



Mapping of Soil Micronutrients in Someshwar Agricultural Watershed using IDW Interpolation Approach

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Abstract: Inverse distance weighing interpolation method accurately reveals the spatial distribution of the micronutrients and site-specific management-prone areas. For an economically and environmentally sound soil managements plan spatial mapping is the need of the hour. The main objectives of this study were (a) to map spatial variability of Fe, Mn, Zn and Cu content of Someshwar watershed agricultural soils and (b) to locate problematic areas requiring site specific management strategies for the nutrient elements. Spatial analyses were performed using IDW method. Mean Fe content for surface soils (0–15 cm) was 52.87 mg kg⁻¹, Mn was 2.80 mg kg⁻¹, Zn was 0.56 mg kg⁻¹ and Cu was 0.65 mg kg⁻¹ with the differences between maximum and minimum being 53.7 mg Fe kg⁻¹, 4.7 mg Mn kg⁻¹, 1.19 mg Zn kg⁻¹ and 4.44 mg Cu kg⁻¹. For the surface soil, site-specific management-prone areas of Mn, Zn and Cu for low medium and high classes were found to be 39.62–50.9–9.48 %, 42.52–55.6–1.86 %, and 32–40.06–27.92 %, respectively. Fe concentration was sufficient in the study area. Consequently, lands with excessive nutrient elements require preventive- leaching practices, whereas nutrient-poor areas need fertilizer applications in favor of increasing plant production.

Key words: Fe, Mn, Zn and Cu, Inverse Distance Weighing..

I. Introduction

Soils vary widely in their micronutrient content and in their ability to supply micronutrients in quantities sufficient for optimal crop growth. The soil micronutrients have an important role in crop growth and development, and often they are present in small quantities in the soil. Micronutrients content in soil are dependent on the parent material, pedogenic processes and soil management which may promote, in some cases, a reduction of micronutrients content (Cu, Zn, Fe and Mn). Soil micronutrient maps covering large areas improve our understanding of the nature and extent of micronutrient problems, and aid in determining their relationships with climate, soil properties, and soil genetic characteristics determined at similar scales. Intermediate scale maps can be useful in delineating specific areas where deficiencies or toxicities are likely for agriculture, and in determining localized soil characteristics that may be associated with such problems. Highly detailed maps of soil micronutrient content and availability in individual fields are being developed for site-specific precision agriculture.

Advances including the global positioning system (GPS), geographic information systems (GIS), inductively coupled plasma (ICP) spectrometry, geostatistics, and precision agriculture facilitate soil micronutrient mapping and provide quantitative support for decision and policy making to improve agricultural approaches to balanced micronutrient nutrition. There has been growing interest in the study of spatial variability of soil properties using geostatistical techniques since 1970s, and geostatistics has been proved to be a powerful tool in characterizing spatial soil variability. Spatial variability of soil properties enables economical usage of agricultural inputs by maximizing the yield, enhancing the quality of agricultural products while minimizing the environmental hazards. In other words, it produces valuable site-specific soil information to develop new land management strategies at farm or regional scale and to detect environmental problems regarding plant nutrients and/or heavy metals as pollutants [2].

Several interpolation methods such as inverse distance weighting (IDW), ordinary and lognormal ordinary kriging, and splines for spatially predicting the variability of chemical, physical and biological soil properties from field scale to regional scale are frequently used [2; 3; 6; 10;]. Any of these interpolation methods may perform better results than the others depending on the soil parameters, sampling density, number of sampling nodes, and distribution of the soils data set, and nature of the investigated specific area [3]. Inverse distance weighing can be used to generate contour maps of any soil property from grid samples [4]. A significant improvement in the accuracy of spatial mapping of soil properties may be obtained through using IDW by manipulating the exponent value [6].

Soil quality is the most important factor for sustaining the global biosphere. To quantify soil quality, specific soil indicators need to be measured spatially [11]. Balanced plant nutrition with micronutrient is critical in producing enough and quality food to meet the growing demands, and for sustaining soil fertility. The future supply of micronutrients to agriculture needs to recognize the increasing food security, safety and environmental

quality. The objective of this study was to evaluate and to map the spatial distribution of soil micronutrients (Cu, Zn, Fe and Mn), in an agricultural area in Someshwar watershed under temperate climatic conditions using inverse distance weighting (IDW).

II. Materials and methods

The study area is located at Someshwar watershed, Uttarakhand, India. The geographical coordinates of the area are between latitude of 29° 76'N & longitude of 79° 60'E. with an average elevation of about 1430 msl. The study area is covered by SOI toposheet No. 5309 and about 461.5 ha of net sown area. . The soil of the region is generally sandy-loam type with high organic content and acidic in nature. Soil was well drained with average thickness ranging from 0.1 to 0.5 m. The color of soil ranges from light to moderately dark. The average annual rainfall is about 1152 mm. The maximum and minimum humidity ranged are from 66 to 98 per cent and 25 to 67 per cent, respectively. The mean maximum and minimum temperatures were found to be 28.2 and -1.2 °C, respectively.

III. Sampling and analyses

The locations of sampling nodes, drainage channel, within the agricultural watershed are illustrated in Fig. 1. Surface (0–15 cm) and subsurface (15–30 cm) soil samples were taken from each intersection point (node) by means of a soil-sampling auger at a total number of 40 points. Then soil samples were air-dried and sieved through a 2 mm mesh opening. Micronutrients were determined using DTPA extractant [7]. 1.965 gram of DTPA (Diethylene triamine pentaacetic acid) was added to 400 ml double glass distilled water in one liter volumetric flask. 13.3 ml tri-ethanol amine (TEA) buffer was added to flask for dissolving DTPA. 1.47 gram of calcium chloride (CaCl₂) was added to flask and volume made up by using redistilled water. pH was adjusted to 7.3 with diluted hydrochloric acid (HCl) and ammonia buffer. This extractant consisted of 0.005 M DTPA + 0.1 M TEA buffer + 0.01 M CaCl₂. Ten gram soil was shaken for two hours in 20 ml of extractant. The content of copper, zinc, manganese and iron were measured by using Atomic Absorption Spectrophotometer (AAS).

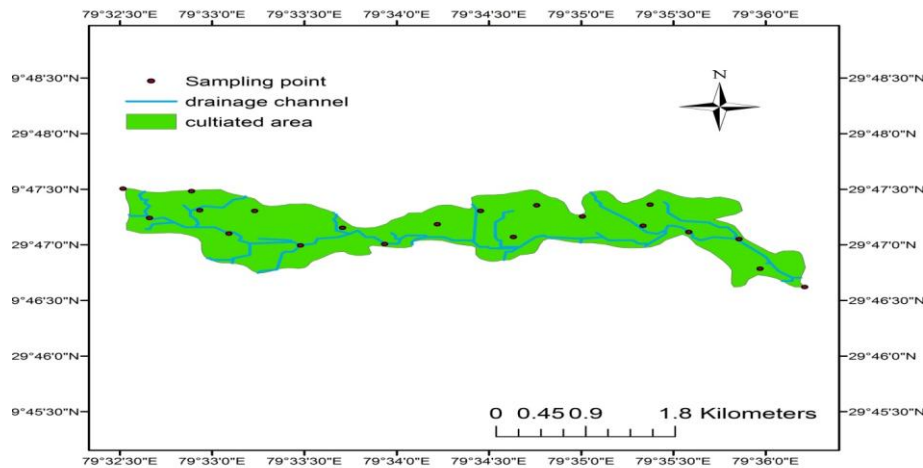


Fig. 1: Study area and sampling nodes

IV. Inverse distance weighting

Inverse distance weighting was employed to delineate the spatial variation of DTPA extractable Fe, Mn, Zn and Cu. The IDW is a simple spatial interpolant that often yields satisfactory results [10]. The IDW directly implements the assumption that a value of a soil variable at an unsampled location is a weighted average of known data points within a local neighborhood surrounding the unsampled location. The formula of this exact interpolator is (Burrough and McDonnell 1998):

$$\bar{z}(x_0) = \frac{\sum_{i=1}^n z(x_i) d_{ij}^{-r}}{\sum_{i=1}^n d_{ij}^{-r}} \quad (1)$$

where x_0 is the estimation point and x_i are the data points within a chosen neighborhood. The weights (r) are related to distance by d_{ij} , which is the distance between the estimation point and the data points. The IDW formula has the effect of giving data points close to the interpolation point relatively large weights while those far away exert little influence. The higher the weight used the more influence the points close to x_0 are given.

V. Spatial distribution of soil properties

After digitizing the boundaries of the study area maps, location of sampling points, Fe, Mn, Zn and Cu content of respective nodes were identified according to their geographic coordinates in Universal Transverse Mercator

System (UTM) and values were assigned to the map. The soil nutrient status was classified as low, medium and high categories using standard soil nutrient rating values for each nutrient. Nutrient index value was calculated from the proportion of soils under low, medium and high available nutrient categories for each soil sample. The rating limits for available soil nutrient are given as below in Table 1.

Table 1: Rating limits for available soil nutrients.

Nutrient	Low	Medium	High
Fe (mg/kg)	<4.8	4.8-8.0	> 8.0
Mn (mg/kg)	<2	2-4	> 4
Zn (mg/kg)	<0.6	0.6-1.2	> 1.2
Cu (mg/kg)	<0.2	0.2-0.4	> 0.4
Nutrient Indices (NI)	<1.5	1.5-2.5	>2.5

*parker *et al* [8]

The IDW interpolation routine within ArcGIS (Version 9.3) was used to interpolate between sampling nodes and assigned an average Fe, Mn, Zn and Cu value on the map. The interrelationships between the micronutrients were also analyzed using SPSS (version 16).

VI. Results and Discussion

A statistical summary of DTPA extractable Fe, Mn, Zn and Cu. for the soils are presented in Table 2.

Table 2: Descriptive statistics of Fe, Mn, Zn and Cu

Statistical parameters	Fe (mg/kg)		Mn (mg/kg)		Zn (mg/kg)		Cu (mg/kg)	
	(0-15) cm	(15-30) cm	(0-15) cm	(15-30) cm	(0-15) cm	(15-30) cm	(0-15) cm	(15-30) cm
Mean	52.87	42.75	2.80	1.51	0.56	0.49	0.65	0.64
Standard error	0.41	0.45	0.03	0.03	0.01	0.01	0.03	0.01
Median	53.85	37.2	2.36	1.33	0.51	0.5	0.25	0.53
Standard deviation	16.48	17.95	1.31	1.20	0.36	0.32	1.00	0.46
Kurtosis	-0.78	-1.00	0.82	1.12	-0.08	0.21	13.11	-1.71
Skewness	0.34	0.52	1.20	1.01	0.79	0.56	3.43	0.33
Maximum	83.7	74.3	5.9	4.7	1.29	1.27	4.52	1.38
Minimum	30	21.3	1.2	0.11	0.1	0.01	0.08	0.13
CV (%)	31.17	41.99	46.64	79.13	62.99	64.46	154.03	70.88

The skewness coefficients of the dataset ranged from 0.33 to 1.20. While the variables were not normally distributed, the IDW did not require any transformation to reduce the skewness of the data. The soils of Someshwar agricultural watershed were generally rich in Fe for both surface (52.87 mg kg⁻¹ for 0–15 cm depth) and subsurface layers (42.75 mg kg⁻¹ for 15–30 cm depth), low for Zn with a mean of 0.56 and 0.49 mg kg⁻¹ for surface and subsurface, respectively. Mn and Cu were found to be in the medium range for surface soils with a mean value of 2.80 and 0.65 mg kg⁻¹ as well as for subsurface soils with a mean value of 1.51 and 0.64 mg kg⁻¹ respectively. The coefficient of variation is a useful and an independent measure of relative dispersion of parameters in different units. The CV of the soil variables were very high and ranged from 31.17 for Fe (0-15 cm) to 154.03 % for Cu of surface soils (0–15 cm depth). The CV may vary dramatically for easily manageable soil parameters such as nutrients applied as fertilizers and is dependent on the farmer's habits and crop pattern at regional scale. The presence of genetically different parent materials and soil groups along with the different input managements and crop patterns in the study area further pronounced high CV of the parameters.

Pearson's linear correlation coefficients are shown in Table 3 in the correlation matrix.

Table 3: Correlation coefficients between micro nutrients studied.

Parameters	Fe mg kg-1 (0-15cm)	Fe mg kg-1 (15-30cm)	Mn mg kg-1 (0-15cm)	Mn mg kg-1 (15-30cm)	Zn mg kg-1 (0-15cm)	Zn mg kg-1 (15-30cm)	Cu mg kg-1 (0-15cm)	Cu mg kg-1 (15-30cm)
Fe (0-15cm)		0.948**	-0.227	-0.067	0.140	0.010	-0.221	0.230
Fe (15-30cm)			-0.250	-0.162	0.162	0.074	-0.201	0.214
Mn (0-15cm)				0.357	-0.144	0.040	0.292	-0.148
Mn (15-30cm)					0.039	0.158	0.464*	0.286
Zn (0-15cm)						0.804**	-0.136	0.225
Zn (15-30cm)							0.231	0.418
Cu (0-15cm)								0.342

** Correlation is significant at the 0.01 level (2 tailed)

* Correlation is significant at the 0.05 level (2 tailed)

Positive and significant correlation coefficients were observed between Fe, surface and sub surface ($r=0.948^{**}$), Mn surface soil-Cu surface soil ($r=0.464^{*}$) and Zn surface and sub surface soil ($r=0.804^{**}$). There was not significant correlation between Zn-Zn and Cu-Cu for both surface and subsurface soils.

VII. Spatial variability of parameter

The reclassification map of IDW of Fe for both surface (0-15 cm) and subsurface soil (15-30 cm) showed (Fig 2, 3) that, Fe concentration of the study area was very high and almost 100% of the study area was sufficient in Fe concentration. As small area as 9.48% was classified as high concentration of Mn, 39.62 % area under medium concentration and 50.90 % area under low concentration respectively for the surface soils of the study area (Fig 4). The threshold value of the micronutrients was defined as given by Parker *et al.* (Table 1). In case of the sub-surface soils, an area of as small as 0.75 % was under high concentration of Mn, medium concentration of about 16.57 % and about 82.66 % with a low concentration of Mn. (Fig 5). The level of concentration in the surface soils of Zn amounts to 55.60 % area with medium concentration, 42.52 % area was under low concentration and for higher concentrated area it was as small as 1.86 % area respectively (Fig 6). Likewise in case of sub-surface soils the lower concentration of Zn (Fig 7) occupied about 67.12 % area, medium concentration of about 31.93 % area and about 0.94 % area with a high concentration in the study area. Similarly the concentration of Cu was well distributed in the agricultural watershed as 32.06 % area with low concentration, 40.06 % area with medium concentration and about 27.92 % area with a higher concentration respectively (Fig 8). The subsurface soils showed a lesser percentage of area about 13.75 % under low concentration, medium range concentration of about 31.31 % area and about 54.93 % area under higher concentration respectively for the agricultural watershed.(Fig 9).

VIII. Conclusions

It can be concluded that the IDW with weighting exponent 1 can successfully be used to explore spatial variation of the micronutrients in the Someshwar watershed to locate agricultural areas requiring fertilizer usage for economically sound agriculture and requiring preventions of environmental pollution risks. Fe concentration was found to be sufficient in the agricultural areas, while a medium range of concentration for Mn as well as Cu and a low concentration of Zn was observed in most part of the study areas. This research study evaluated agriculturally and environmentally problematic areas regarding the soil micro nutrients under the current production management practices. The deficient nutrients have to be restored through chemical fertilizers and/or organic manures to maintain soil health. For efficient and sustainable crop production in these soils, a farming system that is both soil enriching and restoring needs to be developed.

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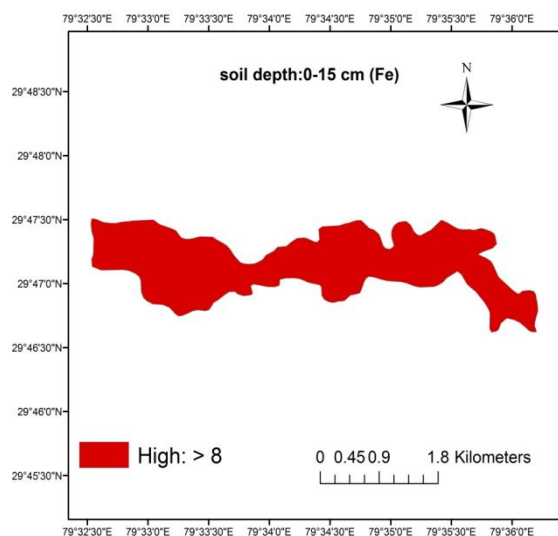


Fig. 2 Reclassed map of Fe content for the surface soil (0–15 cm depth)

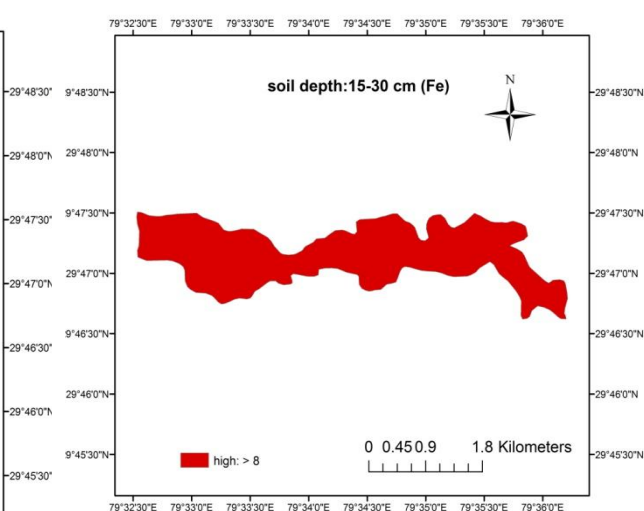


Fig. 3 Reclassed map of Fe content for the sub-surface soil (15–30 cm depth)

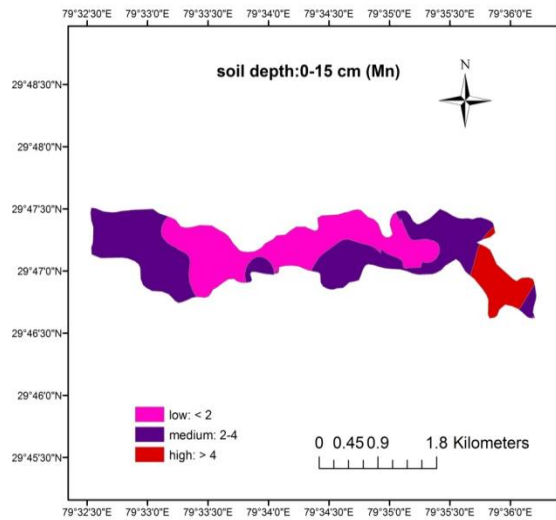


Fig. 4 Reclassed map of Mn content for the surface soil (0–15 cm depth)

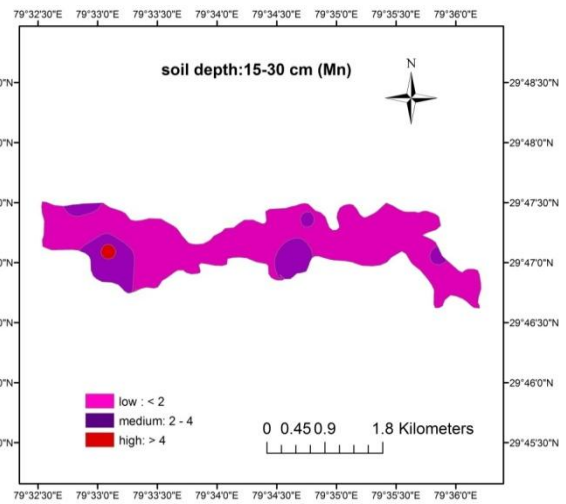


Fig. 5 Reclassed map of Mn content for the sub-surface soil (15–30 cm depth)

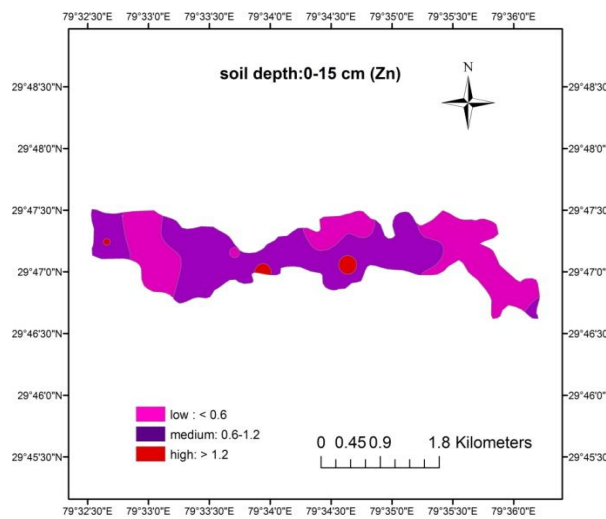


Fig. 6 Reclassed map of Zn content for the surface soil (0–15 cm depth)

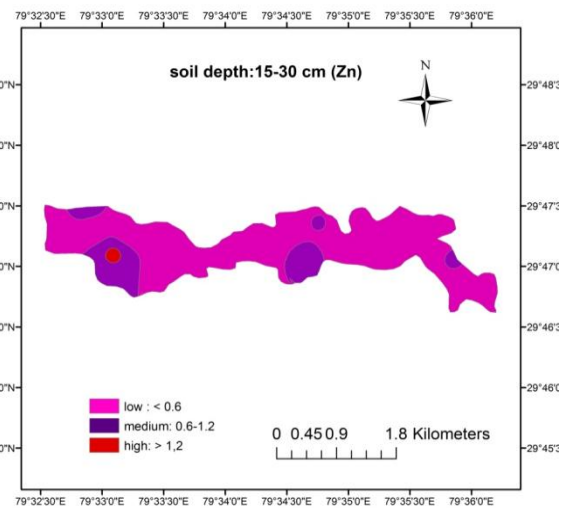


Fig. 7 Reclassed map of Zn content for the sub-surface soil (15–30 cm depth)

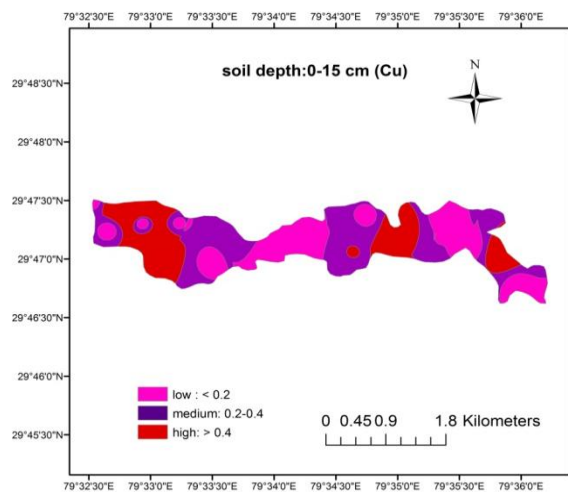


Fig. 8 Reclassed map of Cu content for the surface soil (0–15 cm depth)

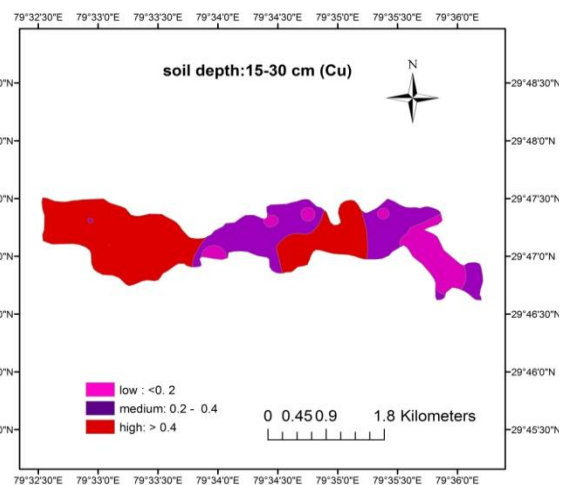


Fig. 9 Reclassed map of Cu content for the sub-surface soil (15–30 cm depth)

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