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Indexing plant available sulfur content in the major oil seed producing districts of Potohar, Pakistan

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Abstract

Sulfur is an essential, fourth major nutrient required by plant after nitrogen, phosphorus and potassium. The Potohar plateau covers an area of more than one million hectares. Nitrogen and phosphorus deficiency is well documented in Potohar plateau. Preliminary surveys suggested plant available SO_4-S deficiency in Potohar Plateau, but no work has been carried out for accounting spatial variability of plant available SO_4-S. A field survey was conducted in the two districts (Attock and Chakwal) of Potohar region for mapping plant available sulfate sulfur content in the soils. One hundred and fifty-one farmers' fields growing oilseed crops {Mustard (Brassica napus) and Sarson (Brassica juncea)} i.e., 78 from district Attock and 72 from district Chakwal were sampled. Soil sampling was done at the depth of 0-20 cm with stainless steel augur. Geo-referencing of the sampled location was carried out using GPS (Garmine etrex). Spatial data along with attribute data was used to carry out geo-statistical analyses. The results indicated a widespread SO_4-S deficiency in both districts i.e., 85 and 95% of total analyzed soil samples were categorized as deficient in plant available SO_4-S contents in district Chakwal and Attock, respectively. Plant available sulfur was strongly spatial dependent in both districts which provided an opportunity to prepare digital maps indicating differential nutrient status of both districts.

Keywords: Sulfate-sulfur, gis, mapping, plant available, soil, geo-statistics

Introduction

Sulfur (S) is a component of the amino acids like cysteine (26% S), cystine (27% S), methionine (21% S) which are the fundamental structural component of protein molecules (Goswami, 2014). Sulfur-Sulfur bonds provide specific three dimensional protein shape and play important role in catalytic processes (Havlin *et al*., 2005). Soil is the key part of the worldwide bio geochemical sulfur cycle acting as a source and sink for different S species and interceding changes of oxidation state. Agricultural crops are more prone to sulfur deficiency (White, 2013). Sulfur plays a major role in determining seed yield and quality of oilseed crop. Sulfur improves the quality of vital oil (mustard oils) and gives flavor. It is an essential component of vitamin A and in addition, it activates certain enzymes in plants (Parlawar *et al*., 2018). Average S removal for food grain is estimated at 3-4 kg ha^{-1} for cereals (wheat and rice), 5-8 kg ha^{-1} for sorghum and millet, 8 kg ha^{-1} for pulses and legumes and 12 kg ha^{-1} for oilseeds (Kanwar & Mudahar, 1986).

Sulfur deficient plants tend to spindle and grow slender stems and petioles. They exhibit slow development, and it may delay their maturity. They also have chlorotic light green or yellow appearance (Brady & Weil, 2013). According to some preliminary surveys, sporadic S deficiency has been observed in some areas of the Potohar region (Khalid, 2009).

Nutrient availability to plants is affected by physico-chemical properties of soil and for successful implementation of site-specific nutrient management, it is necessary that spatial variability of properties is taken into account as continual spatial variability is one of the important characteristics of the soil properties (Ahmed *al*., 2014).

Laborious soil sampling, analysis and usual statistical methods make it impossible to observe the nutrient content

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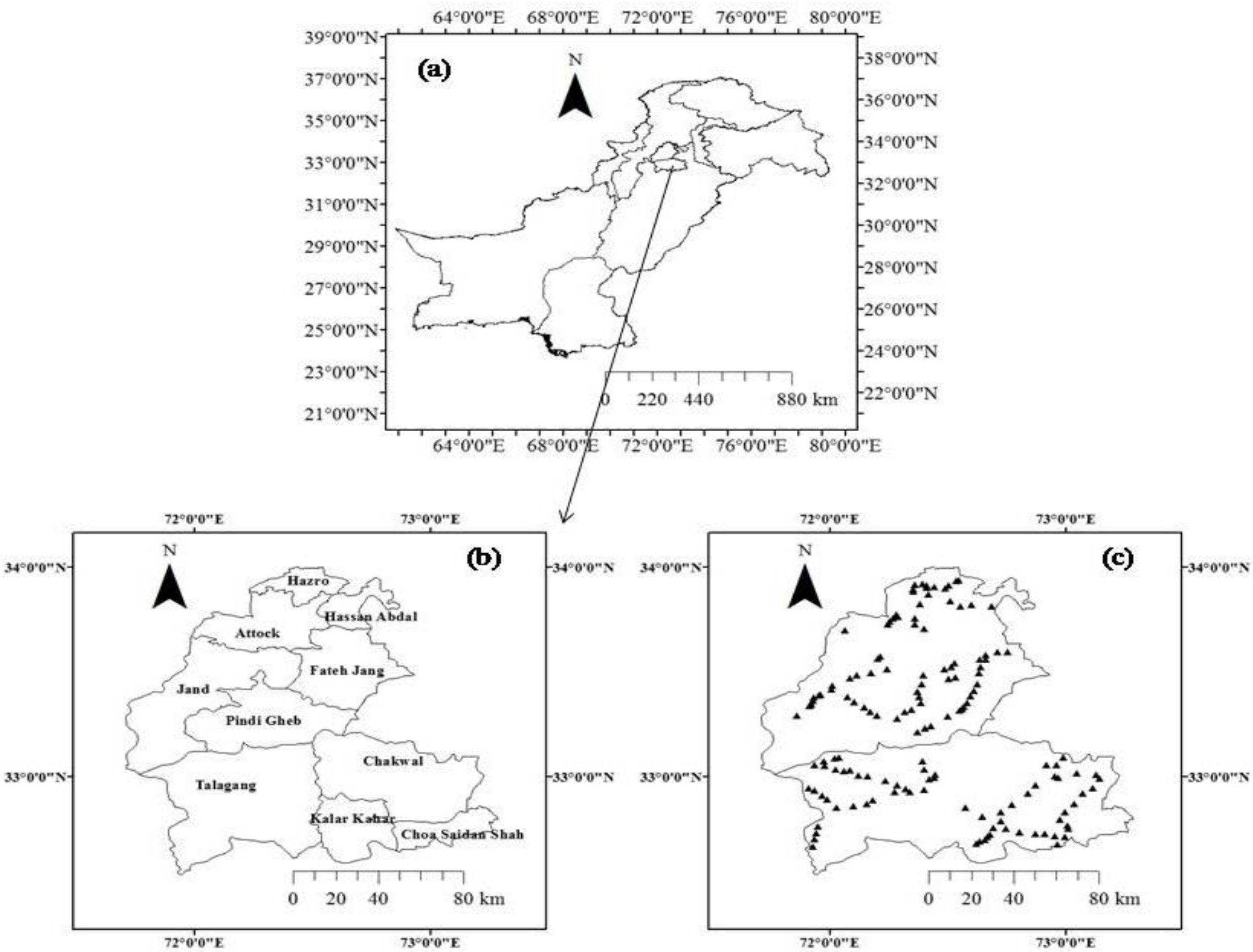

Figure 1: Geographical location of surveyed area (a) Pakistan (b) District Attock and Chakwal (c) Sampling distribution

on regional basis. Application of modern techniques like GIS and geo-statistics becomes in-evitable for efficient and site-specific nutrient management (Attar *et al*., 2012). These technologies greatly reduce the destructive sampling and excessive use of expensive chemicals for traditional soil analyses and provide information of un-sampled locations relative to sampled location.

Keeping in view the scarcity of information regarding plant available SO_4-S content in the oilseed producing area of Pakistan, this research work was conducted to examine the sulfur status in the soil and foliage of oil seed crops grown in the area.

Materials and Methods

Site description

Chakwal district is situated in southwest of federal capital while Attock district is located on Indus River eastern bank, north-east of the province of Punjab. Climate of surveyed area comprised of hot summers and cold winters. Soils of district Chakwal have been derived from late Pleistocene loess and are moderately fine to fine textured, calcareous in nature. Soils of district Attock have been derived from limestone bedrock, shallow and deep loamy soils in highlands and valleys. The main crops of both districts include wheat, ground nut, maize, vegetables chickpea and oilseed. Geographical location and sampling distribution is exhibited in Figure 1.

Soil sampling and processing

A total of 150 sampling sites{Mustard (*Brassica napus)* and Sarson (*Brassica juncea*)} i.e., 78 and 72 from district Attock and Chakwal were selected, respectively. Sampling was done from soil depth of 0-20 cm with

Table 1: Precise location (coordinates) of sampling sites in district Chakwal

Sr. No	Lat	Long	Sr. No	Lat	Long	Sr. No	Lat	Long
1	33.09364	72.99178	25	32.81077	72.64666	49	32.75362	73.01191
2	33.05869	72.96124	26	32.85348	72.57666	50	32.71615	72.99738
3	33.05869	72.91933	27	32.86238	72.10257	51	32.67812	72.96462
4	33.00578	72.95486	28	33.0941	72.04031	52	32.61238	72.89127
5	32.99623	72.96909	29	33.70076	72.06761	53	32.72038	72.95344
6	33.01768	73.04657	30	33.08909	72.02391	54	32.72769	72.9115
7	33.14472	73.10561	31	33.07489	71.97798	55	32.72776	72.87251
8	33.0115	73.12839	32	33.05638	71.93797	56	32.73497	72.80693
9	32.99302	73.14472	33	33.05391	71.98205	57	32.75443	72.74975
10	32.94832	73.11543	34	33.03618	72.02843	58	32.86927	72.77408
11	32.92179	73.07469	35	33.02766	72.06125	59	32.83393	72.7275
12	32.87286	73.03557	36	33.03401	72.08878	60	32.79122	72.72485
13	32.83403	72.99839	37	33.0069	72.12155	61	32.75848	72.69459
14	32.96256	72.87169	38	33.00418	72.16132	62	32.72466	72.67943
15	32.92145	72.84221	39	32.98194	72.2366	63	32.71504	72.66946
16	32.79755	72.97565	40	32.96103	72.28708	64	32.70176	72.65877
17	32.76839	73.00721	41	32.94302	72.32453	65	32.69441	72.6382
18	32.68479	72.62293	42	32.911	71.96803	66	32.94621	71.91331
19	32.92828	72.27834	43	32.99848	72.44305	67	32.73341	71.9443
20	32.89029	72.18393	44	33.01162	72.44885	68	32.70446	71.93726
21	32.87172	72.15877	45	33.03773	72.40298	69	32.66811	71.92909
22	32.92994	72.34234	46	33.07515	72.39614	70	32.85598	72.03124
23	32.94011	72.40089	47	33.7768	71.96549	71	32.89408	71.98969
24	32.98836	72.42384	48	32.76338	71.95349	72	32.93558	71.93757

stainless steel augur. Coordinates of the sampled location were recorded using Garmine *etrex* GPS. Recorded precise location (coordinates) are summarized in Table 1 for district Chakwal and Table 2 for district Attock. Collected soil samples were brought to the Institute of Soil Science, PMAS-Arid Agriculture University, Rawalpindi. Soil samples were dried, sieved through 2 mm sieve and used for analysis.

Soil analyses

Physico-chemical properties and nutrient

Soil samples were analyzed for texture (Gee and Bauder, 1986), pH (Mclean, 1982), EC (Rhoades, 1982), organic matter (Nelson and Sommers, 1982) and SO_4-S (Verma, Swaminathan and Sud, 1977).

Statistical analysis

Descriptive statistics including mean, standard deviation, minimum, maximum, skewness and kurtosis were applied to observe the standard tendency of obtained dataset. Coefficient of variance was applied to examine the heterogeneity of datasets.

Geo-statistical modeling and mapping

Semi-variogram analysis was used to investigate the degree of spatial dependence of plant available sulfur. This technique is widely adopted to examine the spatial dependence of macronutrients (Rizwan*et al*., 2016) micronutrients (Noor *et al*., 2013; Ahmed *et al*., 2014; Ziad *et al*., 2016), Physico-chemical properties (Nabi *et al*., 2018) and was also recommended by Bhatti *et al*. (1991) in the country. Establishment of spatial dependence is used as a criterion for interpolation of nutrients in soils, nugget is regarded an experimental error or uncertainty. Sill depicts differences due to parent material variability and vegetation. Semi-variance states that all observations are SO_4-S dispersed below the data set mean or target value. The range defined the distance of separation over which the spatial reliance was observed to be clear (Aishah *et al*., 2010). Spatial ratio is taken as an indicator to group variables according to their spatial dependency either strong, moderate or weak. Spatial ratio of less than 25% indicates highest spatial dependence, whereas the ratio between 25 and 75% indicates moderate spatial dependence. The spatial ratio exceeding 75% indicates weak spatial reliance (Cambardella *et al*., 1994). Different models were contrasted to examine their simulation accuracy using cross validation indicators i.e., Mean Error (ME), Root Mean Square Error (RMSE), Average Standard Error (ASE), and Root Mean Standardized Square Error (RMSSE) (Robinson and Metternicht, 2006). Closer average standardized error and RMSE were regarded a prerequisite for accurate prediction (Hani *et al*., 2010; Ahmed *et al*., 2017).

Table 2: Precise location (coordinates) of sampling sites in district Attock

Sr. No	Lat	Long	Sr. No	Lat	Long	Sr. No	Lat	Long
1	33.5984	72.7546	28	33.3833	72.3806	53	33.3886	71.9538
2	33.5957	72.7135	29	33.3547	72.3863	54	33.3807	71.9328
3	33.5845	72.6612	30	33.3222	72.3472	55	33.3663	71.9288
4	33.5623	72.6378	31	33.3129	72.3195	56	33.35	71.9249
5	33.5428	72.5304	32	33.28	72.2886	57	33.3441	71.9181
6	33.5251	72.5153	33	33.2939	72.2002	58	33.341	71.9159
7	33.4752	72.5336	34	33.3109	72.1732	59	33.2934	71.8613
8	33.4677	72.5044	35	33.3315	72.1473	60	33.4372	72.0118
9	33.515	72.4892	36	33.3584	72.1062	61	33.4721	72.0884
10	33.4846	72.3983	37	33.2168	72.3718	62	33.4849	72.1147
11	33.4436	72.3923	38	33.2331	72.4042	63	33.4982	72.177
12	33.3528	72.5834	39	33.2331	72.4042	64	33.5137	72.2436
13	33.3858	72.5966	40	33.2437	72.4311	65	33.5771	72.2161
14	33.411	72.6138	41	33.2905	72.5033	66	33.5666	72.205
15	33.4429	72.6258	42	33.3176	72.5531	67	33.7304	72.2465
16	33.4962	72.6351	43	33.325	72.561	68	33.7429	72.2557
17	33.5243	72.6419	44	33.3365	72.571	69	33.7588	72.271
18	33.561	72.661	45	33.3829	72.0756	70	33.7759	72.2829
19	33.4082	72.3728	46	33.4175	72.0091	71	33.7639	72.2904
20	33.3936	71.9609	47	33.7569	72.3621	72	33.8164	72.6872
21	33.7293	72.3636	48	33.8955	72.3542	73	33.901	72.4897
22	33.0718	72.382	49	33.919	72.3624	74	33.9137	72.5042
23	33.7093	72.4027	50	33.9224	72.3962	75	33.9346	72.5366
24	33.8266	72.3847	51	33.9138	72.4127	76	33.9413	72.5474
25	33.8733	72.4188	52	33.9038	72.4135	77	33.8391	72.5122
26	33.8867	72.3571	53	33.9082	72.4438	78	33.8163	72.5546
27	33.8209	72.6008						

Results and Discussion

Physico-chemical properties of surveyed areas

Data regarding physico-chemical properties is summarized in Table 3. Soil pH is considered as an indicator for nutrient bioavailability. In district Chakwal it ranged from 7.48 to 8.69 having mean value of 8.10 ± 0.22 while in district Attock it ranged from 7.84 to 8.53 with mean value of 8.17 ± 0.16. Kurtosis, skewness and coefficients of variance CV% values were 0.68, -0.30 and 2.71 for Chakwal and -0.72, -0.09 and 1.9 for Attock, respectively. Our results indicated that soils of the surveyed districts were alkaline. The reason might be the calcareous nature of the parent material and the low content of organic matter (Pervaiz *et al*., 2002; Rehman *et al*., 2000). Electrical conductivity (EC) values for both districts were found < 4dS m^{-1} as an indicator of healthy soils i.e., soils were free from salinity and sodicity hazard. Organic matter contents in soil indicate soil quality and play a crucial role in soil fertility and plant nutrition. Soil organic matter content of Chakwal as high as compared to that in Attock. Soil organic matter content ranged from 0.24 to 2.54% having mean value of 0.94 ± 0.41 in district Chakwal while in district Attock, it ranged from 0.23 to 1.39% having mean value of 0.72 ± 0.24. Kurtosis, skewness and coefficients of variance (CV%) values observed in dataset related to district Chakwal and Attock were 2.50, 1.17, 43.6 and 0.45, 0.46, 33, respectively (Table 3). Most of the analyzed soil samples were categorized as deficient in organic matter content, when compared with the critical values established by FAO,

(1980) (Table 4). Only 16.6 and 1.26% of surveyed agricultural sites in Chakwal and Attock were adequate in organic matter, means have better ability to provide nutrients to the growing crops (Table 3).

Table 3: Soil physico-chemical properties of surveyed districts

Parameter	Mean	SD	Minimum	Maximum	Skewness	Kurtosis	CV%
--------------------------------District Chakwal-------------------------							
EC	1.65	0.78	0.51	02.24	01.41	01.57	47.00
pH	8.10	0.22	7.48	08.69	-00.30	0.680	02.71
OM	0.940	0.41	0.24	02.54	01.17	02.50	43.60
Sand	64.80	22.32	23.45	93.40	-00.55	-0.840	34.44
Silt	23.00	11.45	03.20	85.00	00.55	-0.800	49.78
Clay	12.20	5.55	0.050	15.65	01.89	01.30	45.49
-------------------------District Attock----------------------------------							
EC	1.45	0.410	0.760	02.82	1.29	01.17	28.00
pH	8.17	0.160	07.84	08.53	-0.09	-0.72	01.90
OM	0.72	0.240	0.230	01.39	0.46	0.45	33.00
Sand	61.24	19.20	18.55	97.30	-0.27	-0.65	31.35
Silt	30.48	17.01	02.50	68.40	0.41	-0.74	55.80
Clay	08.28	03.50	0.20	22.25	0.59	-0.35	42.27

n = 151 Chakwal (n) = 72 Attock (n) = 79

Our results indicated that data related to pH was found to be least heterogeneous for district Chakwal as the CV% was found to be less than 15. Data regarding sand was categorized as moderately variable as the CV% value was found between 15 and 35. Data regarding EC, organic matter, silt and clay was found to be highly heterogeneous as the CV% value was found to be greater than 35. Data related to surveyed area of district Attock indicated that EC, organic matter and sand was moderately heterogeneous. Data regarding silt and clay was categorized as highly variable as the CV% value was found to be >35. Data regarding physico-chemical properties of the soils indicated that soils of the surveyed areas of district Attock and Chakwal are suitable for growing agronomic crops and have potential for supporting good crops if provided optimum inputs.

Table 4: Guideline values used to classify the organic matter (%) content of the soils

Status	Organic Matter
Low	<0.86
Marginal	0.86-1.29
Adequate	>1.29

(FAO, 1980)

Plant available SO_4-S status in the surveyed area

Sulfate sulfur ranged from 0.60 to 15.55 with mean value of 6.54±3.60 mg kg^{-1} in Chakwal district (Table 5), when compared with the critical values described by Rizwan *et al*.(2007) (Table 6), 85% of total analyzed soil samples were categorized as deficient in plant available SO_4-S contents. Dataset regarding plant available SO_4-S was highly heterogeneous as the CV% values was 55 in district Chakwal (Table 5). Deficiency of sulfate sulfur in the soil of surveyed area might be due to alkaline pH and low organic matter content. Alkaline pH of the soils usually decreases the solubility of nutrients in the soils while low organic matter results in the decrease in cation exchange capacity of the soils and is a good source of nutrient (Ahmed *et al*., 2010). Sulfate sulfur content ranged from 2.90 to 11.52 with mean value of 5.80±1.81 in Attock District, when compared with the critical values, 95% samples were categorized as deficient and remaining samples were categorized as marginal in plant available sulfate sulfur contents. The observed CV% for sulfate sulfur content in district Attock was 31.2 (Table 5) indicating moderate variation in the data.

Relationship between physico-chemical properties and plant available SO_4-S content

Our results indicated that a significant positive relationship (r = 0.51, $p<0.05$) was observed between plant available SO_4-S and clay content in the soil (Table 7), Whereas a non-significant negative relationship was observed between plant available SO_4-S and sand (r = 0.17) and silt (r = 0.37). It indicated that clayey soils retain more plant available soil as compared other soil textures. The sulfur content in soils has been found to be a function of clay content. It is believed that clayey and clay loam soils contain greater sulfur content than sand and sandy loam soils. Such variation is mainly due to variations in texture and the relationship between organic matter and clay colloids. The plant available SO_4-S also proved an important positive correlation with clay and a negative correlation with sand content in the soils of the Potohar region of Pakistan (Khalid *et al*., 2009).

ground than in sub-surface soils contributing to recycling of organic waste products. Such enhanced sulfur accumulation in soils, however, depends on the nature and type of decomposing organic residues. Sulfur release from organic waste products is primarily a microbial process that also depends on the material C or N / S proportion. In Potohar

Table 6: Guideline values used to classify the plant available sulfur (mg kg^{-1}) in the soils

Status	SO_4^{-2}-S
Deficient	<10
Satisfactory	11-30
Adequate	31-100
Toxicity	>100

(Tandon, 1991; Srinivasarao *et al*., 2004)

Table 7: Relationship between plant available SO_4-S and physico-chemical properties of soil

	Clay	EC	OM	Sand	Silt	pH
EC	0.18					
	0.18					
OM	-0.03	-0.03				
	0.82	0.79				
Sand	0.00	0.47	-0.15			
	0.99	0.00	0.20			
Silt	-0.20	-0.51	-0.17	-0.97		
	0.08	0.00	0.15	0.00		
pH	0.24	0.82	-0.28	0.43	-0.49	
	0.04	0.00	0.02	0.00	0.00	
SO_4-S	0.51	0.11	0.65	-0.17	-0.37	-0.49
	0.05	0.36	0.01	0.3	0.05	0.03

A significant relationship (r = 0.65, $p < 0.05$) was also observed between plant available SO_4-S and organic matter content in the surveyed soils (Table 7). Because of the greater release of sulphate sulfur arising from the mineralization method, soils comprising an appropriate quantity of organic matter have greater capacity to supply sulfur to the plant. Again, organic matter adsorbs S in some soils and becomes less available to plants. Overall, total sulfur in most Indian soils is function of soil organic matter content which is significantly and positively correlated. It is obvious that greater quantities of total S are found in the

soils, the available plant sulphur (CaCl$_2$ extractable Sulfate-Sulfer) also had a substantial beneficial association with organic carbon content (Havlin *et al*., 2005). A negative relationship between plant available SO_4-S and pH indicated its restrained availability under prevailing alkaline condition of surveyed area (Table 7). Soil pH is regarded to be a significant factor influencing soil sulfur availability to plants. More retention through adsorption, availability reduces in strong acid soils. The quantity of sulfur produced, however, is directly proportional to the pH of the soil up to 7.5. Our results were in line with Srinivasarao *et al*. (2004)

Table 8: Parameters related to Semivariogram models and interpolation of SO_4-S in the soils of district Chakwal and Attock

Parameter	Model	Range (A_0)	Nugget/Sill (%)	RMSSE[1]	ASE[2]	RMSE[3]
	------District Chakwal------					
SO_4-S[a]	Spherical	0.204	20.00	1.51	02.52	03.79
	------District Attock------					
	Exponential	0.068	16.66	0.98	01.80	01.72

who observed a negative correlation of bio-available SO_4-S with pH and $CaCO_3$ content in soil.

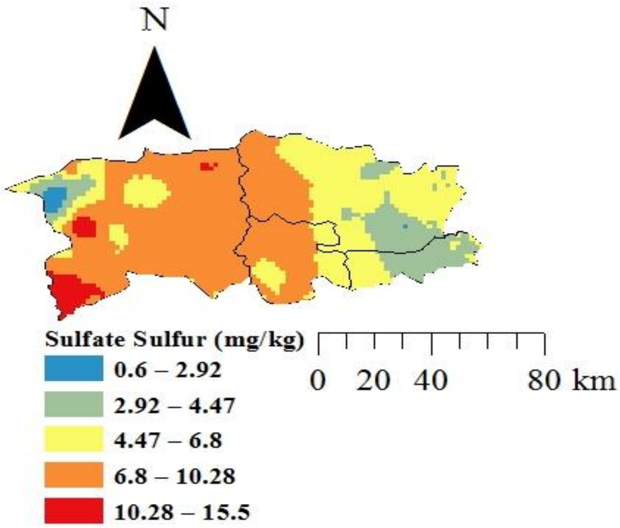

Figure 2: Digital map indicating plant available Sulfate Sulfur in the soils of district Chakwal

Spatial distribution of SO_4-S in the soils of surveyed area

Central tendency of dataset regarding plant available SO_4-S was determined by kurtosis and skewness, as a criterion for normal distribution skewness and kurtosis of data set regarding plant available SO_4-S was found between +2 and -2 values, considered as a prerequisite for the normal distribution of data set (Gravetter and Wallnau, 2005). Spatial correlation of plant available SO_4-S was best described by the spherical model in the Chakwal district. Spatial dependence was categorized as strong as the nugget to sill ratio was found to be 20 (Table 8). Spatial structure of plant available SO_4-S was best described by the exponential model with the range of 0.068 km in district Attock . Calculated nugget to sill ratio was 16.66% which indicated its strong spatial dependence (Table 6).Close average standardized error values and root mean square error indicated strong spatial dependence of the plant available sulfur content for preparing digital maps. Close average standardized error (2.52) and root mean square error (3.79) for plant available SO_4-S also indicated strong spatial dependence for preparing digital to classify the whole district Chakwal to different nutrient management zones. In district Attock, close root mean square error and average standardized error values i.e., 1.72 and 1.80, indicated strong spatial dependence of predicted plant available sulfur from un-sampled locations. Strong spatial dependence of plant available SO_4-S was not found to be disturbed by anthropogenic activities. This might be due to lack of use of sulfur containing fertilizers in the area. Spatial dependence in the seemed to be maintained by inherent soil factors like parent material. It is more probable that moderate to weak spatial dependence mostly arises due to anthropogenic activities which alter the natural processes or concentration of a particular variable in the area (Chunfa *et al*., 2010; Banerjee *et al*., 2011; Ahmed *et al*., 2014).

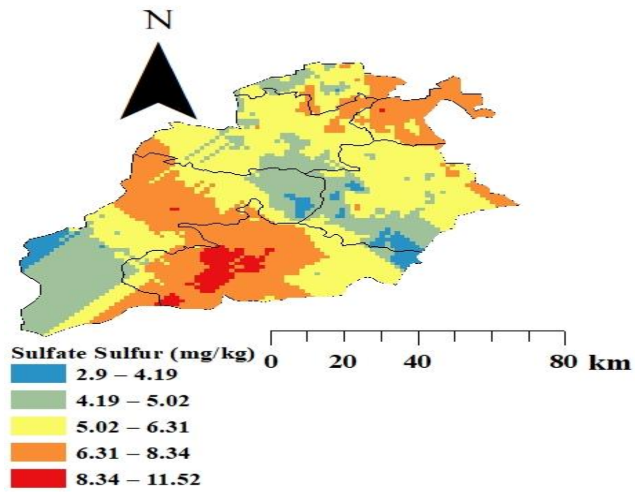

Figure 2: Digital map indicating plant available Sulfate Sulfur in the soils of district Attock

Interpolation of SO_4-S in the soils of surveyed area

Prepared maps show low plant available sulfate sulfur (SO_4-S) values ranged from 0.6-3.67 mg kg^{-1} in northwestern part of tehsil Talagang and southern part of tehsil Chakwal while maximum sulfate sulfur content ranged from 13.4-20.3 mg kg^{-1}. Bio-available sulfate sulfur indicated in north to south areas of tehsil Chakwal and whole tehsil of Choa Saiden Shah ranged from 3.67-5.72 mg kg^{-1}. In tehsil Kallar Kahar, north and south part of Chakwal and large area of tehsil Talagang, sulfate sulfur ranged from 5.72-8.79 mg kg^{-1}. Northern areas of tehsil Chakwal and some parts of northern Talagang and some parts of southern Talagang have bio-available sulfur content ranged from 13.4-20.3 mg kg^{-1} (Figure 2). Maps indicating maximum bio-available sulfate sulfur (SO_4-S) ranged from 8.34-11.52 mg kg^{-1} in the areas of central Pindi Gheb while lowest value ranging from 2.9-4.19 mg kg^{-1} covered areas of tehsil Jand, Pindi Gheb and in some patches of tehsil Fateh Jhang. Bio-available sulfur ranged from 4.19-5.02 mg kg^{-1} present in south Attock and western part of tehsil Fateh Jhang, southwestern part of tehsil Jand and in small areas of tehsil Hazro. Observed value ranged from 5.02-6.31 mg kg^{-1} indicated areas of northern Fateh Jhang, north eastern parts of Tehsil Pindi Gheb, most of the areas of tehsil Attock and in some areas of tehsil Jand. In most of the parts of tehsil Pindi Gheb, central and western part of tehsil Jand and northern part of tehsil Hassan Abdaal have sulfate sulfur content ranging from 6.31-8.34 mg kg^{-1} Figure 3.

Conclusion

Soil fertility status is generally assessed through point sampling at selected locations. This approach requires laborious sampling and extensive chemical analyses. Moreover, traditional fertility assessment approaches present certain bias due to various sampling schemes. Digital mapping through geographical information system presents better scenario as employed in the current studyfor regional scales fertility assessment. Deficiency of SO_4-S and organic matter was observed in the surveyed area. A positive relationship between plant available SO_4-S, organic matter and clay content was observed whereas a negative relationship was observed between plant available SO_4-S content and soil pH and sand.

Maps of plant available SO_4-S showed variation in different areas and can be managed accordingly. Based on the results, the whole area can be divided into different categories on the basis of plant available SO_4-S as shown in the maps. Variable rate fertilizer management strategy can be developed using the information generated through such techniques for different zones, which will increase the efficiency of fertilizers. The data generated through GIS mapping techniques can help avoiding over or under-fertilization and will be economical, and environmentally safe. Moreover, a need for detailed study to evaluate the sulfur dynamics was felt. Quantification of various pools of sulfur in the soil will help to understand the chemistry of nutrient in the soil of surveyed districts to devise particular management practices.

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