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MICRONUTRIENTS (Zn, Cu, Fe, Mn, B) AVAILABILITY STATUS IN THE SOILS OF SARGODHA DISTRICT, PUNJAB, PAKISTAN

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ABSTRACT: Soil micronutrient deficiency is a major factor in achieving the optimal yields of the crops. To find a possible solution for this deficiency is surveying the micronutrient status of soils at a specific site. Thus current research focused on variability of soil properties and indicated the spatial pattern of soil micronutrients in Sargodha district, Punjab, Pakistan. 40000 soil samples were collected through Random soil sampling to assess soil micronutrient status at a depth of 0-15cm. . Soil samples were analysed to measure the soil Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn) by DTPA extraction method and quantified by Flame Atomic Absorption Spectroscopy. Hot-water soluble (HWS) Boron (B) was determined by spectrophotometer. In this study, properties of soil were investigated with the help of statistical and interpolation methods (Kriging). The available Zn, Fe, Cu, Mn and B ranged from 0.1 to 5 mg/kg, 0.2 to 10 mg/kg, 0.1 to 5 mg/kg, 0.2 to 10 mg/kg and 0.1 to 4.74 mg/kg, respectively, with mean value of 0.82 mg/kg, 4.9 mg/kg, 0.87 mg/kg, 4.04 mg/kg and 0.5 mg/kg, respectively, with standard deviation 0.35, 1.9, 0.383, 1.8, and 0.14, respectively. Regarding "Poor" class out of 40,000 analysed samples, 13% samples were deficient in Zn, 0% in Cu, 43% in Fe, 2% in Mn, and 41% in B. Regarding "Marginal" category 63% samples were at marginal deficient/adequate in Zn, 14% in Cu, 0% in Fe, 87% in Mn, and 59% in B. Regarding "Adequate" category, 24% samples were at adequate level in Zn, 86% in Cu, 57% in Fe, 11% in Mn, and 0% in B. The alarming situation was appeared for B which demands immediate mitigating steps to cover up the deficiency and should be incorporated essentially in fertilizer recommendation.

Key word: Available Zn, Cu, Kriging, Productivity map, DTPA.

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INTRODUCTION

Pakistan is an agricultural region, and 70% of its population depends on agriculture. The Punjab province is a food bowl of Pakistan with a cultivated area of 12.40 million hectares. Punjab province covers 205,344,000 square kilometres (79,284,000 square miles), making it the second largest area of Pakistan. Previous research has shown that soil nutrients are periodically changed in Punjab and can be accessed through interpolation and classification techniques. The soil quality and value of soil nutrients is subject to change in time and location (Rogerio *et al*., 2006). Maintaining soil productivity or fertility status at an optimal level is a significant factor in crop production. Low levels of crop nutrients can result in diminished yield and quality. Nutrients of the plant kingdom are primarily classified into macronutrients and micronutrients. The importance of micronutrients in food production and their relation to nutrition security and human health has become more prevalent in recent years. Many of the nutrients required for human health come from soil, either from plants or from products of animals eaten by humans (Shukla *et al*., 2014 and Steffan, *et al*., 2018). Soils differ widely in their macro and micronutrient content and in their ability to supply adequate quantities for optimal crop growth (Celestina *et al*., 2019). Soil that is poor in its ability to provide nutrients to crops is alarmingly around the world, and this issue is compounded by the fact that many cultivars of major crops are highly susceptible to insufficient levels of the macronutrients and micronutrients (Rehman *et al*., 2018). A task for the Agricultural scientists is to provide nourishment for the world population with nutritious food. In the past, people expected high grain production which meant low amounts of micronutrients in their grains (Zhao and Shewry, 2011, Cakmak, 2012, Shukla *et al*., 2014a, Shukla *et al*., 2014b and Rehman and Adnan 2018). Initial geological baseline and subsequent geochemical and pedogenic modalities assess total soil micronutrient levels (McKenzie *et al*., 2008). However, as availability depends on soil pH, organic matter content, adsorbent surfaces and other physical, chemical and biological conditions in the rhizosphere, total levels are rarely representative of plant availability (Dhaliwal *et al*., 2019). The availability of micronutrients to plants can be assessed in direct uptake experiments or estimated using techniques that compare the quantity of micronutrients extracted chemically from soil to plant uptake and the response to micronutrient fertilization (Shukla *et al*., 2014c). Rational management of micronutrient fertility and toxicity includes an awareness of how total and plant-available soil micronutrients differ across the land (White and Zasoski, 1999 and Willy *et al*, 2019). Various methods have been used to survey and map the spatial distribution of soil micronutrient content and availability at scales ranging from global to single-field production sites (Pan *et al*., 2014). Wide-area soil micronutrient maps improve our understanding of the existence and severity of micronutrient problems and help to assess their relationships with climate, soil properties, and soil genetic characteristics calculated on similar scales, such as order, sub-order, or large group level soil taxonomy (Brevik *et al*., 2016). Intermediate scale maps can be useful in identifying geographic areas where deficiencies or toxicity are likely to occur in agriculture and in assessing local soil characteristics that may be associated with such problems (Chiprés *et al*., 2009). Detailed maps of soil micronutrient contents and their availability in individual fields for site-specific precision agriculture are being developed (Cook and Bramley, 1998). Studies indicated that consuming foods rich in micronutrients would significantly aid in combating micronutrient deficiencies (Welch and Graham, 2004). Micronutrient maps of soil have facilitated the exploration of the relationship between soil micronutrient quality and availability and certain human and livestock health problems (Vanlauwe *et al*., 2014). The problem of micronutrient deficiency is linked to food and nutritional safety (Meenakshi *et al*., 2010). Starvation with micronutrients is a global issue, and micronutrients influence crop productivity as well as output quality (especially micronutrients concentration). Micronutrient shortages are difficult to detect and thus the problem is called 'hidden hunger'. Advances like the Global Positioning System (GPS), Geographic Information Systems (GIS), Atomic Absorption Spectroscopy, Geostatistics and Precision Agriculture promote soil micronutrient mapping and provide quantitative support for decision-making and policy-making to enhance agricultural approaches to balance micronutrient nutrition (White and Zasoski, 1999 and De Paul and Lal, 2013). The GPS-based sampling improves the ability to map micronutrient fertility, which is valuable for farmers, policy-makers, and other stakeholders. In addition, GPS-based technologies help to re-assess sites after an interval of time (Shukla *et al*., 2014c). This research focuses on the current status of micronutrient levels in soils, its impact on agricultural yields, and its relation to food security.

MATERIALS AND METHODS

Study area: Sargodha is situated in the semi-arid and sub-tropical area of Punjab Province and has both a hot and dry climate throughout the year. The land of this district was created from the River Jhelum with a slight contribution from the River Chenab. The main crops grown in this region are wheat, rice and sugar cane. The Sargodha is also famous for its citrus production, like Kinnow, orange or lemon. The territory of the area is 5.864 km^2. The goal of this study was to conduct a comparative analysis of soil micronutrients in the Sargodha district with the spatial distribution of soil nutrients and their digital mapping (Figure 1) (SFRI, 2021).

Soil sampling and laboratory testing: In order to achieve a soil micronutrient analysis in order to keep farmers well informed about their soil status and to increase crop production with quality and to make maximum profits from their existing resource, a random sampling of soil in grids of 10 × 10 acre in the whole Sargodha district was carried out in the project PMU Ext 2.0 of the Government of Punjab in the Department of Agriculture. Soil samples were obtained using a special soil auger with a GPS system and submitted to the Soil and Water Testing Laboratory for Research, Soil Fertility Research Institute (SFRI), Punjab. About 40,000 soil samples were obtained from random sites throughout the study area. The soil samples were taken from 0-15 cm of depth. DTPA extraction was performed as defined by Lindsay and Norvell (1978) and all micronutrients viz Zinc, Copper, Iron and Manganese were analyzed by atomic absorption spectroscopy with the exception of Boron, which was analyzed by spectrophotometer. The protocol used by the analyst is listed below.

About 20 g of soil was weighed and 40 ml of DTPA solution was added. The suspension was shaked continuously on a horizontal shaker for 2 hours and filtered. A blank solution (0 ppm) containing all reagents except soil was run as blank. Prepared 4 standards with DTPA as matrix for each element with a range for Zn and Cu (0.5, 1.0, 1.5, 2.0 ppm) and for Fe and Mn (0.5, 10, 20, 30, ppm). Fed the sample to Atomic Absorption Spectrophotometer and Record the absorbance.

For Boron analysis, the Boron standards were prepared in 0.05 M HCl for HCl extraction. A 430 nm wavelengths was used to determine boron (ppm) by spectrophotometer using the colour development method. About 10 g soil was shaked with 20 ml of 0.05 M HCl for 5 minutes and then filtered. Transferred 1 ml of aliquot to 50 ml of polypropylene volumetric flask, then added 2 ml of buffer solution, then added 2 ml of azomethine-H reagent and mixed. Absorption at 430 nm on the spectrophotometer at concentration mode or by graph using the standard curve was observed after 30 minutes. Boron standards were developed in 0.05 M HCl for extraction of HCl.

Spatial distribution of soil data: Spatial distribution of soil nutrients was interpolated using the most reliable statistical method called Kriging and was based on the actual soil surface data. The accuracy of Kriging was confirmed with standard errors calculated by the cross-validation process, which indicates the accuracy of the Kriging method, and it was conventional. Kriging was used to turn soil data points into continuous soil properties fields. ArcGIS Semivariogram 10.5 software package was used to predict soil properties maps. The most widely used Kriging model was used to produce the most reliable estimation values for the particular area on the basis of the measured values (Histograms, 2021). Kriging takes each approximation value and assigns weight according to the location of the sampled points relative to the estimated position of the interpolated points. In order to assign weight to the estimated values, the following formula was used:

$$\hat{Z}(x_0) = \sum_{i=1}^{N} \lambda_i \, z(x_i)$$

RESULTS AND DISCUSSION

Micro-nutrient soils are very important for good crop yield and are used in very small quantities by plants. Plants normally take one pound per acre. According to the soil variation maps of Sargodha, many changes have occurred in Sargodha soil which have an impact on the crop production of Sargodha 10]. Soil nutrients were standardized according to SFRI standards and their frequency in study area is discussed in table 2.

Results

Spatial distribution of available Zinc (DTPA-Zn): Zinc available in this study ranges from 0.1 to 5 mg/kg soil with a mean of 0.82 mg/kg soil and 0.35 standard deviation (Table 1). Systematic survey and analysis of 40,000 soil samples analyzed under the project PMU Ext 2.O of the Government of Punjab in the Department of Agriculture revealed a deficiency of 13%, while 63% in the marginal range and 24% remained in the adequate class of Zn as shown in Table 2. Analysis of soil data for zinc showed that the agricultural area of the Sargodha district was marginal for Zn, but localized Zn had an adequate value near the Chenab River and other water bodies in the Sargodha district (Figure 2). Zinc deficiency observed near chak 57 shumali, Chak 81 and Noon jahgir.

The results conflict with the findings of Zia *et al*. (2006) who documented a significant lack of Zn in the region. The most appropriate explanation for marginal availability of Zn and an improvement in adequate availability was the use of recommended fertilizers in the study area.

Spatial distribution of available copper (DTPA-Cu): DTPA-extractable Cu in soils of the Sargodha district ranged from 0.1 to 5 mg kg^{-1} soil with a mean of 0.87 mg/kg soil and 0.383 standard deviation (Table 1). Of the total soil samples analyzed, 14% contained 0.2-0.5 mg Cu kg^{-1} soil, which could possibly be susceptible to Cu deficiency in the future (Table-2) and 86% of soils in the Sargodha district had sufficient Cu level to meet the crop needs. The interpolated map of Cu shows the area of appropriate and marginal status in the district of Sargodha (Figure 3).

Spatial distribution of available iron (DTPA-Fe): The available Fe in the Sargodha district ranged from 0.1-10 mg Fe/Kg soil with a mean of 4.9 mg/Kg with a standard deviation of 1.9 (Table 1). Analysis data for iron indicates that 43% of samples were in poor class and 56% of samples were in an adequate class of Fe, as shown in Table 2. No sample was contained in the marginal category. The interpolated map of Fe shows the area of adequate and marginal status in the Sargodha district (Figure 4). Low Fe values are mostly found in the villages of Chak 68, 91, 31, 74, 23 Alif and Noon Kalo.

Spatial distribution of available manganese (DTPA-Mn): The available plant manganese was found between 0.2 and 10mg Mn/Kg soil with a mean of 4.04 mg/Kg with a standard deviation of 1.8(Table-1). According to analytical data, 87% of the soils are found in the "Adequate" class, 11% for the "marginal" class and just 2% for the "Poor" class for Mn (Table-2). The interpolated Mn map shows the region in the Sargodha district of adequate, marginal and poor status (Figure-5). While considering the spatial Pattern the low class Mn spots found in villages Chak no 23 and Chak no 81 shumali.

Spatial distribution of available boron (HWS-B): Plant usable B was between 0.1 and 4.74 mg/kg soil with a mean of 0.5 mg/kg and 0.14 mg/kg as standard deviation (Table 1). Analysis data showed that soil boron status was found to be low and marginal in two groups. No sample was found to be satisfactory in the entire district. 41% of soil samples were poor and 59% were in the marginal water soluble B class (Table 2). Boron's assessment of the study zone revealed its broad inadequacy in the developed areas of the Sargodha district. Our results are in line with the results and observations of Rashid *et al*. (1997), who reported a far-reaching B insufficiency at Potohar level in Pakistan. Nazif *et al*. (2006) also defined B inadequacy in the soils of Azad Jammu and Kashmir. Interpolated map B shows the area of low and marginal status in the district of Sargodha (Figure 6).

Discussions

Spatial distribution of available Zinc (DTPA-Zn): The world's most common micronutrient problem is zinc deficiency in crops. Zinc malnutrition has thus become a significant health burden for resource-poor populations (Sharma *et al*., 2011). Zn soil is an index of the content of Zn in feed and grain, which relies heavily on the available soil content of Zn (Shukla, 2014d). In the study, the critical limits used for Zn were <0.5 as low, 0.5-1.0 as marginal and >1.0 mg kg^{-1} as adequate for soil as per the Directorate of Soil Fertility Research Institute (SFRI), Punjab, Lahore. However, it varies with soil and crop types and in Sargodha soils, due to low and marginal levels of Zn, crops and citrus fruits have been shown to respond to the application of Zn. As soils and crops vary widely in their nutrient supply and utilization efficiency, their critical limits need to be refined with regard to soil characteristics and plant parts for individual crops in order to clearly predict possible deficiencies.

Spatial distribution of available copper (DTPA-Cu): In Pakistan, copper deficiency is mainly seen in the calcareous mountains and poorly drained soils and in soils where some horticultural crops are grown on soils with low organic matter. Application is most often seen in higher valued fruit plants with only limited applications in field crops. According to the findings, in the case of available copper, the majority of the soils in the Sargodha district are average and in the "Adequate" class, only 14% of the soils are in the "Marginal" class and no deficiency was observed (Table 2 and Figure 3). Moreover, none of the soil sample out of 40000 analyzed samples in the district reported in deficit of Cu. It may be due to the use of micronutrients, in particular Cu, in a fertilizer recipe.

Spatial distribution of available iron (DTPA-Fe): Fe is another limiting micronutrient for crops as a plant Fe deficiency is known to have been occurring in alluvial soils for a long time in many parts of the world. After oxygen, silicon and aluminium, Fe is present in large amounts as it makes up around 3-5% of the soil, making it the fourth most abundant part of the Earth's crust. However, much of the Fe in soils is not available for absorption of plants Meng *et al*., 2005). As far as Fe is concerned, soil samples with a Fe content above >4.5 mg kg^{-1} soil are categorized as adequate. Crops grown in such soils do not react to the application of Fe and soils containing Fe <4.5 mg Fe kg^{-1} soil are considered to be of a potentially deficient category (Table-2). Intensive cultivation, especially with horticultural crops and potato and corn crops in these soils, will show a crop deficiency if maintenance doses are not provided. Approximately 57% of the soils in the Sargodha district have adequate Fe content to sustain intensive farming, given that sufficient moisture is available in the fields. For the formation of chlorophyll and protein, photosynthesis, electron transfer, oxidation and reduction of nitrates and sulphates, and other enzyme activity, Metabolic Fe is necessary. Its deficiency in newly emerging young leaves causes interveinal chlorosis due to decreased chlorophyll synthesis, resulting in poor growth and yield loss (Mengel and Geurtzen, 1986) Among the crops, Fe response was frequently seen in citrus, sugar cane, potatoes, maize and horticultural crops grown in the Sargodha district.

Spatial distribution of available manganese (DTPA-Mn): The frequency analysis of Mn in the soils of the Sargodha district showed that approximately 2% of the samples contained Mn below <1.0 mg Mn kg^{-1}. Furthermore, 11% of samples in the range of 1.0 to 2.0 mg Mn kg^{-1} soil could be considered to be potentially insufficient in the future due to the marginal distribution class. And the remaining 87% of soils in the Sargodha district with a Mn content of more than 2.0 mg kg^{-1} soil are considered adequate to meet the long-term crop demand (table-2, Figure-5). The total soil content of manganese has been documented to be very high in the soils of the Sargoha district. However, its availability becomes an issue particularly in sandy loam soils, which are often wet and dry. In addition, availability/solubility depends on the parent material, the geomorphic, physico-chemical, biological processes of the soil that regulate the total content of Mn as well as its distribution in the soil and supply to the crops grown therein. Mn deficiency was found in light textured and calcareous soils in India (Katyal and Sharma, 1991 and Sharma *et al*., 2011).

Spatial distribution of available boron (HWS-B): The frequency distribution of B in the soils of the Sargodha district showed that approximately 40% of soil samples with a B content of less than 0.5 mg kg^{-1} were considered deficient and ranged from 0.5 to 1.0 mg kg^{-1} soils were graded as Marginal Deficient. Approximately 59% of samples falling within the range of 0.5 to 1.0 mg kg^{-1} B was classified as marginal, and such soils did not display B crop deficiency in response to B application. Samples with a B content >1.0 mg B kg^{-1} soil are grouped into an appropriate B-category level and it is interesting to note that no single sample is included in an adequate category. It demands for the attention of policy makers and all stakeholders, including the farming community and fertilizer business enterprises, to mitigate this alarming situation of B in the Sargodha district (Table-2 and Figure-6). Boron (B) is a specific non-metallic micronutrient necessary for the growth and development of normal plants. It is mobile and is most frequently leached with excess moisture down to the soil profile. The B deficiency and toxicity spectrum is very limited. Boron concentrations and soil bioavailability are affected by a variety of factors, including parent material, texture, clay mineral composition, pH, organic matter content, sources of irrigation, interrelationship with other components, and environmental conditions such as moderate to heavy rainfall, dry weather, and high intensity of light (Moraghan and Mascagni, 1991). Consequently, knowledge of these factors affecting B uptake is essential for the assessment of B deficiency and toxicity under different conditions.

Table 1. Soil properties of Sargodha district (maximum, minimum, mean, Standard deviation) (maximum, minimum, mean, Standard deviation).

Soil Parameter (mg/kg)	Min	Max	Mean	Standard deviation
Zn	0.1	5.0	0.82	0.35
Fe	0.2	10.0	4.9	1.9
Cu	0.1	5.0	0.87	0.383
Mn	0.2	10.0	4.04	1.8
B	0.1	4.74	0.5	0.14

Table 2. Standardized soil parameter classes with their percent distribution of comparative frequency in Sargodha district agriculture.

Soil Parameter (mg/kg)	Class	Status	Frequency distribution
Zn	<0.5	Poor	13 %
	0.5-1.0	Marginal	63 %
	>1.0	Adequate	24%
Fe	<4.5	Poor	43%
	-	Marginal	-
	>4.5	Adequate	57%
Cu	< 0.2	Poor	-
	0.2-0.5	Marginal	14%
	>0.5	Adequate	86 %
Mn	<1.0	Poor	1%
	1.0 -2.0	Marginal	11%
	>2.0	Adequate	87%
B	<0.5	Poor	41%
	0.5 – 1.0	Marginal	59%
	>1.0	Adequate	-

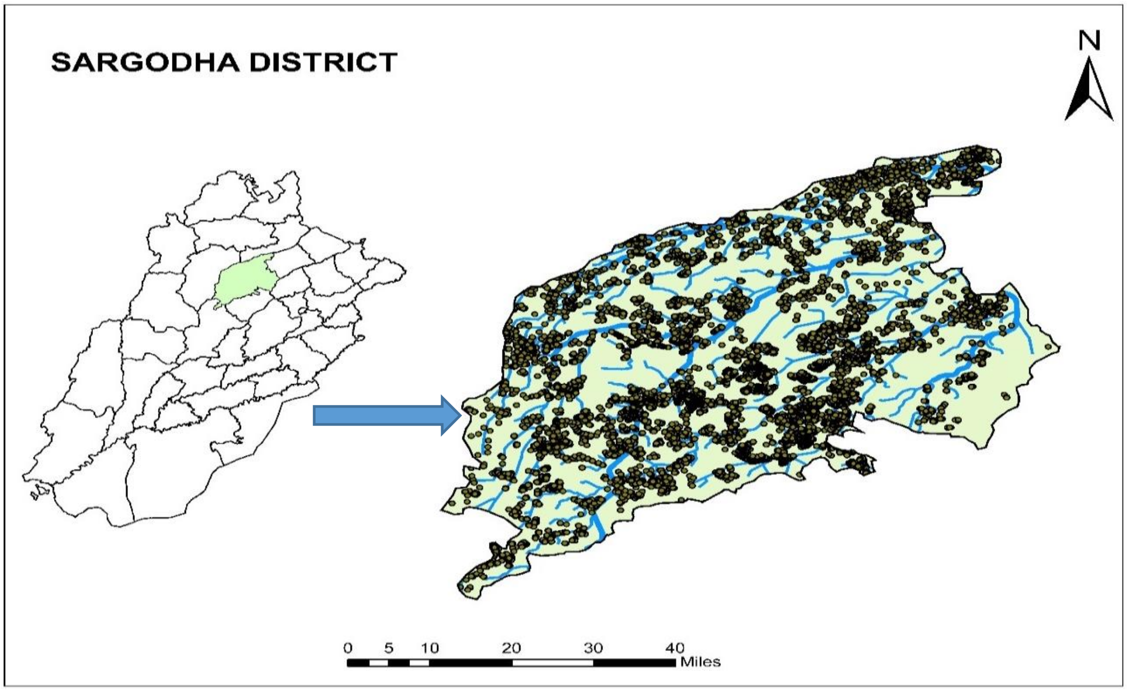

Figure 1. Spatial Map of Sargodha district with random soil sampling points.

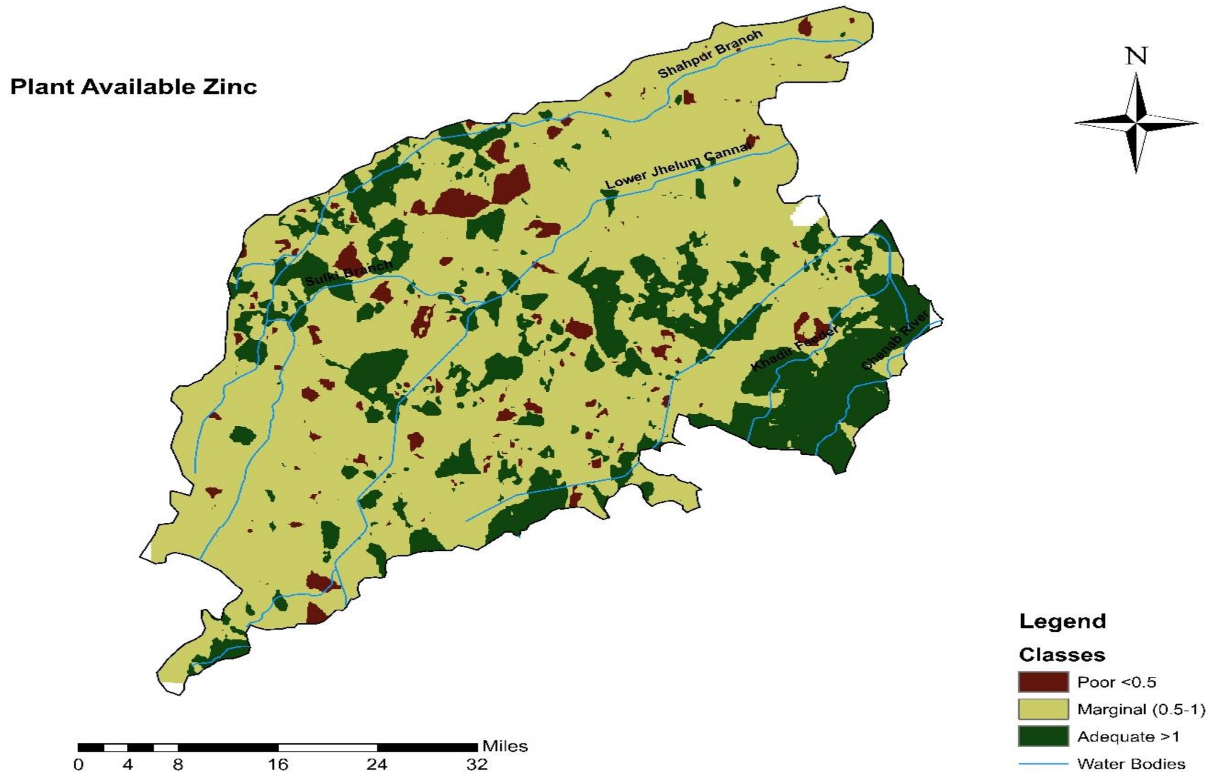

Figure 2. Spatial pattern of soil available zinc in district Sargodha.

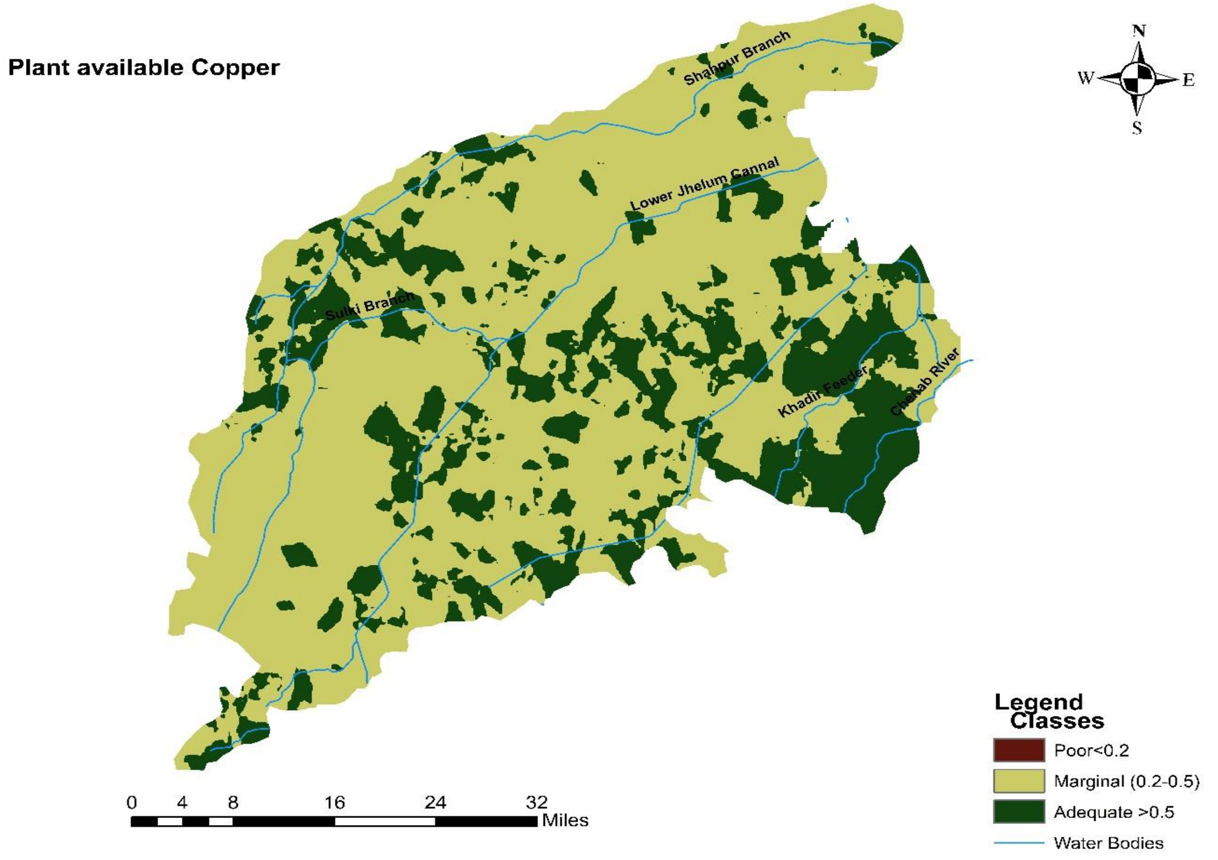

Figure 3. Spatial pattern of soil available Copper in district Sargodha.

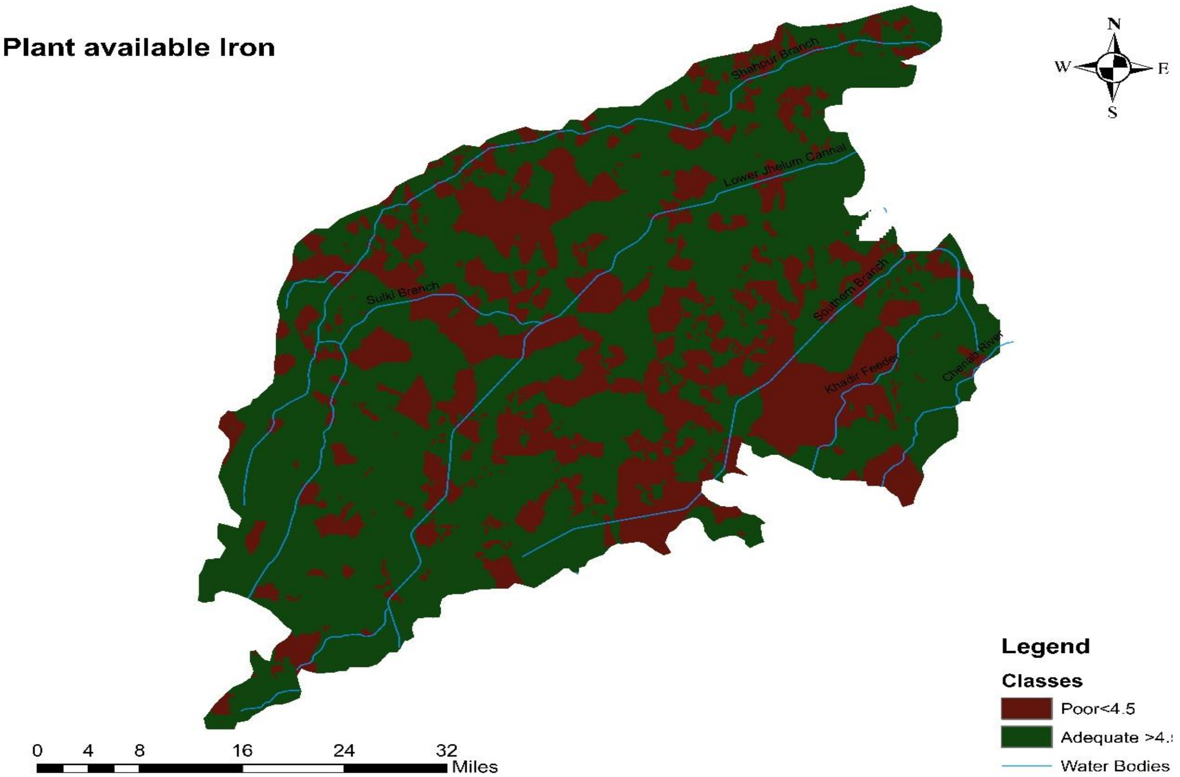

Figure 4. Spatial pattern of soil available Iron in district Sargodha.

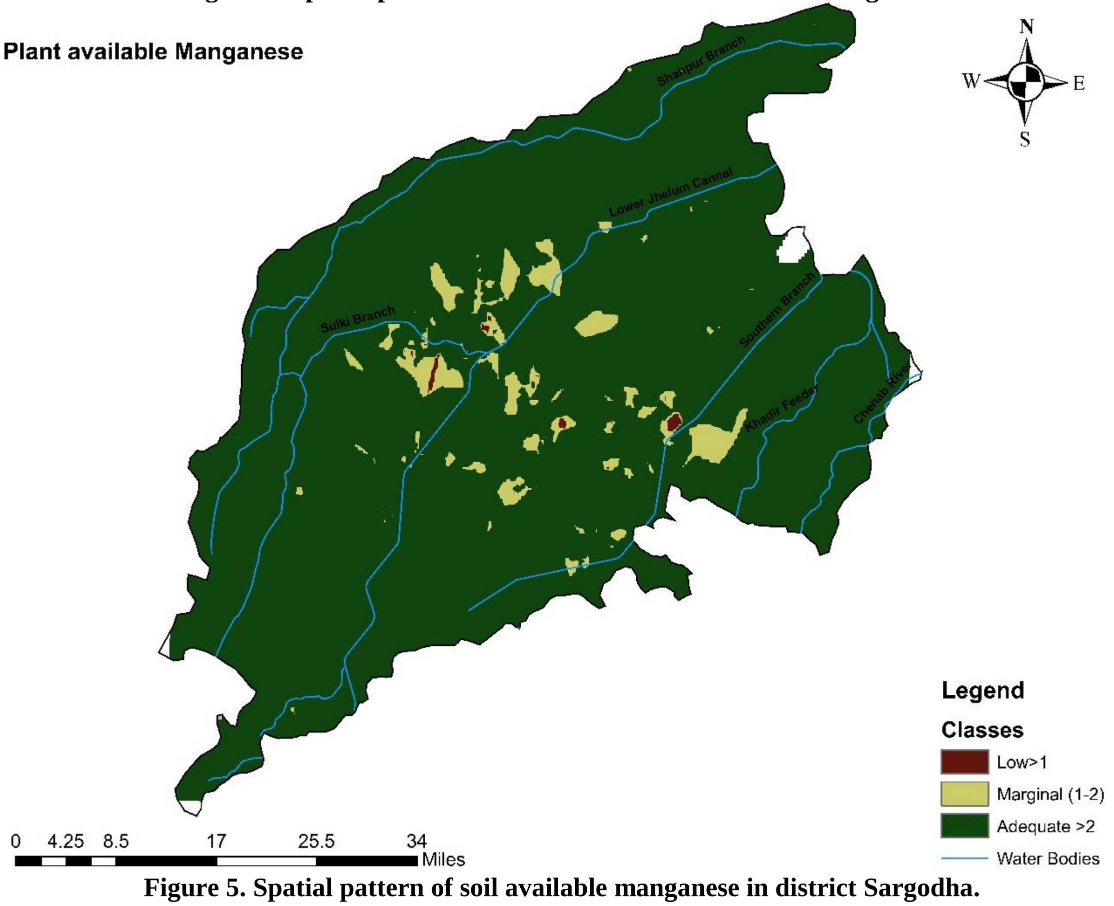

Figure 5. Spatial pattern of soil available manganese in district Sargodha.

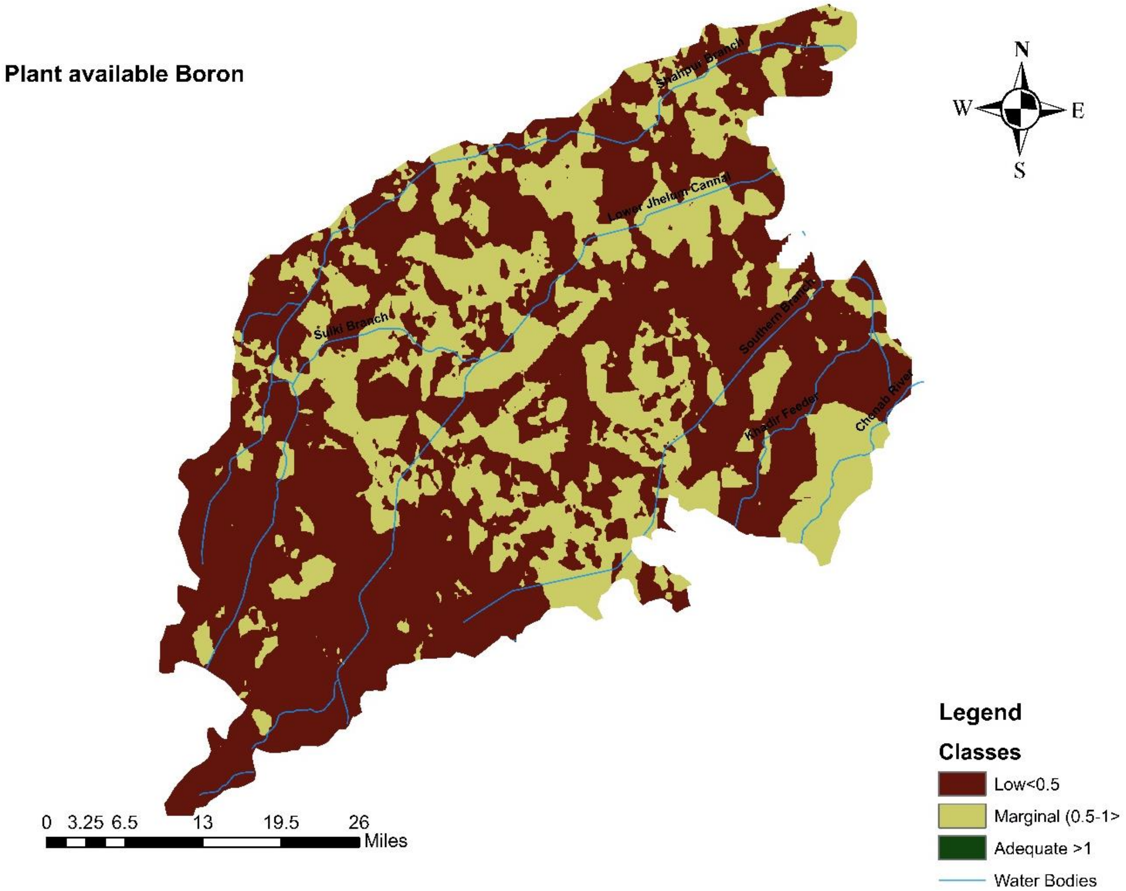

Figure 6. Spatial pattern of soil available boron in district Sargodha.

Conclusions: In this study, properties of soil are investigated with the help of statistical and interpolation methods (Kriging). The available Zn, Fe, Cu, Mn and B ranged from 0.1-5 mg/Kg, 0.2-10 mg/Kg, 0.1-5 mg/Kg, 0.2-10 mg/Kg and 0.1-4.74 mg/kg respectively with mean 0.82 mg/Kg, 4.9 mg/Kg, 0.87 mg/Kg, 4.04 mg/Kg and 0.5 mg/Kg respectively with standard deviation 0.35, 1.9, 0.383, 1.8, and 0.14 respectively. Regarding “Poor” class out of 40,000 analyzed samples, 13% samples were deficient in Zn, 0% in Cu, 43% in Fe, 2% in Mn, and 41% in B. Regarding “Marginal” category 63% samples were at marginal deficient/adequate in Zn, 14% in Cu, 0% in Fe, 87% in Mn, and 59% in B. Regarding “Adequate” category 24% samples were at adequate level in Zn, 86% in Cu, 57% in Fe, 11% in Mn, and 0% in B. These soil micro-nutrients has become less accessible for plants at higher pH or alkaline soil. In Pakistan most of the agricultural land is alkaline and calcareous by nature which is the main reason of micro-nutrients deficiency if not managed wisely. The appropriate management of soil nutrient strategy can be helpful to overcome this deficiency. The alarming situation is for B which demands immediate mitigating steps to cover up the deficiency and should be incorporated necessarily in fertilizer recommendation.

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