Plant Archives Vol. 26, Supplement 1, 2026 pp. 1879-1887 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-1.252

SPATIAL VARIABILITY OF SOIL CHEMICAL PROPERTIES, AVAILABLE SULPHUR AND MICRONUTRIENTS STATUS OF SOILS IN AHMEDNAGAR DISTRICT OF MAHARASHTRA, INDIA

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(Date of Receiving : 14-10-2025; Date of Acceptance : 15-12-2025)

ABSTRACT

Spatial variability in availability of secondary and micro nutrients in Ahmednagar district of Maharashtra were studied using Global Positing System (GPS). Georeferenced surface soil samples from fourteen (14) tehsils were delineated using stratified random sampling method investigation was carried out at All India Co-ordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plant under Department of Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra to assess the chemical properties, available sulphur and micronutrients status in soils of Ahmednagar district in the year 2023-2024 of four hundred and sixty four (464) soil samples at the depth of (0-20 cm) were collected across the Ahmednagar district of Maharashtra at 5 kms grid were collected and analysed in the laboratory. The results revealed that pH, EC, $CaCO_3$ and OC of soils collected across different tehsils of Ahmednagar district varied from 7.07 to 8.44, 0.10 to 0.97 dS m^{-1}, 1.50 to 21.63 % and 1.76 to 9.12 g kg^{-1} respectively. Whereas available S in soils ranged from 5.48 to 47.36 mg Kg^{-1}.The DTPA -Zn, Fe, Cu, Mn and B in soil of Ahmednagar district ranged from 0.28 to 2.15 mg Kg^{-1}, 0.53 to 40.57 mg Kg^{-1}, 0.21 to 9.48 mg Kg^{-1} and 0.46 to 35.74 mg Kg^{-1} and 0.10 to 1.90 mg Kg^{-1}. respectively. The results obtained in present study clearly showed a large variability in physio-chemical properties of soil across the Ahmednagar district with low nutrient indices were found in respect to iron (1.65) and boron (1.64), medium for Sulphur (2.33) and zinc (1.83), high for copper (2.97) and manganese (2.71). This information could aid in decision making for application of plant nutrients and selection of cropping sequence for higher monetary returns to the farmers.

Keywords **:** Spatial Variability, Secondary, Micro, Nutrients, Ahmednagar District.

Introduction

Information technology has provided tools *viz.* Global Positioning System (GPS) helps in collecting a systematic set of georeferenced soil samples and generating the spatial data about the distribution of nutrients through Geographical Information System (GIS). Understanding spatial variability and distribution of soil properties is critical for farmers attempting to increase nutrients use efficiency and crop productivity.

Demographic explosion in developing countries over the past years has increased the demand for food, leading to intense pressure on soils and land fertility decline. This work aims to determine the effects of different land use systems on soil physico-chemical properties, nutrient status and fertility classification in order to understand the causes of soil fertility and crop productivity decrease (Kunghe *et al.,* 2023).

Green revolution has triggered to achieve higher production and nutritional security in the country. However, intensive cultivation of high yielding varieties, increased imbalanced use of fertilizers devoid of secondary and micronutrients, decreased use of organic manures and lack of crop residue recycling

have let to depletion of native nutrient fertility and resulted in wide spread deficiencies of all nutrients. Application of fertilizers on the basis of soil characteristics associated with fertilizers recommendation may aid in minimizing the fertilizers input without any yield loss (Yadav *et al.,* 2018). The information about spatial variability in physio-chemical properties of soil had great importance in the selection of crops and cropping system and also extent the ideas about prevailing management practices (Weindorf and Zhu, 2010 and Liu *et al.,* 2013).

Spatial variability in pH, organic carbon, total and available of NPK and micronutrients has been studied by various researchers under contrasting soil and management systems to refine and implement the site-specific management (Li *et al.,* 2011). The deficiency of micronutrients has become major constraint in sustainable crop productivity and hence there is need to know the spatial variability of nutrients of the soil (Katkar *et al.,* 2018).

Increasing population and overexploitation of productive lands creates serious problem of lowering the fertility status of soil and leads to deterioration of soil. The deficiency of nutrients directly affects the growth of crops and crop response become poor (Jagtap *et al.,* 2018). Hence sustainability of the present agricultural system and management of soil resources, database regarding the fertility status of soils is required.

The soil factors viz., texture, pH, organic matter content, type of clay minerals and interactions among the nutrients markedly regulate the availability of nutrients in soils (Malewar, 2005). Imbalanced and inadequate use of fertilizers coupled with poor use efficiency of other inputs led to decline in the response efficiency of chemical fertilizer nutrients under intensive agriculture in recent this in view, the present investigation was undertaken to assess the status of chemical properties, available sulphur and micronutrients in soils and to identify and delineate areas of nutrient deficiencies in Ahmednagar district of Maharashtra, India.

Material and Methods

The present investigation was carried out at All India Co-ordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plant under Department of Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra to assess the chemical properties, available sulphur and micronutrients status in soils of Ahmednagar district in the year 2023-2024. GPS based four hundred and sixty four (464) soil samples at the depth of (0-20 cm) were collected from 14 tehsils across the Ahmednagar district of Maharashtra at 5 kms grid were analysed in the laboratory.

Description of the study area

Ahmednagar district of Maharashtra tropical wet and dry or savanna climate (Classification: Aw) and the average annual rainfall of this district is 621 mm depending on the strength of the monsoon and its average temperature ranging from 10^{o} C to 38^{o} C throughout the year. It is situated between 19.08333333 North latitude and 74.73333333 East longitude at standing at 655.81 meters (2151.61 feet) above mean sea level.The geographical area of the district is 1704800 ha is divided into fourteen tehsils (Nevasa, Shrirampur, Kopargaon, Rahata, Sangamner, Akole, Rahuri, Parner, Shrigonda, Karjat, Jamkhed, Nagar, Pathardi, Shevgaon).

The GPS data (Latitude, Longitude and Altitude) was recorded at each sampling site distributed over the entire district. Four hundred and sixty four (464) samples were collected. The collected georeferenced soil samples were dried in shade and processed. The processed soil samples were used for analysis of pH, EC, $CaCO_3$, organic carbon, S and micronutrients (Zn, Fe, Cu, Mn and B).

Soil sampling and analysis

The survey has been carried out in Ahmednagar district. The district and tehsils were divided by grids at 5 Km and samples were collected from each grid squares. From each block in the district about 20-30 villages were selected for surface soil samples (0-20 cm).

GPS based four hundred and sixty-four surface soil samples (0-20 cm) were collected from 14 tehsils across the Ahmednagar district. The samplings were selected using stratified random method. The soil samples were processed and analyzed for pH and EC in soil:water suspensions (1:25 w/v) as described by Jackson (1973). Organic carbon was determined by wet oxidation method described by Walkley and Black (Nelson and Sommers, 1982) and free $CaCO_3$ was determined by Rapid method (Piper, 1966) and available S was estimated by turbidimetric method (Chesnin and Yien, 1951). Soil samples were extracted with 0.005M diethylenetriamine penta acetic acid (DTPA) for estimation of available Zn, Fe, Cu and Mn using Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). Available boron was determined by 0.01 M $CaCl_2$ extract with Azo-methine method (Berger and Troug, 1939). The nutrient indices were calculated by using the formula given by Parker *et*

al.(1951) and categorized into low (<1.66), medium (1.66-2.33) and high (>2.33).

$$\text{Nutrient index} = \frac{\text{Per cent samples low} \times 1 + \text{per cent samples medium} \times 2 + \text{per cent sample high} \times 3}{100}$$

The major and micronutrients were categorized as low, medium and high which in Maharashtra state (Table 1).

Table 1 : Categorization of soil parameters and nutrients.

Sr. No.	Parameters	Low	Medium	High
1	pH (1:2.5)	<6.5 (Acidic)	6.5-7.5 (Neutral)	>7.5 (Alkaline)
2	EC (dS m^{-1})	<1.0	1-2	>2.0
3	O.C. (g kg^{-1})	<4.0	4-8	>8.0
4	$CaCO_3$ (%)	<3.0	3-8	>8.0
5	S (mg kg^{-1})	<10.0	10-20	>20
6	Zn (mg kg^{-1})	<0.60	0.60-1.80	>1.80
7	Fe (mg kg^{-1})	<4.50	4.50-18.0	>18.0
8	Cu (mg kg^{-1})	<0.20	0.20-0.80	>0.80
9	Mn (mg kg^{-1})	<2.0	2.0-8.0	>8.0
10	B (mg kg^{-1})	<0.50	0.50-1.0	>1.0

(Source: Dr. DPKV, Akola)

Table 2 : Chemical properties of soils in Ahmednagar district.

Sr No	Name of Tehsil	No. of samples	pH (1:2.5)		EC (dS m^{-1})		$CaCO_3$ (%)		Org. carbon (g kg^{-1})	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Nevasa	34	7.41- 8.37	7.77	0.10 - 0.70	0.33	1.88 - 21.63	14.02	2.50 - 8.38	4.77
2	Shrirampur	25	7.40- 8.44	7.90	0.13 - 0.70	0.35	5.63 - 17.63	13.60	4.56 - 9.12	6.68
3	Kopargaon	30	7.29- 8.31	7.75	0.12 - 0.48	0.31	3.13 - 20.63	14.28	6.03 - 8.38	6.96
4	Rahata	25	7.36- 8.18	7.66	0.22 - 0.84	0.47	5.38 - 15.50	10.68	3.82 - 6.62	5.18
5	Sangamner	37	7.15- 7.96	7.67	0.20 - 0.94	0.48	4.25 - 21.38	12.22	3.68 - 7.65	5.40
6	Akole	43	7.07- 8.12	7.43	0.13 - 0.74	0.33	2.88 - 12.75	6.71	4.71 - 8.82	7.02
7	Rahuri	30	7.39- 8.04	7.61	0.16 - 0.82	0.46	6.38 - 15.38	10.34	4.85 - 8.06	6.60
8	Parner	37	7.46- 8.21	7.73	0.19 - 0.80	0.43	6.00 - 18.63	11.76	1.76 - 7.06	5.20
9	Shrigonda	34	7.38- 8.04	7.61	0.19 - 0.86	0.46	6.75 - 18.88	11.25	4.71 - 7.79	5.66
10	Karjat	36	7.32- 8.13	7.62	0.32 - 0.78	0.54	8.00 - 18.50	13.61	4.85 - 6.62	6.05
11	Jamkhed	31	7.16- 8.08	7.66	0.17 - 0.97	0.35	1.50 - 13.88	6.89	4.56 - 5.29	4.85
12	Nagar	34	7.31- 7.88	7.65	0.17 - 0.88	0.45	2.75 - 17.50	7.72	3.97 - 4.85	4.58
13	Pathardi	36	7.41- 7.83	7.63	0.18 - 0.57	0.27	6.63 - 12.63	10.20	3.24 - 6.03	4.58
14	Shevgaon	32	7.25- 7.77	7.61	0.15 - 0.54	0.29	6.75 - 15.50	11.63	3.38 - 5.74	4.30
Ahmednagar district		**464**	**7.07-8.44**	**7.66**	**0.10-0.97**	**0.39**	**1.50-21.63**	**11.06**	**1.76-9.12**	**5.65**

Table 3 : Available Sulphur and micronutrients status (mg kg^{-1}) of soil in Ahmednagar district.

Sr. No	Tehsil	Available S		DTPA-Zn		DTPA-Fe		DTPA-Cu		DTPA-Mn		$Cacl_2$. B	
		Range	PSD	Range	PSD	Range	PSD	Range	PSD	Range	PSD	Range	PSD
1	Nevasa	5.73 – 47.01	11.76	0.74-2.15	0	0.94 – 23.18	38.24	0.94 – 3.57	0	2.29 – 19.88	0	0.98 – 1.90	0
2	Shrirampur	5.48 – 43.77	12.00	0.28-1.75	32	1.81 – 24.93	36.00	0.78 – 3.49	0	3.20 – 18.32	0	0.28 – 1.75	0
3	Kopargaon	9.63 – 46.00	6.67	0.41-1.57	30	1.20 – 7.74	66.67	0.91 – 2.79	0	5.00 – 19.72	0	0.33 – 1.61	6.67
4	Rahata	8.12 – 46.35	12.00	0.46-1.71	16	0.76 – 9.60	48.00	0.21 – 3.00	0	3.56 – 17.07	0	0.22 – 0.80	48.00
5	Sangamner	8.26 – 47.36	10.81	0.50-2.00	2.70	5.44 – 20.78	00	0.64 – 3.83	0	2.65 – 28.29	0	0.10 – 0.89	51.35
6	Akole	6.47 – 40.85	27.91	0.50-1.65	16.97	4.06 – 40.55	2.33	0.19 – 7.75	0	3.62 – 35.02	0	0.13 – 1.16	67.44
7	Rahuri	8.89 – 45.20	13.33	0.40-1.80	23.33	1.55 – 23.68	46.67	1.27 – 5.97	0	4.99 – 29.85	0	0.36 – 0.88	16.67
8	Parner	6.70 – 47.08	13.51	0.33-1.38	21.02	0.93 – 40.57	10.81	1.08 – 6.99	0	7.69 – 35.74	0	0.14 – 0.68	64.86
9	Shrigonda	8.28 – 46.74	11.76	0.29-1.65	26.47	3.15 – 28.98	26.47	0.52 – 4.43	0	10.24 – 26.72	0	0.12 – 0.82	91.18
10	Karjat	8.67 – 46.85	13.89	0.30-1.41	38.89	1.61 – 18.41	38.89	0.81 – 5.17	0	0.82 – 26.52	27.78	0.14 – 0.92	41.67
11	Jamkhed	9.74 – 45.85	9.68	0.42-1.74	19.35	0.53 – 13.10	67.74	0.38 – 7.0	0	0.46 – 11.50	77.42	0.10 – 0.67	93.55
12	Nagar	9.60 – 46.30	5.55	0.35-1.70	25.0	1.16 – 16.98	80.56	0.77 – 9.48	0	4.15 – 19.04	0	0.28 – 0.62	75.00
13	Pathardi	8.62 – 46.14	11.76	0.41-1.55	14.71	1.23 – 9.67	76.47	0.89 – 5.49	0	2.0 – 16.49	0	0.31 – 0.74	52.94
14	Shevgaon	8.85 – 46.02	9.38	0.44-1.92	18.75	1.47 – 6.29	90.63	0.47 – 5.13	0	4.32 – 26.09	0	0.30 – 0.72	43.75
Ahmednagar district		**5.48-47.36**	**12.50**	**0.28-2.15**	**19.18**	**0.53-40.57**	**43.32**	**0.21-9.48**	**0**	**0.46-35.74**	**7.33**	**0.10-1.90**	**48.49**

*PSD- Percent Sample Deficient

Table 4 : Nutrient index values of soil available nutrients in different tehsils of Ahmednagar district.

Sr.No	Name of the Tehsils	No. of Samples	S	Zn	Fe	Cu	Mn	B
1	Nevasa	34	2.24	2.09	1.65	3.00	2.85	2.94
2	Shrirampur	25	2.28	1.68	1.68	2.96	2.76	2.48
3	Kopargaon	30	2.13	1.70	1.33	3.00	2.87	2.30
4	Rahata	25	2.52	1.84	1.52	2.92	2.88	1.52
5	Sangamner	37	2.38	2.08	2.03	2.95	2.86	1.49
6	Akole	43	1.98	1.93	2.42	2.98	2.95	1.35
7	Rahuri	30	2.37	1.80	1.57	3.00	2.90	1.83
8	Parner	37	2.38	1.81	2.22	3.00	2.95	1.35
9	Shrigonda	34	2.59	1.74	2.18	2.94	3.00	1.09
10	Karjat	36	2.22	1.61	1.64	3.00	1.94	1.58
11	Jamkhed	31	2.32	1.81	1.32	2.90	1.35	1.06
12	Nagar	34	2.61	1.75	1.19	2.97	2.94	1.25
13	Pathardi	36	2.26	1.85	1.24	3.0	2.74	1.47
14	Shevgaon	32	2.34	1.84	1.09	2.94	2.91	1.56
Ahmednagar district		**464**	**2.33**	**1.83**	**1.65**	**2.97**	**2.71**	**1.64**

Table 5 : Nutrient index value Fertility rating of soil available nutrients in different tehsils of Ahmednagar district

Sr.No	Name of the Tehsils	No. of Samples	S	Zn	Fe	Cu	Mn	B
1	Nevasa	34	M	M	L	H	H	H
2	Shrirampur	25	M	M	M	H	H	H
3	Kopargaon	30	M	M	L	H	H	M
4	Rahata	25	H	M	L	H	H	L
5	Sangamner	37	H	M	M	H	H	L
6	Akole	43	M	M	M	H	H	L
7	Rahuri	30	H	M	L	H	H	M
8	Parner	37	H	M	M	H	H	L
9	Shrigonda	34	H	M	M	H	H	L
10	Karjat	36	M	L	L	H	M	L
11	Jamkhed	31	M	M	L	H	L	L
12	Nagar	34	H	M	L	H	H	L
13	Pathardi	36	M	M	L	H	H	L
14	Shevgaon	32	H	M	L	H	H	L
Ahmednagar district		**464**	**M**	**M**	**L**	**H**	**H**	**L**

Results and Discussion

Soil properties

The pH of soils in Ahmednagar district was recorded slightly acidic to alkaline (6.56-8.44) (Table 2). The highest pH was observed in Shrirampur tehsil (8.44) and lowest in Akole (7.07) with mean of 7.66. Maximum soil samples were found slightly to moderately alkaline in nature. Soil pH is considered to be the “master variable” of soil chemistry due to its profound impact on countless chemical reactions involving essential plant nutri ents” (Penn and Camberato 2019). Lu *et al.* (2020) measured zeta potentials of plant roots and showed that, as the pH increased, the sur faces became increasingly negative. There are also specific effects of pH on the uptake mechanisms. The overall effects of pH on the avail ability of nutrients to plants are a combination of the effects of pH on sorption by soils and the effects of pH on plant uptake.

All the soils were non-saline (0.10-0.97 dS m^{-1}) in nature and suitable for healthy plant growth with a mean value of 0.32 dS m^{-1} which was in normal range (<1 dS m^{-1}). The organic carbon content in soils ranged from 1.76 to 9.12 g kg^{-1}. The highest organic carbon content found in Shrirampur tehsil (9.12) and lowest in Parner tehsil (1.76). Maximum soil samples were found low to medium organic carbon content. Calcium carbonate content in soils of the district varied from 1.50 to 21.63 percent, which indicated, the soils are calcareous in nature. High calcium carbonate is harmful; it reduces the concentration of micronutrients cations in soils to such a level that the sensitive plant suffers from the deficiency of micronutrients (Deb *et al.* 2009). The highest calcium carbonate content was

noticed Sangamner, Kopargaon, Nevasa, shrigonda, parner and karjat tehsils.

Major nutrients status

The available Sulphur varied from low too high in the range from (5.48 to 47.36) and indicating less 12.50 percent deficiency. The highest (47.36) in sangamner and lowest (5.48) in Shrirampur tehsil. The intensive cultivation of crops and application of fertilizers devoid of sulphur might be depleting the sulphur from soil. The application of balanced nutrition to the crops under intensive cultivation is essential for maintaining the soil fertility and sustainable productivity.

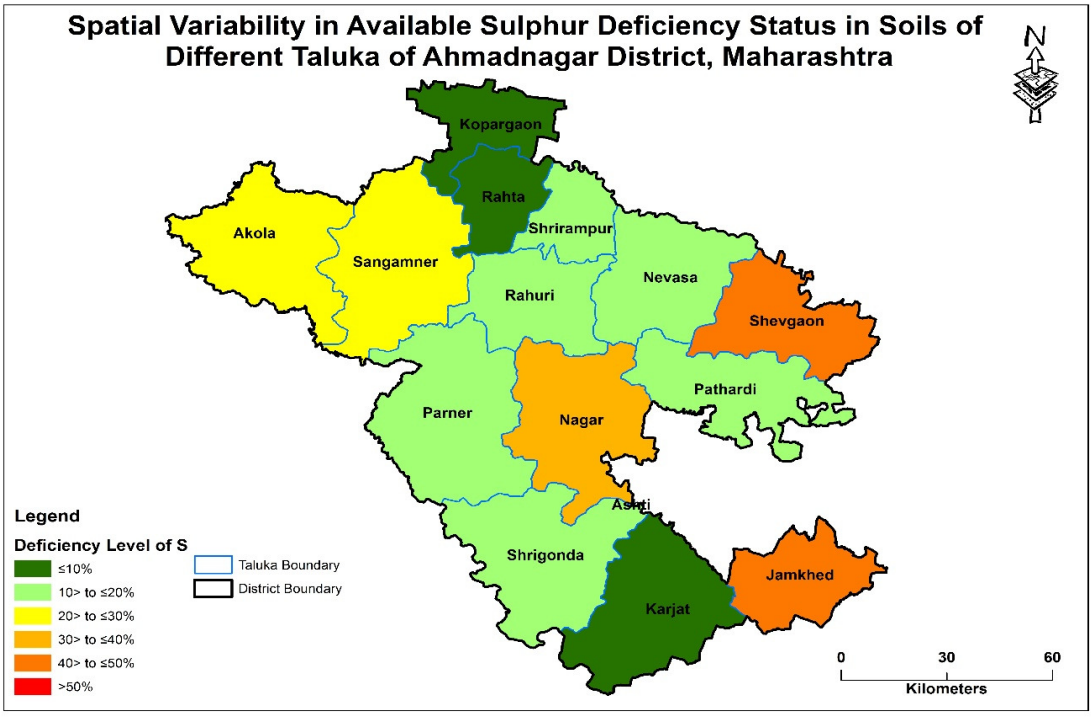

Fig. 1 : Spatial variability of available Sulphur in soils of Ahmednagar district of Maharashtra

Micronutrients status

Data pertaining to DTPA- Zn in soils of Ahmednagar district showed that DTPA- Zn of Ahmednagar district as a whole varied from 0.28 to 2.15 mg kg^{-1} the highest value in Nevasa tehsil (2.15) and lowest in Shrirampur tehsil (0.28) and indicating 19.18 percent deficiency, whereas 78.88 percent samples of available Zn were noticed in medium category. The highest deficiency was showed in Karjat followed by Shrigonda. The availability of micronutrients cations is generally low in alkaline soils and crops grown on these soils suffer from hidden hunger (Malewar, 2005). The deficiency of nutrients creates imbalance in soils which results into nutritional stress in plants. High pH and high contents of $CaCO_3$ can fix Zn in the soil and results in reduction of available zinc (Hafeez *et al.,* 2013).

Under alkaline soil condition (pH higher then 7.0) the micronutrient cations are changed largely to their oxides and hydroxides which ultimately reduced their availability (Deb *et al.,* 2012).DTPA-Fe content showed wide variation (0.53 to 40.57 mg kg^{-1}) and highest in Parner tehsil (40.57) and lowest in Jamkhed tehsil(0.53) and indicating 43.32 percent deficiency.

The DTPA-Cu in the soils of the study area ranged from (0.21 to 9.48) and highest in Nagar tehsil (9.48) and lowest in Rahata tehsil (0.21) and indicating zero (0) deficiency. All the soils in Ahmednagar district were found sufficient in Copper content. Patil and Sonar (1994) reported that in swell-shrink soils of Maharashtra.

The DTPA-Mn in the soils of the study area ranged from (0.46 to 35.74) and highest range in Parner tehsil (35.74) and lowest range in Jamkhed tehsil (0.46) and indicating 7.33 percent deficiency and all soils in the Ahmednagar district were founded well sufficient in Mn- content.

$CaCl_2$-B the available boron in soils of Ahmednagar district ranged from (0.10 to 1.90 mg kg^{-1}) and highest range (1.90) in Nevasa and lowest (0.10) in Jamkhed tehsil and indicating 48.49 percent deficiency (Das, 2007) who reported that available

phosphorous and potassium exhibited a positive correlation with Boron and there by availability of Boron getting increased with NPK additions.

Micronutrients play a crucial role in maintaining soil health and environmental sustainability. They are essential for maintaining the physicochemical properties of the soil, improving its fertility and enduring the growth of healthy crops (Shailesh *et al.*, 2023).

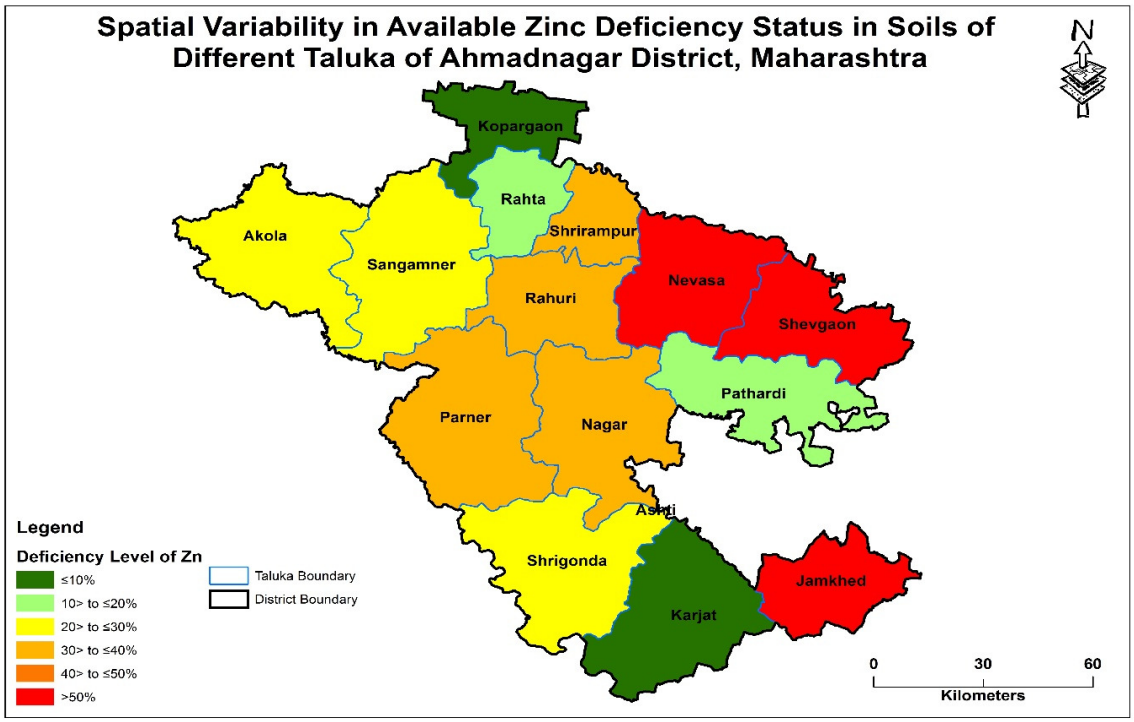

Fig. 2 : Spatial variability of available Zinc in soils of Ahmednagar district of Maharashtra.

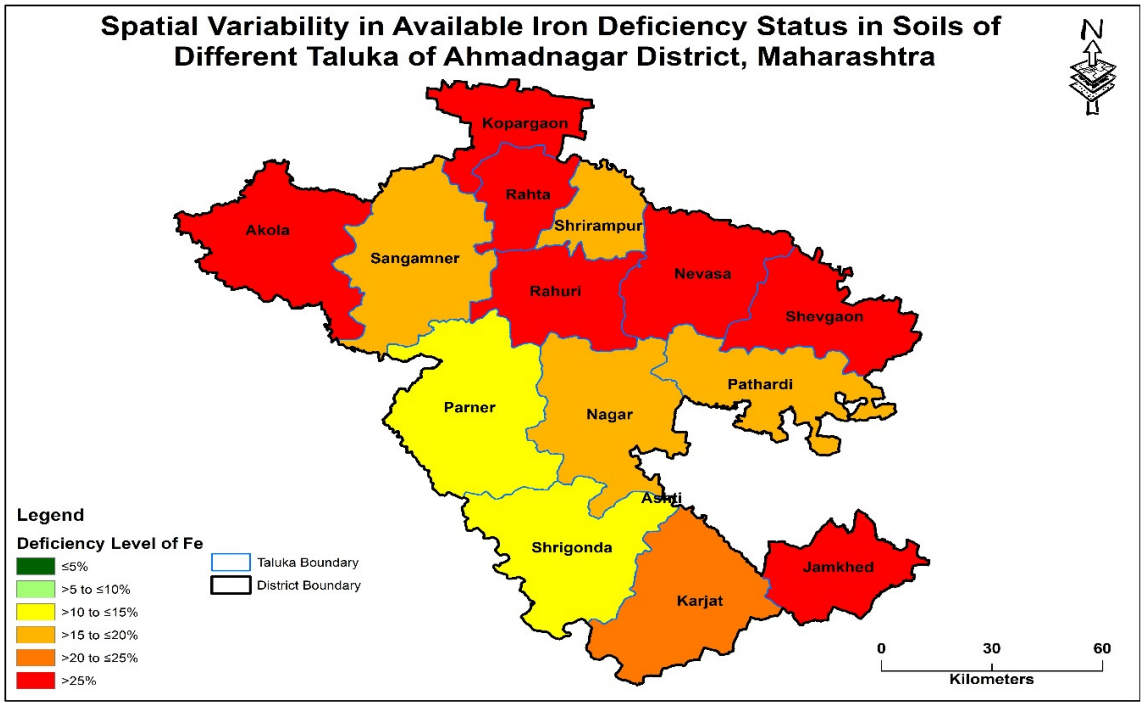

Fig. 3 : Spatial variability of available Iron in soils of Ahmednagar district of Maharashtra.

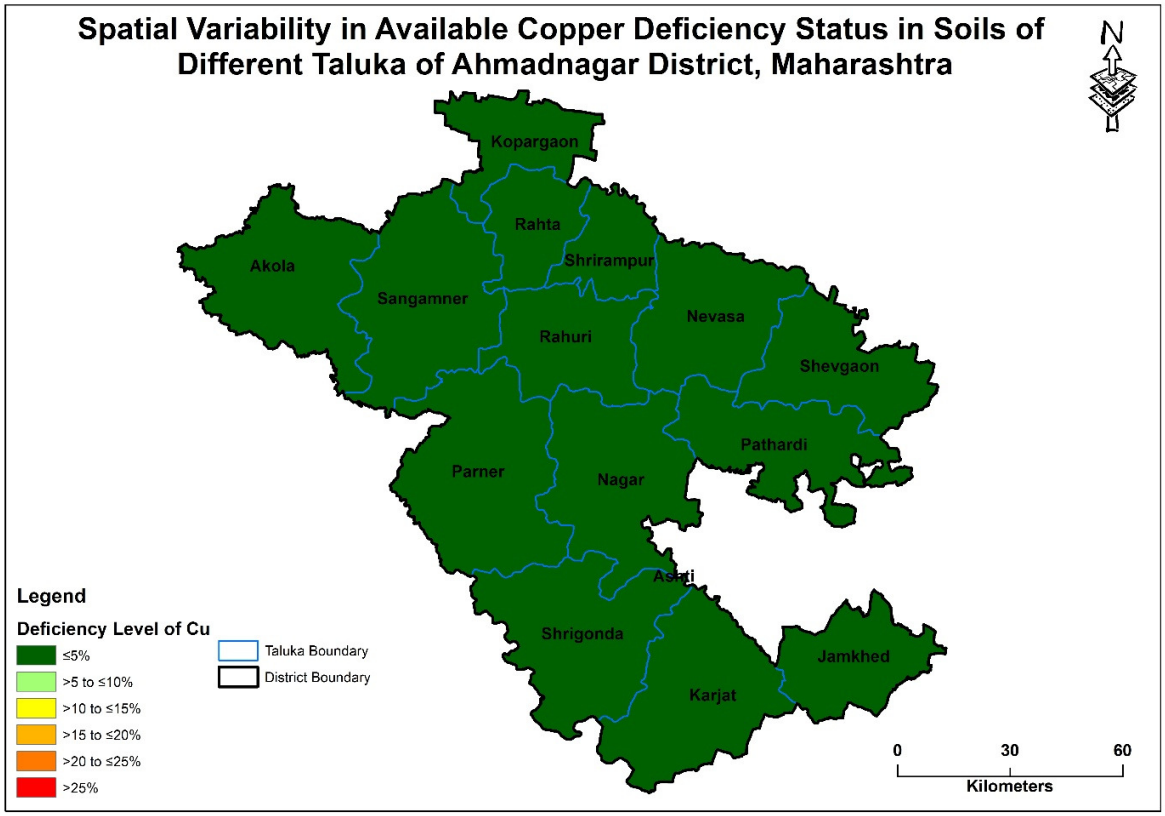

Fig. 4 : Spatial variability of available Cu in soils of Ahmednagar district of Maharashtra.

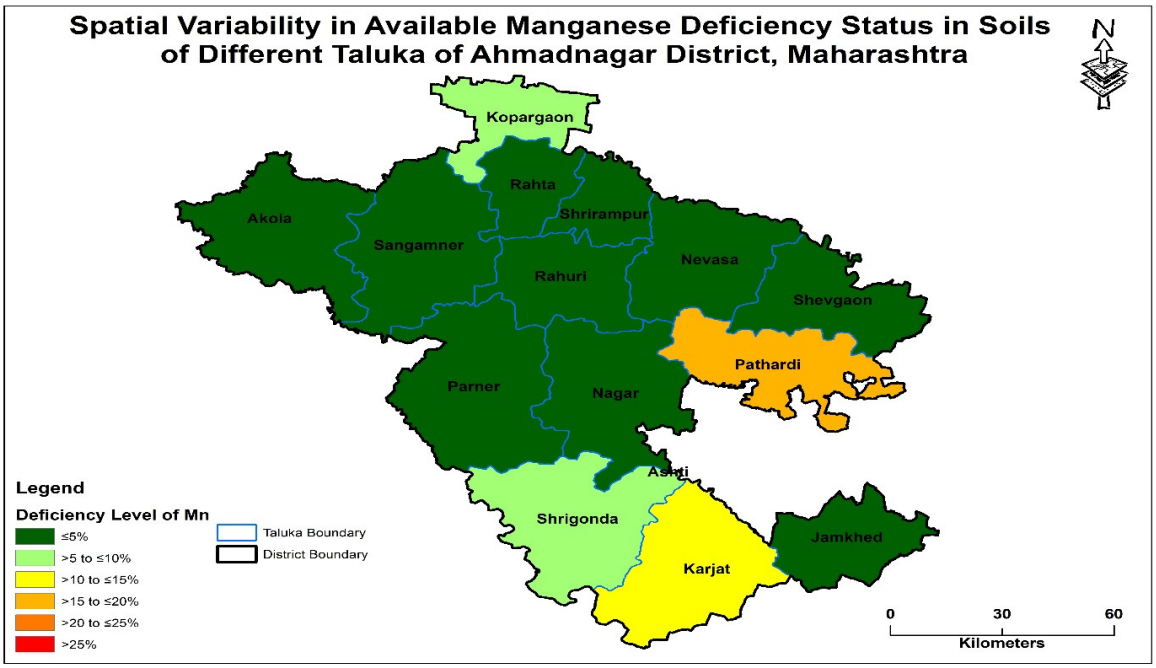

Fig. 5 : Spatial variability of available Mn in soils of Ahmednagar district of Maharashtra.

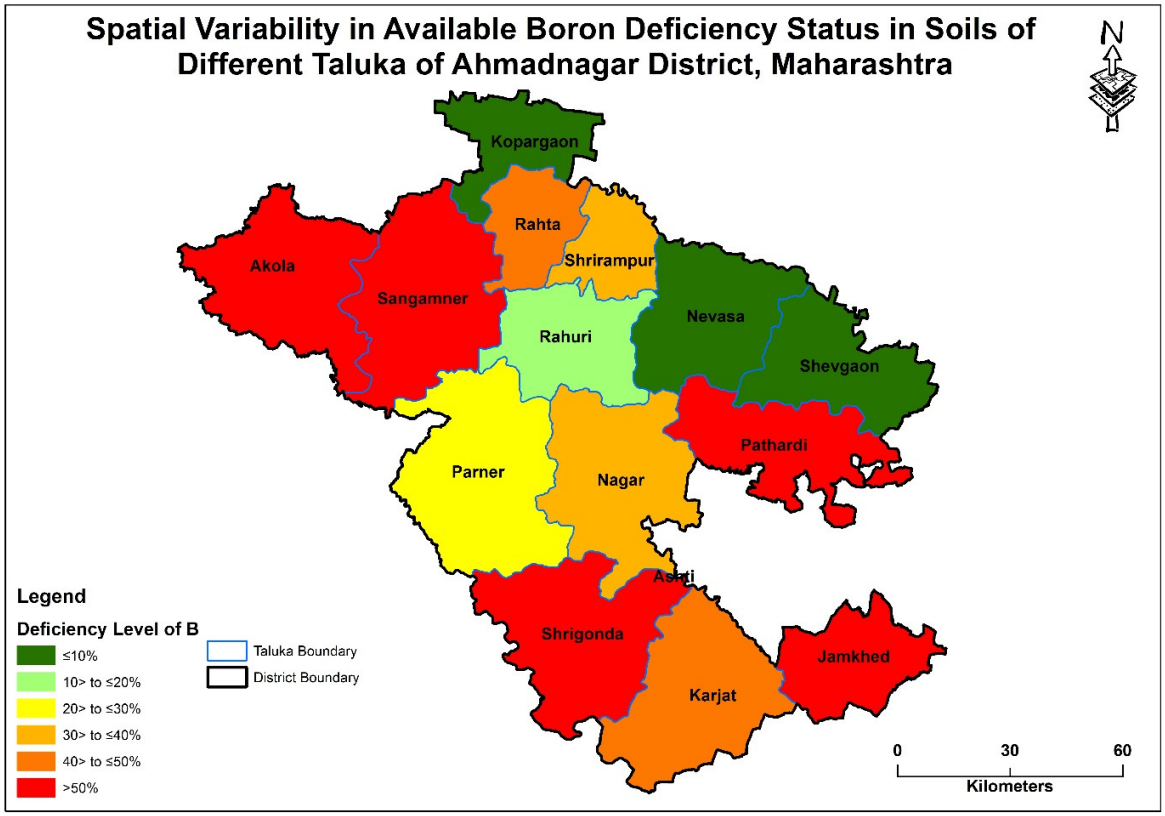

Fig. 6 : Spatial variability of available B in soils of Ahmednagar district of Maharashtra.

Nutrient indices

The nutrient indices across the Ahmednagar district ranged from 1.98-2.61 for S, 1.61-2.09 for Zn, 1.09-2.42 for Fe, 2.90 -3.0 for Cu, 1.35-3.0 for Mn and 1.06-2.94 for B. Notably low fertility rating was recorded for Fe, B and high in Cu, Mn and for medium in S, Zn. In nutshell, overall fertility rating for nutrients in the soils of Ahmednagar district revealed low in Fe and B, marginal in S and Zn, high in Cu and Mn status. The area where the status of nutrients is medium may show deficiency in near future if the due care is not taken for addition of organic manures, inorganic fertilizers and micronutrients fertilizers based on soil testing by the cultivators in the districts of intensive cultivation of different crops (Malewar, 2005).

Conclusion

The information technology-based GPS-GIS technique has been found useful for systematic mapping of spatial variability of macro and micro nutrients. Among the secondary nutrient of Sulphur (12.50 percent) was found deficient. The micronutrients viz., zinc (19.18 percent), iron (43.32 per cent), Manganese (7.33) and boron (48.49 per cent) showed deficiency. Deficient nutrients have to be restored through chemical fertilizers and /or organic manures to maintain soil health. The current status of spatial variability of micronutrients in soils of Ahmednagar district will be helpful to suggest the efficiency ways and methods of balanced nutrient application for enhancing the yields by using recommended quantities of organic manures and inorganic fertilizers in the areas of major and micro-nutrients deficiency.

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