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QUANTITATIVE ANALYSIS OF PLANT AVAILABLE ZINC, COPPER, IRON, MANGANESE BY DTPA-EXTRACTANT, BORON BY HOT-WATER SOLUBLE AND VISUALIZATION OF THEIR SPATIAL DISTRIBUTION USING GEOGRAPHIC INFORMATION SYSTEM (GIS) IN PUNJAB, PAKISTAN

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Abstract

Micronutrient deficiency in high pH (alkaline) soil is the most promising factor to achieve optimal crop yield for the food, feed, and fiber needs of 7 billion people globally. After examining the micronutrient status of a specific site, then site-specific nutrition management could be a feasible solution. The goal of this study was to determine quantitatively and illustrate the distribution of DTPA extractable micronutrients in the Sialkot district. Throughout the sampling region, 1432 georeferenced soil samples were taken to the fertile depth of arable land, while preserving a sampling grid area of 100 acres (404686 m2). Following the Diethylenetriamine Penta-Acetate (DTPA) extraction process, these samples were analyzed for plant available Zinc (Zn), Copper (Cu), Iron (Fe), and Manganese (Mn). Flame Atomic Absorption Spectroscopy (FAAS) was used to perform the quantification analysis. The UV-visible spectrophotometer was used to determine hot water soluble (HWS) Boron (B). Electrical conductivity (EC), soil pH, and soil organic matter (SOM) concentration were also determined and calculated in soil samples. Zn, Cu, Fe, and Mn extractable by DTPA varied from 0.12-7.22, 0.09-2.14, 0.43-10.29, and 0.06-2.71 mg kg-1 soil, respectively. Boron concentrations in the soil ranged from 0.01 to 1.66 mg kg-1. The soil EC and pH of the tested samples varied between 0.16 and 3.12 dS m-1 and 6.81 and 9.30, respectively. There was no threat of high soluble salt concentration in the Sialkot soil. When it came to sodicity, 90% of the sampling locations were normal, whereas 10% were sodic characteristics. The soil samples, on the other hand, revealed a lack of SOM, with a mean value of 0.53 %. Significant and negative correlations were found between soil pH and DTPA extractable Zn, Cu, Fe, and B. At non-sampling sites, the micronutrient status was assessed using the standard kriging technique. The micronutrients could be applied more accurately and site-specifically utilizing digital maps created with the Quantum Geographic Information System (QGIS).

Keywords: Micronutrients, Zinc,Copper,Iron,Manganese,Boron, Sialkot Soil, DTPA Extractant, GIS, Quantum Geographic Information System

Introduction

By the end of 2050, the world's fast ex-pat population will demand an exponential increase in food, feed, and fiber output of up to 50% above what is currently required. (Giller, G. L. 2020; Fisk et al., 2015). This situation demands a sustainable and intensive farming system to feed the increasing population demand. Meanwhile, the maintenance of optimal soil fertility, productivity, and health, is the most important resource for long-term sustainability. Nutrient deficiency is a major concern in agricultural productivity and food quality. Plant nutrients are divided into macro and micronutrients based on their requirements for metabolic processes, respectively (Marschner, 2012). Micronutrients are metallic chemical compounds found in plant biomass that are required considerably in lesser amounts than macronutrients. However, these are compulsory components, like macronutrients (Marschner, 2012), and are divided into groups based on their vital role in plant growth and development.Plant metabolic processes are directly influenced by essential micronutrients., their role does not replace by another element, however, the plant cannot complete its life span properly, if they are not present (Hwangbo et al.2020). Metalloproteins include the intrinsic micronutrients molybdenum (Mo), manganese (Mn), iron (Fe), and copper (Cu), which accelerate redox processes through electron transfer chain (ETC) reactions. A few micronutrients (like Fe, Cu, Ni, and Zn e.t.c) also form an enzyme-substrate complex, or co-factor, and speed up the reactions by changing the molecular structure of the substrates or enzymes (Strohmeier et al.2020).

Boron (B) is a metalloid in nature, which are intermediate between metal and non-metal ions, and it plays an important role in RNA metabolism, cell wall production, lignification, carbohydrate production, and sugar molecules transport within the cell. B is also linked to pollen tubes and pollen germination in plants (Marschner, 2012).

Micronutrients are found in the earth's crust and form soil minerals through a variety of molecules. These molecules mostly are present in chelated forms with organic or inorganic ligands, trapped in solution (ammonia) andare water soluble, and sometimes adsorbed by exchangeable sites, or they are reported in complexes with naturally occurring organic molecules. In most cases, the metal oxides and the components inside theSecondary clay minerals' crystal lattices include insoluble forms of micronutrients. Moreover, inorganic metallic complexes are more easily available to plants than organically bound intractable metals (Suhr et al.2021). The micronutrient absorption and availability to plants are induced by soil physicochemical characteristics, especially affected by soil organic carbon (SOC), soil microbes diversity (mo), and soil reaction (pH). SOC forms metal-organic complexes, which could enhance or reduce metal accessibility rely on the metal-organic complex's stability constant. Metals have inconsistent levels of attraction for SOC, resulting in variable metal-organic complex stability constant values. For example, eliminating the cadmium (Cd) by a Cd-organic ligand complex (CdOC) is simpler (lower stability constant) as comparatively, the copper (Cu) is removed through a Cu-organic ligand complex (CuOC) which has high stability constant. Other essential micronutrients i.e., nickel (Ni) and zinc (Zn) have a low chemical attraction for SOC and can be removed simply through various organic compounds (Jun et al. 2020). Similarly, the chemical attraction of their functional groups to the metal compounds varies. The enolate compounds (dissociated into the phenolic group, -OH ions, and reactive O-molecules) have a very high force of attraction for the metal compounds, while the carbonyl (C=O) group has the lowest attraction (Yin et al.2020). Long chained poly-cyclic organic compoundssuch as lignin, produce potent, non-water-soluble, and high metal-complexes in contrast to simple organics, which have loloweredetal extraction.

The extraction of metal elements is influenced by the pH of the soil both directly and indirectly the metal speciation and oxidation states are affected by soil pH. Copper (Cu), for example, could be recovered as single molecules ion (Cu2+) or hydroxide ions (CuOH+) relying on the solution pH. Secondly, Zn also exists in two main forms: Zn2+ in acidic environments and ZnOH+ in alkaline environments, and with ea, ch unit increase in pH, Zn solubility drops by 100 times (Khoshru et al.2020)

Similar to copper, cobalt (Co) is far more water-soluble and available at acidic pH levels and could be removed with flowing water (Peeters et al.2020). The polarity of exchange sites is indirectly influenced by the pH of the soil because the charge on soil exchange sites (mainly pH depending) has a direct impact on the adsorption and desorption of charged particles or metallic nutrients elements. Fe-Mn oxides, which bond to metal components and decrease their extractability under alkaline conditions are also advantageous. (Wang et al.2021).

Most of Pakistan's soils are pH (7.5-8.5) and alkaline-calcareous in nature (Hussain et al.2021). The high pH (basic) decreases the dissolution of micro-nutrients in soil mixtures because metal ions are co-precipitated and no longer available to plants. (Li et al.2020). Even thoughthe micro-nutrient shortage is commonly documented around the world, there has been little research reported in Pakistan to analyze the soil's nutritional status especially micro-nutrient concentration evaluation and application for the arable soil (Ahmed et al., 2014). According to a report collected in Murree (Pakistan), 38 percent of the arable soils reported are insufficient in plant-accessible Zn. Secondly, in the region of Bhimber AJK, about 26.6 percent and 80 percent of arable sites are lacking in zinc and boron respectively (Nazif et al., 2006; Ahmad et al., 2010). The main districts of the Jhelum and Chakwalarea unitare poor in B, withabout one hundred and forty evaluated arable soils in the Jhelum and one hundred and fifteen arable soils in Chakwal showing 50 percent of micro-nutrient deficiencies (Rashid et al., 1997).

This investigation's goal was to assess the state of the soil's micronutrients in the Sialkot district. Sialkot is a city in Punjab, Pakistan, that runs from the Ravi Valley in the south to the Chenab River in the north and has a humid subtropical climate. Summers are hot, with an average high of 102°F and a mean monthly temperature of above 30°C, while winters are frigid, with an average low of 43°F. Generally, their soil is considered as productive as comparatively (Khalil-ur- Rehman et al., 2009).

This study's main objectives: (I) To assess the plant-available fraction of micro-nutrients present in the arable soils of the Sialkot area using diphenyl triamine pentaacetic acid (DTPA) extraction techniques and (II) the use a geographic information system (GIS) to produce digital maps showing the geographical distribution of micronutrients. The resulting spatial variability would aid in monitoring and adjusting their application versus availability rate at a specific locationto quantify the time off location Khan etal.,2018;Meenaetal.,2006).

Materials and Methods

Soil Sample Collection and Processing

A regular grid of 100 acres was used to divide the study area (404686 m2). Soil samples were taken at an outermost depth of 0-15cm the fertile layer of arable soil from each grid, and positions were recorded as latitude and longitude datausing the global positioning system (GPS) (GOP, 2018). The sample distribution field is between 32.06679- and 32.79343-degrees north latitude and 74.21327- and 74.89288-degrees east latitude. Figure 1 shows sampling locations overlayed on a map of the Sialkot area.Soil samples were grounded by pestle and mortar to make the soil homogenized and pass through a 2mm sieve for sorting out pebbles and gravels out of the sample collected, air dried soil samples were crushed Using NARC's methodology and critical limit analysis, soil properties i.e., the electrical conductivity of soil extract (EC), soil pH of saturated paste were measured, analyzed soil organic matter (SOM), and soil texture classdetermined through standard protocols. (Lazaar et al.2020).

A DTPA extraction solution that was calibrated for neutral to alkaline pH soils was represented by Lindsay and Norvell (1978). Pakistan's soils are primarily alkaline due to their parent materials and bio-geographic distribution (Bashir and Bantel, 2005). In alkaline soils, the DTPA extraction method was therefore shown to be suitable for measuring plant-available micronutrients. Exchangeable metals in soil were used to bind with the water-soluble and weakly adsorbed chelating agent diethylenetriamine penta-acetate (DTPA).Chelation is a slow process, and equilibrium might take weeks or months to achieve.

As a result, the soil to DTPA solution (1:2) was formulated to include a specific quantity of DTPA which could bind/chelate metal ions up to 10 times their molecular weight. The competition between metal ions for chelating agents may be lessened the binding as a result. Calcium chloride (CaCl2) prevents metals bound to CaCO3 from being released into the soil by inhibiting CaCO3 dissolution in calcareous soils. The Metal-DTPA complex forms best at a pH of roughly 7.3. When performing an AAS chemical analysis, the triethanolamine (TEA) buffer maintains the pH at 7.3 without interfering with the flame (Lindsay and Norvell, 1978).

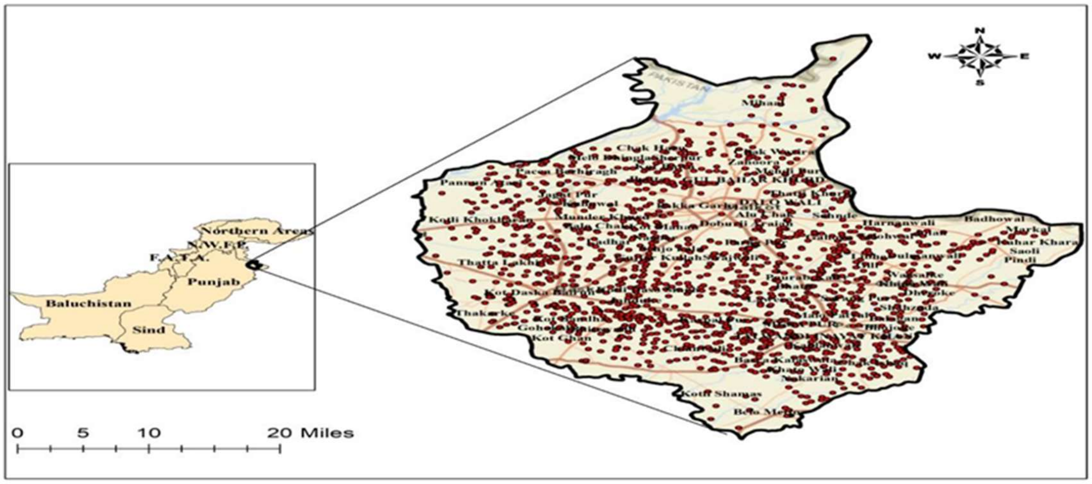

Figure1:Basic Map for soilsamples collection sites from the district of Sialkot; The sampling units are mentioned by pink dotson the location map.

The extractant solution was prepared from 0.005 Molar DTPA, 0.01 Molar calcium chloride, and 0.10 M triethanolamine (TEA) combined to make the 1 litter extracting solution. The pH of the extracting solution was maintained at 7.3 by strong acid of hydrochloric acid (HCl) and a strong base of ammonium hydroxide (NH4OH) solution. A 1:2 mixture of soil sample and extractant solution was shaken for 120 minutes at 25 ± 2 °C and filtered through Whatman® no. 42 ashless circles of 125mm Ø filter paper (Cat No 1442 125). Atomic Absorption Spectrophotometer (AAS) was standardized to determine the specific metal elements through their specific filters of hollow cathode lamps (HCL).

In DTPA extraction solution, working standards for every specific nutrient e.g., Zn+2, Mn+2,Cu+2, and Fe+3was formulated through the certified reference material available in thetraceable section mentioned by the National Institute of Standards and Technology (NIST). AAS was standardized and calibrated through the working standards according to the instrument's functional guide. Boron (B) was extracted through the hot-water extractant solution process and measured using the Azomethine-H compound colorimetrically (William-Horwitz, 2005). After this complete analysis, results were calculated and compared with the reference standards proposed by the NARC subdivision of the Pakistan Agriculture Research Council (PARC). Micronutrients evaluated through the DTPA-extractantwere regulated to micronutrientents'ientents productivity and soil fertility status (Rayment and Lyons, 2011). These values were utilized to classify the soils as low (L), marginal soils (M), and adequate soils (A) in terms of the availability of micronutrients that would be readily accessible to plants. (Ryan et al., 2001).

Spatial maps distribution

The project coordinated system WGS 1984 UTM: Zone 43 was used for soil samples collections and this system was further applied to indicate the micronutrient status of these georeferenced soil by their specific latitude and longitude, while the range of micronutrients was mentioned to the area as earlier L, M, and S soils.

Data shape files were monitored as comma-delimited text files and uploaded into Quantum Geographic Information System (QGIS) version.3.12 for average kriging and soil fertility status in terms of micronutrient range prediction at the non-sampled field. However, kriging is the linear interpolation-based geostatistical analytical method that delivers the most accurate non-sampling linear estimates. In comparison to the farthest point, the points closest to the sample site would have larger weights (Hu et al. 2020). Moreover, the krigid shape files were categorized using micronutrient criteria proposed by Ryan et al. (2001). The correlation association of soil fundamental parameters (e.g., soil pH and SOC) with plant-accessible micronutrients was investigated and visualized by the R statistical software (Yadav et al.2020).

Results and Discussion

Zinc Distribution

Zinc concentrations in the arable soil, levels from 0.12 to 7.12 mg kg-1, are mentioned in Table 3.1. 72 % of the soil samples fell into the acceptable category as sufficient range, whereas 9% had low plant available Zn levels categorized as low to marginal ranges. The analysis found that the overall agricultural land of district Sialkot was suitable in terms of plant-accessible Zn; nevertheless, the spatial distribution map of Zn shows localized Zn insufficiency on the northern and southern sides of district Sialkot (Figure 3.2).

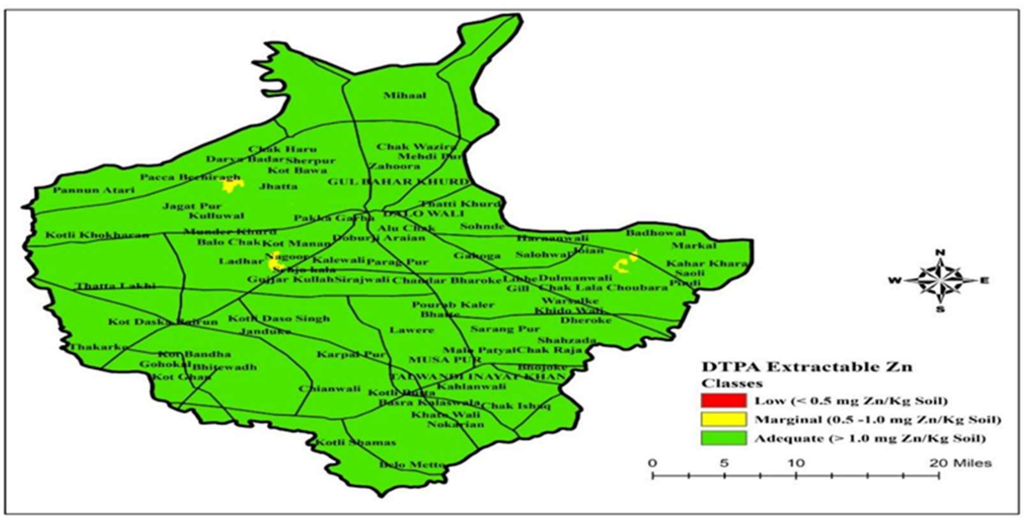

Figure 3.1:Zinc (DTPA-Extractant) distributionpatternin thedistrict of Sialkot.

Micronutrient (mg/Kg)	Minimum	Maximum	Mean	Standarddeviation
Zinc(Zn)	0.12	7.22	2.81	±2.08
Copper(Cu)	0.09	2.14	0.99	±0.60
Iron(Fe)	0.43	10.29	5.14	±2.56
Manganese(Mn)	0.06	2.71	2.16	±0.47
Boron (B)	0.01	1.66	0.37	±0.32

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Table 3.1: Micronutrients maximum, minimum ranges,mean values,andstandarddeviationofthe district Sialkot.

Table 2: Presented the soil saturated paste pHs, the electrical conductivity of soil extract ECe, total soilorganicmatter (SOM),micronutrients concentrations of zinc,copper,iron, manganese (by DTPA-Extractant), and hot water-soluble boron with theirrelative range distribution in arable soils of Sialkot.

Parameter

Parameter	**ClassInterval***	**Relative frequencydistribution**		**Status**
		n(1432)	**(%)**	
Zinc(Zn)(mg kg^{-1}soil)	<0.50	131	9	Low
	0.5 – 1.0	266	19	Marginal
	>1.0	1035	72	Adequate
Copper(Cu)(mg kg^{-1}soil)	<0.20	51	4	Low
	0.20 – 0.50	402	28	Marginal
	>0.50	979	68	Adequate
Iron (Fe)(mgkg^{-1}soil)	<4.5	539	38	Low
	-	-	-	Marginal
	>4.5	893	62	Adequate
Manganese(Mn)(mg kg^{-1}soil)	<1.0	73	5	Low
	1.0-2.0	96	7	Marginal
	>2.0	1263	88	Adequate
Boron (B)(mgkg^{-1}soil)	<0.5	1155	81	Low
	0.5 – 1.0	249	17	Marginal
	>1.0	28	2	Adequate
pH_s	<8.4	1292	90	Normal
	>8.4	140	10	Sodic
EC_e(dS m^{-1})	<4	1432	100	Normal
	>4	Nil	Nil	Saline
Soil organic matter (%)	<0.86	1374	96	Low

	0.86 – 1.2958	4	Marginal
	>1.29 Nil	Nil	Adequate

These findings contradict those of Zia et al. (2006), who found a vast zinc shortage throughout the country by studying 329 different soil experimental sites. Whereas the typical nature of Sialkot's soils could be one factor for the acceptable ranges of Zn in this research area. Sialkot's soils are devoid of salinity problems. Most of the soils in this district are also sodic-free, as the pH of the soil is in the normal soil criteria (Kyebogola et al.2020) and did not interfere with the Zn solubility and availability.

Copper Distribution

Table 3.1 showed the copper criteria for arable soil and normally the minimum level starts from 0.09 mg kg-1 to a maximum of 2.14 mg kg-1soil. One-third (28 %) of Sialkot soil rendered as marginal soil range for plant available copper, while more of the proportion about (68 %)wereadequatecategoryto supply crop, available copper. However, only 51 experimental units of arable soil(4 %) were low-level in available Cu proportion comparatively (Table 3.2).The Cu distribution shape filedepictsthespots for marginal ranges of copper on the northern and southwestern sides of district Sialkot (Figure3).

Iron Distribution

SoilParameter	Minimum	Maximum	Mean	Standarddeviation
Electrical conductivity (ECdSm-1)	0.2	3.1	1.1	±0.41
Soilreaction(pH)	6.8	9.3	7.8	±0.59
Soilorganicmatter(SOM%)	0.1	1.1	0.5	±0.19
Texture	Sandyloam to clay loam			

The plant's accessible Fe+3 was reported as 0.43 mg to 10.29 mg kg-1 arable soil, whereas the average range is 5.14 mg kg-1 agricultural soil (Table 3.1). According to the results, 38 % of arable soil samples had low Fe+3 levels, while 62 % had appropriate levels (Table 3.2). The iron distribution shape file shows that it is widely distributed at a sufficient level throughout Sialkot's district, but that it is low in the central and boundary areas (Figure 3.4).

Table 3.3: The soil physicochemical properties which affect the micronutrient solubility and plant availability.

Table 3.4:Pearson correlationcoefficientbetween soil pH and Zn, Cu, Fe, Mn (DTPA-Extractant)and B (Hot-water).

Soil characteristics	Micronutrients				
	Zn	Cu	Fe	Mn	B
SoilpH	-0.22	-0.28	-0.25	ns	0.17

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	R^2= 0.04**	R^2= 0.03**	R^2= 0.04**		R^2= 0.05*
Soil organicmatter	ns	-0.12 R^2= 0.009***	ns	ns	ns

Where: Ns showed thenon-significantcorrelation between variables'coefficient
*P<0.1,**p<0.05, ***p<0.01.

Manganese Distribution

Mn concentrations in the arable soils ranged from 0.06 mg to 2.71 mg kg-1, and the average value of 2.16 mg Mn kg-1 of soil (Table 1). Most of the experimental sites (88%) were in the acceptable adequate range, whereas 73 experimental unit fields (5%) had a very less proportion of crop available manganese (Table 3.2). Low Mn locations were detected in the district of Sialkot's southwestern side, according to the Mn distribution shape file. Bhikhi Sandhuan, Mianwali Bhangla, Langianwala, Thatha Umra, Chakri, Paharipur, and Chak Sadez are among the villages with low Mn levels (Figure 3.5).

Boron Distribution

B concentrations in the arable soils are from 0.01 mg to 1.66 mg kg-1 of productive soil, and the average value of 0.37 mg kg-1 of arable land (Table 3.1). According to this study, 81 % of the selected experimental unit's soil samples had low levels of water-soluble B, while 17 % had marginal range levels (Table 3.2). Boron shortage was found in large quantities in the agricultural fields of the Sialkot district. Our findings are in line with Rashid et al. (1997), who demonstrated that there is a general B deficiency in Pakistan's Potohar plateau. B deficiency has also been reported in AJK soils by Nazif et al. (2006). B distribution shape file indicates the district's pervasive inadequacy (Figure 3.6).

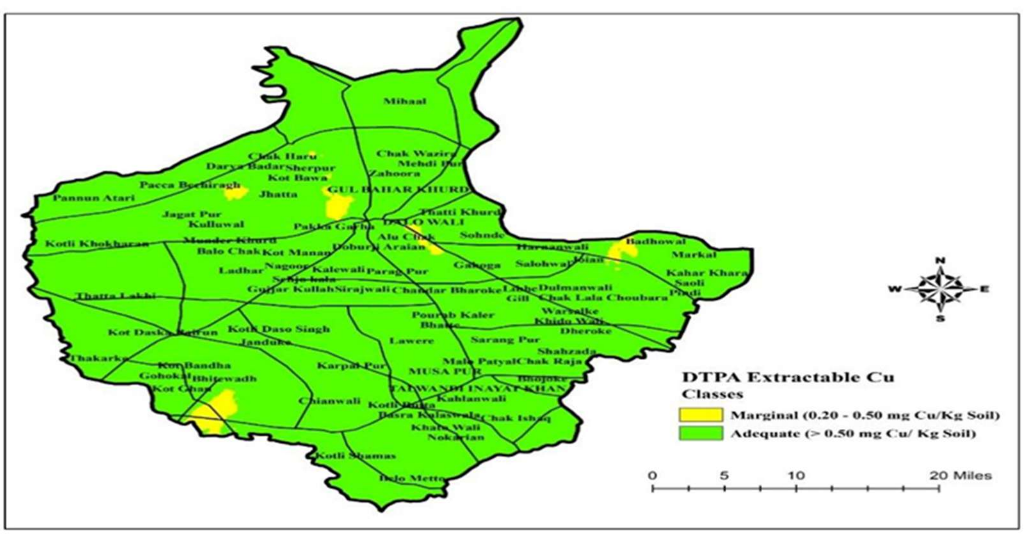

Figure3.3:Copper (DTPA-Extractant) distribution shape file in the district Sialkot.

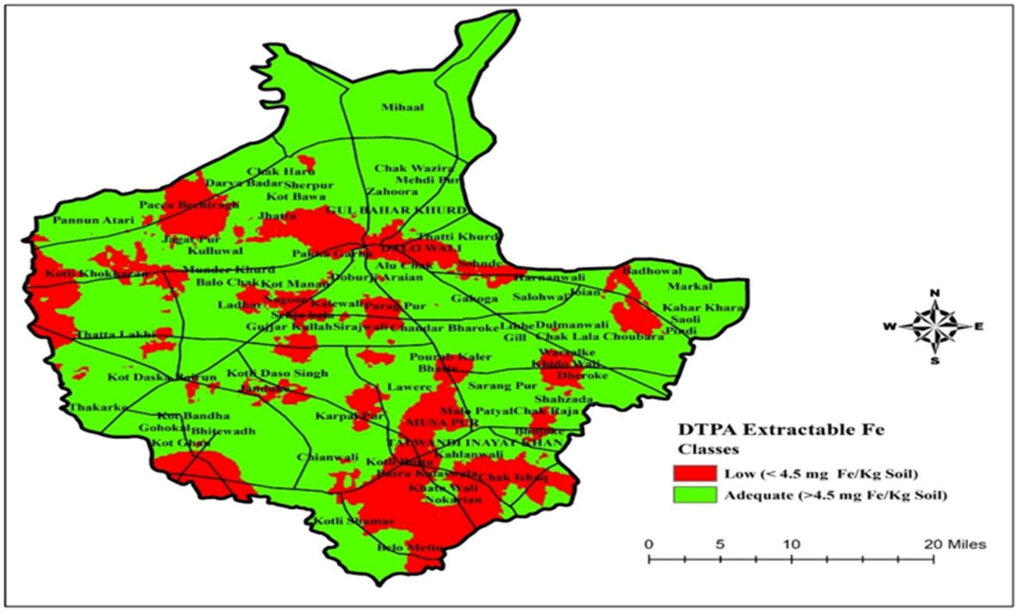

Figure 3.4:Iron (DTPA-Extractant) distribution shape file in the district Sialkot.

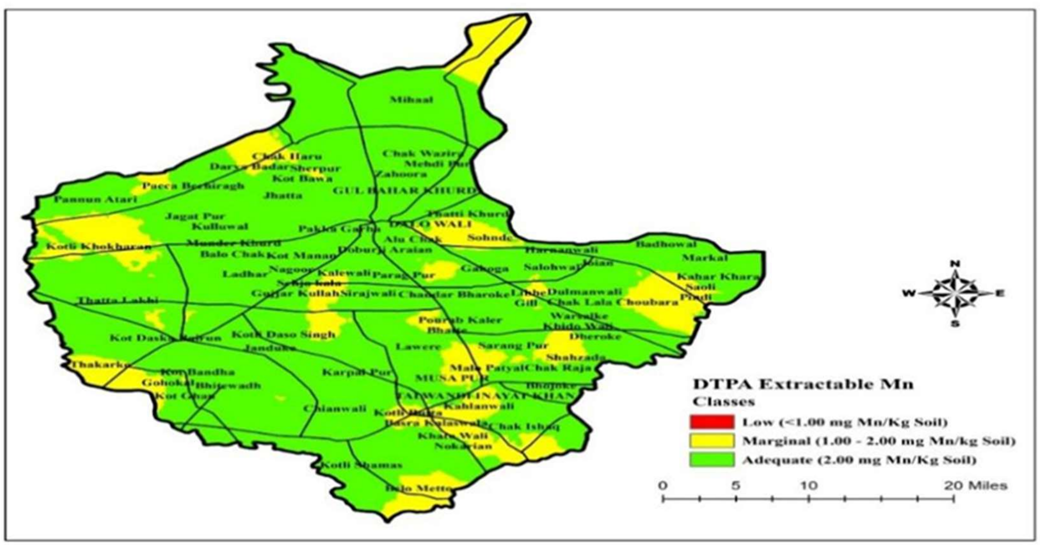

Figure 3.5:Manganese (DTPA-Extractant) distribution shape file in the district Sialkot

Sialkot Soil Classification

The salinity or sodicity state of the experimental site's soil samples was determined using the standardprocedures of electrical conductivity (ECe) and saturated soil paste pH values, while the EC values were monitored from 0.16 to 3.12 dS m-1 and the soil pH of 6.81 to 9.30 mentioned in Table 3.3. All the soil samples were found to be free of salinity problems according to NARC's guidelines. Concernedabout the sodicity problem, most of the samples (90%) were determined to be normal, with only 140 sampling locations (10%) reported to be sodic (Table 3.2).

Soil (Sialkot) Organic Matter

The percentage of OM in the soil was calculated as 0.11 to 1.06 % (Table 3.3). According to our findings, 91 % of soil samples had low SOM levels, while 4 percent had SOM levels that were in marginal ranges (Table 3.2). SOM depletion in arid climates under intensive cropping systems is a serious issue that reduces soil productivity and crop yield simultaneously (Aguilera et al.2020).

Textural Class of Sialkot Soil

The sand, silt, and clay proportion of Sialkot soils are appropriate according to textural classifications and the range of soil sampleswas demonstrated; the Sialkot soil belt is appropriate to produce all sorts of crops with little management (Table 3.3).

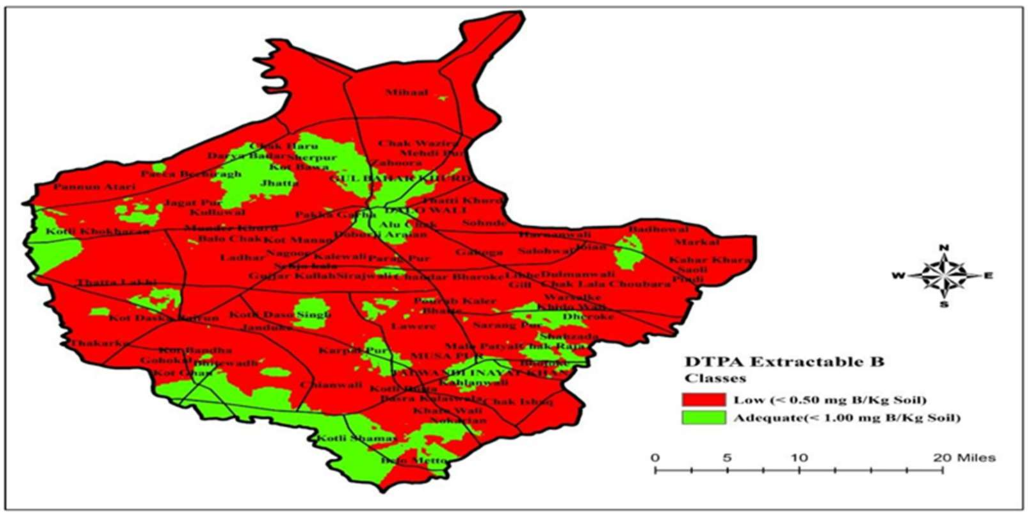

Figure 6:Boron (Hot-water Extractant) distribution shape file in the district Sialkot.

Pearson correlation of soil pH versus Zn+2, Cu+2, Fe+3, and Boron

Plant accessible Zn+2 (R = -0.22), Cu+2 (R= -0.28), Fe+3 (R= -0.25), and B (R= -0.17) were all negatively linked with soil pHs. (Table 3.4, and Figure 3.7). These associations were substantial, explaining 22 %, 28 %, 25 %, and 17 % of Zn, Cu, Fe, and B variance, respectively. Liu et al. (2004) also concluded the same negative relation of associated correlation by pHs of soil solution andcrop available Fe+3 and Mn+2 micronutrient in Pinghu county, south-east China. The relationship between SOC and Cu+2 was also reported negative, explaining only 12% of the variation in Cu+2 availability in terms of soil carbon contents (Table 3.4).

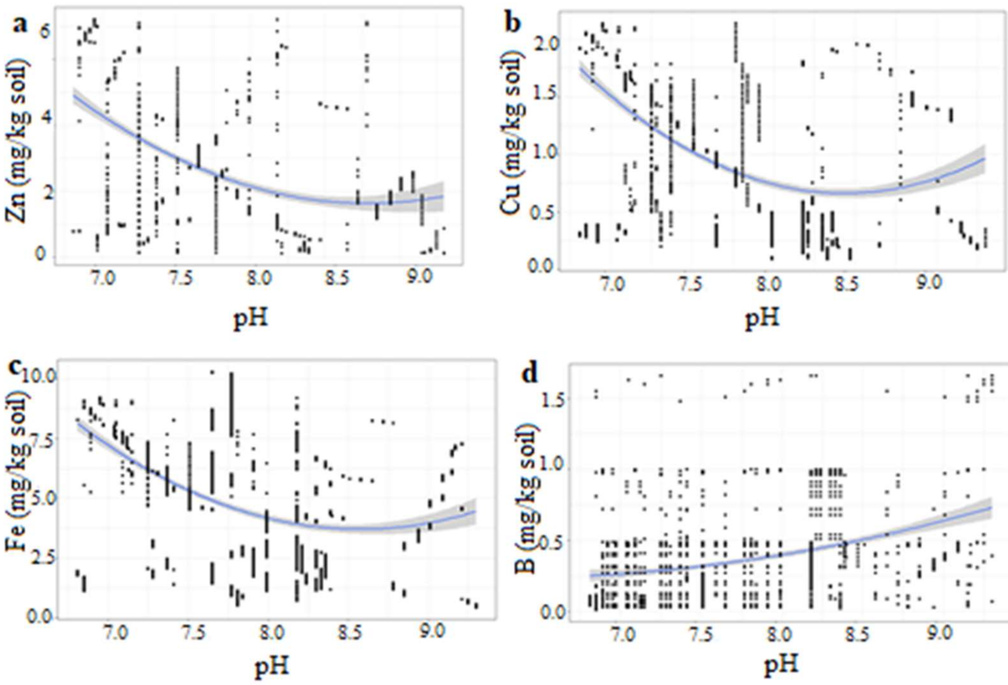

Figure 3.7:Polynomial regressionmodelsSoilpHand(a)Zinc(b)Copper(c)Ironand(d)Boron.Blue lines show the standarderror.

In this study region, strong negative associations of soilsaturated paste pH and the accessibility of trace elements i.e., zinc, copper, iron, and boron were revealed. At higher (alkaline) pH, many micronutrients become less accessible to plants. The majority of Pakistan's agricultural soils are alkaline and calcareous, which can lead to micronutrient deficiencies if not properly managed. The site-specific application of agricultural inputs could be an effective nutrient management method.

Conclusions and Recommendations

In the district of Sialkot, our research found no evidence of a geographical trend in the spatial distribution of plant-accessible micronutrients. The overall significance of plant-accessible Zn, Cu, and Mn was satisfactory, but more lack of Fe and B was discovered in this study. Policymakers, modernized farming communities, agricultural researchers, their departmental extension workers, and students would be able to understand easily the deficiencies andget the distribution maps (shape files) created in this study useful for making productive, calculated, and site-specific decisions. More research is needed to include temporal variance in field data by random sampling method and, as a result, improve forecast maps.

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Conflict of interest

The authors declared that there is no conflict of interest in this study.

References

Aguilera, E., Diaz-Gaona, C., Garcia-Laureano, R., Reyes-Palomo, C., Guzmán, G. I., Ortolani, L., ... & Rodriguez-Estevez, V. (2020). Agroecology for adaptation to climate change and resource depletion in the Mediterranean region. A review. Agricultural Systems, 181, 102809.

Giller, G. L. (2020). Adventures in Financial Data Science: The empirical properties of financial data and some other things that interested me.. (Vol. 1). Giller Investments (New Jersey), LLC.

Hu, Q., Yang, B., Xie, L., Rosa, S., Guo, Y., Wang, Z., ... & Markham, A. (2020). Randla-net: Efficient semantic segmentation of large-scale point clouds. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (pp. 11108-11117).

Hussain, S., Sharif, M., & Ahmad, W. (2021). Selection of efficient phosphorus solubilizing bacteria strains and mycorrhizea for enhanced cereal growth, root microbe status and N and P uptake in alkaline calcareous soil. Soil Science and Plant Nutrition, 67(3), 259-268.

Hwangbo, D. S., Lee, H. Y., Abozaid, L. S., & Min, K. J. (2020). Mechanisms of lifespan regulation by calorie restriction and intermittent fasting in model organisms. Nutrients, 12(4), 1194.

Jun, B. M., Elanchezhiyan, S. S., Yoon, Y., Wang, D., Kim, S., Prabhu, S. M., & Park, C. M. (2020). Accelerated photocatalytic degradation of organic pollutants over carbonate-rich lanthanum-substituted zinc spinel ferrite assembled reduced graphene oxide by ultraviolet (UV)-activated persulfate. Chemical Engineering Journal, 393, 124733.

Khoshru, B., Mitra, D., Mahakur, B., Sarikhani, M. R., Mondal, R., Verma, D., & Pant, K. (2020). Role of soil rhizobacteria in utilization of an indispensable micronutrient zinc for plant growth promotion. Journal of Critical Reviews, 21, 4644-4654.

Kyebogola, S., Burras, L. C., Miller, B. A., Semalulu, O., Yost, R. S., Tenywa, M. M., ... & Mazur, R. E. (2020). Comparing Uganda's indigenous soil classification system with World Reference Base and USDA Soil Taxonomy to predict soil productivity. Geoderma Regional, 22, e00296.

Lazaar, A., Mouazen, A. M., Hammouti, K. E., Fullen, M., Pradhan, B., Memon, M. S., ... & Monir, A. (2020). The application of proximal visible and near-infrared spectroscopy to estimate soil organic matter on the Triffa Plain of Morocco. International Soil and Water Conservation Research, 8(2), 195-204.

Li, Q., Zhong, H., & Cao, Y. (2020). Effects of the joint application of phosphate rock, ferric nitrate and plant ash on the immobility of As, Pb and Cd in soils. Journal of environmental management, 265, 110576.

Peeters, N., Binnemans, K., & Riaño, S. (2020). Solvometallurgical recovery of cobalt from lithium-ion battery cathode materials using deep-eutectic solvents. Green Chemistry, 22(13), 4210-4221.

Strohmeier, G. A., Schwarz, A., Andexer, J. N., & Winkler, M. (2020). Co-factor demand and regeneration in the enzymatic one-step reduction of carboxylates to aldehydes in cell-free systems. Journal of Biotechnology, 307, 202-207.

Suhr, N., Widdowson, M., & Kamber, B. S. (2021). The role of pedogenesis and natural fertiliser as vectors for essential metal content in agricultural topsoils, Central India. SN Applied Sciences, 3(1), 1-23.

Wang, Y., Xu, Y., Huang, Q., Liang, X., Sun, Y., Qin, X., & Zhao, L. (2021). Effect of sterilization on cadmium immobilization and bacterial community in alkaline soil remediated by mercapto-palygorskite. Environmental Pollution, 273, 116446.

Yadav, A. K., Gurnule, G. G., Gour, N. I., There, U., & Choudhary, V. C. (2022). Micronutrients and Fertilizers for Improving and Maintaining Crop Value: A Review. International Journal of Environment, Agriculture and Biotechnology, 7, 1.

Yin, X., Sarkar, S., Shi, S., Huang, Q. A., Zhao, H., Yan, L., ... & Zhang, J. (2020). Recent progress in advanced organic electrode materials for sodium-ion batteries: synthesis, mechanisms, challenges and perspectives. Advanced Functional Materials, 30(11), 1908445.