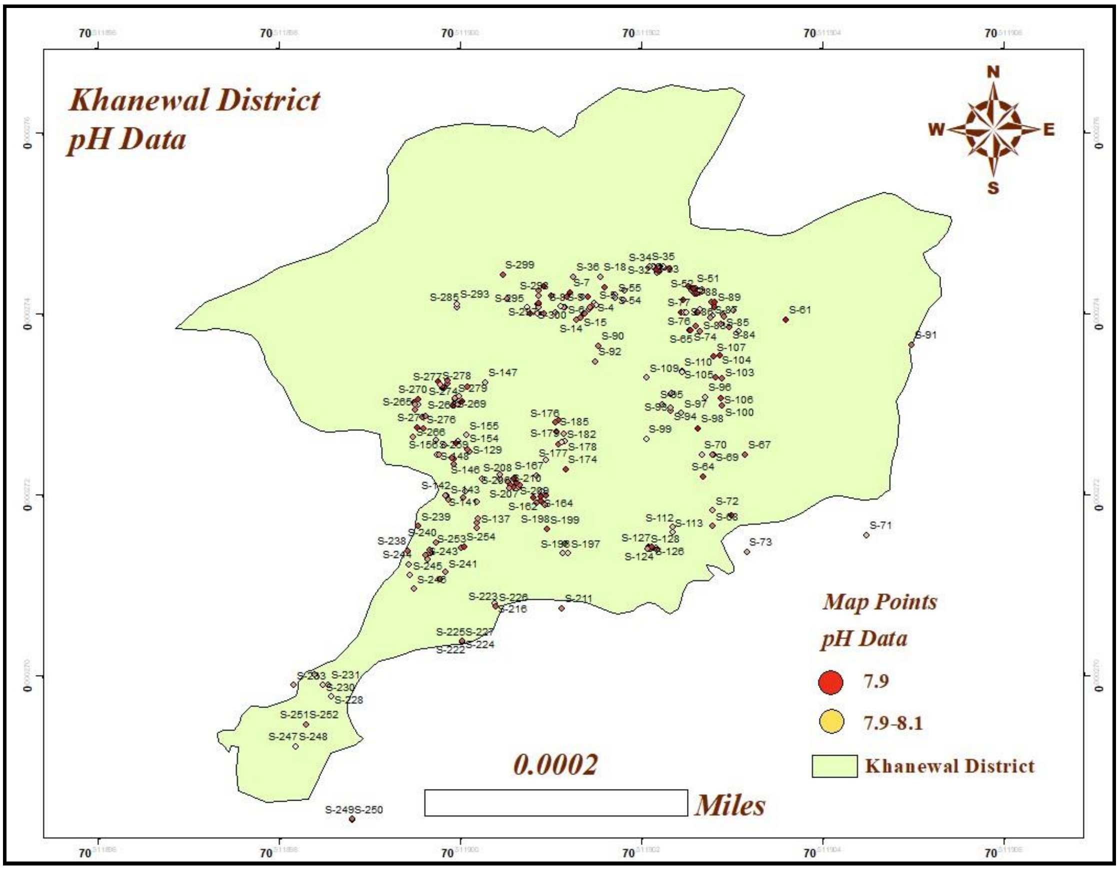

Figure 3. Spatial analysis of soil pH in Khanewal District

Saturation percentage (%) exhibit region have fairly consistent level of saturation. Soil saturation percentage of analyzed samples range between 35-38% which depicted that this rea having soil from sandy loam to silt loam as reported earlier regarding the soils of Pakistan (Jamil *et al.*, 2021).

Khanewal soils are poor in organic matter content having a range of 0.21-0.608. This might be due to the high temperature during summer and prolong heat waves as the decomposition rate is high (Perveen *et al.*, 2010). Another factor behind low organic matter is temperature of the district that reach up to 50°C in summer which speed up the process of decomposition (Jamil *et al.*, 2021). Restricted application of organic amendments such has farmyard manure might also be the reason behind low organic matter content. In fact, the largest source of organic matter is crop residue but negligible amount of crop residue is left in Pakistan after the crop harvest and fodder is burned which leave very little amount of organic matter (Akram *et al.*, 2014). Majority of samples from Tehsil Kabirwala and Mianchanu lie in the higher ranges, while Jahanian and Khanewal have majority of values in the lower ranges. In tehsil Mianchanu, Jahanian, Khanewal, Kabirwala highest observe organic matter was 0.600, 0.603, 0.608 and 0.605 while lowest observe was 0.24, 0.24, 0.21 and 0.23 respectively (Figure 4).

Available Phosphorous (AP): Irrespective of the tehsil data, highest observed value of AP is 23.86 mg P g^{-1} and lowest observed AP is 7.1 mg P g^{-1}. Overall, 54.84% of Khanewal soils have AP level above the bench mark of 15 mg P g^{-1} while 45.1% of soil have AP level below the bench mark. Highest value of AP in Mianchanu, Jahanian, Khanewal and Kabirwala 23.78, 23.86, 23.74 and 23.86 mg P g^{-1} while lowest is 7.68, 8.2, 7.11, 7.86 mg P g^{-1} respectively (Table 1). Phosphorous (P) is the significant nutrients for crop yield, it is also known as "Master key to agriculture" as it is mainly involved in the development of different stages of plant growth and decrease in its concentration directly affect the agricultural production. District Khanewal soil has poor level of P that might be due to poor soil management, precipitation, soil erosion, adsorption and immobilization (Tagung *et al.*, 2022). Two other main process also result in poor level of P i.e., recurrent application of phosphatic fertilizers and its fixation in calcareous soil due to high level of calcium carbonate (Akram *et al.*, 2014).

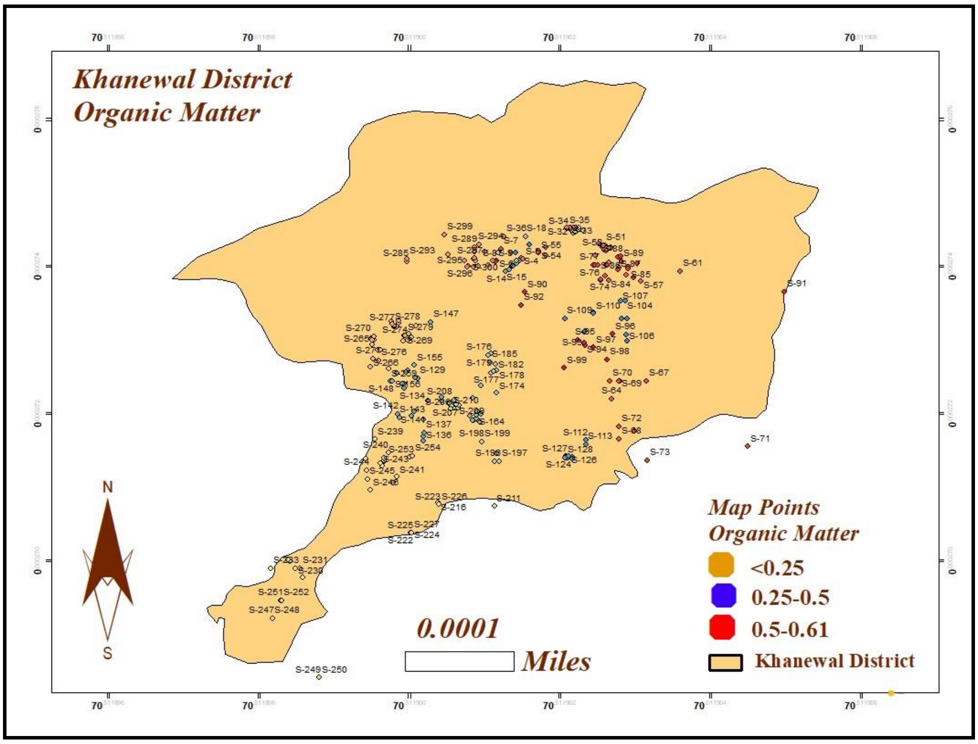

Figure. 4. Spatial distribution of Organic matter in Khanewal district

Table 1: Available Phosphorous in mg P g^{-1}

Range	Category	No. of samples	% of samples	Maximum	Minimum	Average	Standard Deviation
Below 10	Lowest	47	15.67%	9.8	7.1	8.55	0.84
10-20	Moderate	197	65.66%	20.7	10.0	15.59	3.15
Above 20	Highest	56	18.66%	23.86	21.03	22.37	0.87

Available Potassium (AK): The available potassium (AK) content in the soils of district varies significantly. Highest value of AK content was observed in tehsil Jahanian i.e., 190.65 mg Kg^{-1} and the lowest value in district Khanewal i.e., 76.58 mg Kg^{-1}. In Mianchanu AK range from 80.01 mg Kg^{-1}-189.77 mg Kg^{-1}, with a mean value of 137.88 mg Kg^{-1}. In Jahanian AK content varies from 78.82 mg Kg^{-1}-190.65 mg Kg^{-1} with a mean value of 129.27 mg Kg^{-1}. In Khanewal tehsil AK content range from 76.58 mg Kg^{-1}-189.77 mg Kg^{-1} and in Kabirwala AK content range between 84.08 mg Kg^{-1} -190.65 mg Kg^{-1}. 2.5% of Mianchanu soils, 3% of Jahanian 2.8% of Khanewal and 3.2% of Kabirwala soils were found to be AK deficient (Table 2). Potassium (K) is responsible for plant quality and proper growth along with reproduction, low K content in the district might be due the lower amount of clay content and soil organic matter which influence the K leaching in soil. Some other factor might also affect K content include liming and rate of K application etc. (Tagung *et al.,* 2022).

Table 2. Available Potassium in mg Kg^{-1}

Range	Category	No. of samples	% of samples	Maximum	Minimum	Average	Standard Deviation
Below 100	Lowest	57	19%	75.43	99.86	88.38	6.97
101-150	Moderate	143	47.66%	149.30	100.02	125.2	14.88
Above 160	Highest	99	33%	190.00	150.09	170.56	12.72

Soil micronutrient status: The Zn, Mn, B were found to be higher in Mianchanu i.e., 47.6 ppm, 197.53 ppm, 23 ppm while Cu, Fe, were found greater in Kabirwala i.e., 13.08 ppm and 23.6 ppm respectively. Zn, Mn and Cu concentration were lower in Khanewal tehsil i.e., 0.07 ppm, 0.2 ppm and 0.02 ppm. Fe was lower in Mianchanu i.e., 0.171 ppm and B have lower concentration of 0.19 ppm in several samples of all tehsils. 17.1% of samples were found to have low Zn content (Table 3), 1.3% have low Cu (Table 4), 71% of samples were found to be iron deficient (Table 5), 8.3%

samples were low in Mn content (Table 6) and 83% have low boron concentration (Table 7). The soil fitness criteria showed in Table 8. Overall Khanewal district soil has found to be moderate to average in elemental concentration, except Fe and B (Table 8). Zn an essential micro-nutrient required in trace amount for normal growth of plant. Chlorophyll formation linked with zinc and its concentration may be low due to intensive cropping and imbalance use of fertilizer, low organic content might also be the reason behind its minimum concentration in some samples (Mohamed *et al.,* 2019). The Fe and B concentration might be lower due to alkaline pH as at alkaline pH they become less soluble, other reason might include their leaching due to low nutrient holding capacity of soil and low organic matter content (Chuan *et al.,* 1996). The Mn deficiencies may occur in this region due to calcareous soil or heavy application of soil, lower EC and non-calcareous soil might be the reason behind its optimum presence. Cu moderate to optimum content may be due to accumulation of copper over time by the application of sludge, or due to the use of copper containing fertilizers in the district (Akram *et al.,* 2014).

Table 3: Zinc concentration in soil in ppm

Range	Category	No. of samples	% of samples	Maximum	Minimum	Average	Standard Deviation
Below 1	Lowest	92	30.6%	0.99	0.03	0.51	0.26
1-20	Moderate	174	58%	19.29	1.00	4.41	4.07
Above 20	Highest	34	11.3%	47.66	23.38	37.5	7.14

Table. 4. Copper concentration in soil in ppm

Range	Category	No. of samples	% of samples	Maximum	Minimum	Average	Standard Deviation
Below 1	Lowest	149	49.6%	0.98	0.02	0.65	0.20
1-10	Moderate	134	44.6%	9.66	1.007	3.37	2.44
Above 10	Highest	17	5.66%	13.08	10.04	12.2	0.73

Table 5. Iron concentration in soil in ppm

Range	Category	No. of samples	% of samples	Maximum	Minimum	Average	Standard Deviation
Below 1	Lowest	13	4.33%	0.98	0.11	0.60	0.28
1-10	Moderate	234	78%	9.92	1.01	3.07	2.13
Above 10	Highest	53	17.6%	23.69	10.04	16.1	3.34

Table 6. Manganese concentration in soil in ppm

Range	Category	No. of samples	% of samples	Maximum	Minimum	Average	Standard Deviation
Below 10	Lowest	197	65.6%	8.1	0.2	4.28	1.79
10-100	Moderate	89	29.6%	57.7	10.50	28.7	16.1
Above 100	Highest	14	4.66%	197.5	181.3	186.5	5.03

Table. 7. Boron concentration in soil in ppm

Range	Category	No. of samples	% of samples	Maximum	Minimum	Average	Standard Deviation
Below 0.3	Lowest	148	49.3%	0.26	0.12	0.209	0.02
0.3-1	Moderate	151	50.3%	0.87	0.32	0.53	0.207
Above 1	Highest	1	0.3%	23	23	23	0

Table 8. Soil fitness criteria

Parameter	**Normal**	**Saline**	**Sodic**
Electrical Conductivity	<4 dS m^{-1}	4.1-8 dS m^{-1}	>8 dS m^{-1}
Soil Characteristics	**Poor**	**Medium**	**Adequate**
Extractable Phosphorus	<7 ppm	7.1 to 14 ppm	> 14 ppm
Extractable Potassium	<80 ppm	80 to 125 ppm	> 125 ppm
Organic Matter	<0.86%	0.87% to 1.29%	>1.29%
DTPA-extractable Micronutrient (mg/Kg or ppm)			
Zinc (Zn)	<0.5	0.5 - 1.0	>1.0
Copper (Cu)	<0.1	0.1 - 0.2	>0.2
Iron (Fe)	<2.0	2 - 4.5	>4.5
Manganese (Mn)	<0.5	0.5 – 1.0	>1.0

Source: Agriculture Department, Government of Punjab

CONCLUSION

Pakistan is an agricultural country and economic activity of most of its area, depend upon agriculture hence for sustainable agriculture soil fertility assessment and management is a crucial aspect. This study exhibit that Khanewal soil is at safe zone in term of pH, EC and essential micronutrients except Fe and B. But it needs special attention in terms of managing organic matter and macro-nutrient include P and K. It reveals that Khanewal district falls in low to medium category of K and P fertilizer. On the basis of physicochemical index Khanewal district soil varied from good to fair. However, it varied from poor to very poor according to their status of macro-nutrient content especially P and organic matter. Therefore, it is recommended to continuously incorporate farmyard manure, green manure, and crop residues into the soil over an extended period to address the organic matter deficiency. P, K, Fe and B deficient area should be fertilized with variable rate of respective fertilizer. Periodic soil fertility assessment and testing should be adopted for continuous maintenance of soil fertility. In conclusion, the limitations for nutrient and organic matter in the studied area can be improved through proper fertility and land management practices. The study also concludes that GIS is an effective tool to analyze the spatial distribution of the soil fertility.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest and have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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