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Assessment of Spatial Variability of Major and Micro Nutrients in Soils of Satara District, Maharashtra, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Georeferenced surface soil samples from eleven (11) tehsils were delineated using stratified random soil 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, major and micronutrients status in soils of Satara district in the year 2022-2023 of three hundred and thirty soil (330) samples at the depth of (0-20 cm) were collected across the Satara district of Maharashtra and analysed in the laboratory. The results revealed that pH, EC, $CaCO_3$ and OC of soils collected across different tehsils of Satara district varied from 6.00

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to 9.43,0.10 to 0.98 dS m^{-1}, 1.50 to 29.25 % and 0.72 to 7.80 g kg^{-1}. The DTPA -Zn, Fe, Cu and Mn in soil of Satara district ranged from 0.18 to 1.85 mg Kg^{-1}, 1.89 to 12.50 mg Kg^{-1}, 0.36 to 2.15 mg Kg^{-1} and 3.91 to 38.44 mg Kg^{-1} respectively. The $CaCl_2$-B in soils of all the tehsils ranged from 0.18 to 1.69 mg Kg^{-1}. The results obtained clearly showed a large variability in physio-chemical properties of soil across the Satara district with low nutrient indices were in nitrogen (1.12) and iron (1.51), medium for phosphorus (1.99), Sulphur (2.08) and zinc (1.88), high for potassium (2.92), copper (2.96), manganese (2.77) and boron (2.47).

Keywords: Spatial variability; major; micro; nutrients; Satara District.

1. INTRODUCTION

The global Positioning System (GPS) facilitates the systematic collection of georeferenced soil samples, and the Geographic Information System (GIS) generates spatial data regarding the transportation of nutrients. Farmer's efforts to improve crop yield and nutrient usage efficiency depend heavily on their capacity to properly understand the spatial variation and spatial distribution of soil features.

Today, the increasing population growth, the need for more food, intensive land exploitations etc., have led to a widespread of lack nutrient distribution in most places of the world. These factors combine to create a complex landscape of food demand that is challenging to address.

Higher productivity and adequate nutrition have been achieved in the whole country attributable to the green revolution. However, the widespread exhaustion of native initial nutrient fertility and subsequent widespread deficiencies of all nutrients are the result of high-yielding variety farming done intensively, raised unequal application of fertilizers lacking of micro- and supplementary nutrients, diminished use of natural manure, and lack of crop residue recycling. According to Yadav et al. [1] applying fertilizers based on the properties of the soil that are linked to fertilizer recommendations may help minimize fertilizer input without compromising output. In addition to extending views about current management approaches, knowledge regarding the geographical variability of soil physio-chemical characteristics was crucial in crop selection and cropping system design [2,3].

Several researchers have examined the spatial variability of pH, organic carbon, overall and accessible NPK, and micronutrients with varying soil and management regimes in order to improve and execute site-specific management [4]. The lack of micronutrients is now a significant barrier to sustainable agricultural output, so understanding the geographical variability of soil nutrient levels is essential [5].

A major issue of decreasing soil fertility and causing soil degradation is brought on by population growth and overexploitation of arable land. Crop response becomes subpar when there is a nutritional deficit, which directly impacts crop growth [6]. Therefore, a database on soil fertility status is necessary for the management of soil resources and the long-term viability of the current farming system. The texture, pH, organic matter content, type of clay mineral, and elemental correlations all have a major role in controlling the availability of nutrients in soil are the Soil characteristics [7].

The current investigation was conducted to assess the status of significant and micronutrients in soils as well as to identify and define areas of nutrient deficiencies in the Palghar district of Maharashtra, India, in light of a recent decrease in the response and effectiveness of chemical fertilizer nutrients under farming intensively due to disorganized and not enough use of chemicals in combination with improper utilization of other supplies.

2. MATERIALS AND METHODS

In order to evaluate the chemical characteristics and major and micronutrient status in the soils of Satara district in the years 2022–2023, the current investigation was conducted at the All-India Co-ordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plant under the Department of Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. GPS-based soil samples (0–20 cm) were taken at a grid spacing of five kilo-meters from eleven tehsils in the Satara district of Maharashtra. The samples were then analyzed in a laboratory.

2.1 Description of the Study Area

The comparatively high elevation and neighboring mountains of Satara, Maharashtra, contribute to the district's tropical wet and dry climate (Koppen climatic classification). Summer temperatures are higher than winter temperatures, and according to the severity of the monsoon, the region receives between 900 and 1500 mm of rainfall annually. At 1417 meters (4,649 feet) above mean sea level, it is located between latitudes 170 50' and 180 11' North and longitudes 730 33' and 740 54' East.The district is spread across eleven tehsils (Phaltan, Khandala, Koregaon, Satara, Wadul, Dahiwadi, Wai, Mahabaleshwar, Medha, Patan, Karad) with a total geographical area of 10,48,000 ha.

At every sampling point spread around the district, GPS data (latitude, longitude, and altitude) were recorded. A total of 330 samples were gathered. Following collection, the georeferenced soil samples were processed and dried in the shade. The measurement of pH, EC, CaCO3, organic carbon, N, P, K, S, and micronutrients (Zn, Fe, Cu, Mn, and B) was done on the processed soil samples.

2.2 Soil Sampling and Analysis

The district of Satara is where the survey was conducted. Grids were placed five kilo-meters apart between the district and tehsils, and samples were taken from each grid square. Twenty to thirty villages were chosen at random from each block in the district to collect surface soil samples (0–20 cm).

GPS-focused A total of 330 surface soil samples (0–20 cm) from 11 tehsils were collected across the Satara district. For selecting the samplings, randomization with stratification was employed. The soil samples were produced and evaluated for pH and EC in soil:water suspensions (1:25 w/v) by Jackson's [8] guidelines. The Walkley and Black [9] wet oxidation method was used to test the organic carbon, and the Rapid technique [10] was used to assess the liberated CaCO3. Jackson [11] used the ammonium acetate extraction technique to figure out readily available K; Chesnin and Yien [12] used the turbidimetric strategy to predict accessible S; Subbiah and Asija [13] used the alkaline permanganate method to determine accessible N; and Watanabe and Olsen [14] used Olsen's method to calculate existing P. Soil samples were extracted using 0.005M diethylenetriamine pentaacetic acid (DTPA), and the amount of accessible zinc, iron, copper, and magnesium was measured using an atomic absorption spectrophotometer [15]. The Azo-Methine method was used to determine the accessible boron utilizing a 0.01 M CaCl2 extraction [16]. The formula supplied by was used to categorize the nutritional indices into low (<1.66), medium (1.67-2.33), and high (>2.33) groups Parker et al. [17].

Nutrient index = Per cent samples low x 1+ per cent samples medium x 2 + per cent sample high x3 / 100

In the state of Maharashtra, the main and micronutrients were divided into three categories: low, medium, and high (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	N (kg ha^{-1})	<280	280-560	>560
6	P (kg ha^{-1})	<14	14-28	>28
7	K (kg ha^{-1})	<150	150-250	>250
8	S (mg kg^{-1})	<10.0	10-20	>20
9	Zn (mg kg^{-1})	<0.60	0.60-1.80	>1.80
10	Fe (mg kg^{-1})	<4.50	4.50-18.0	>18.0
11	Cu (mg kg^{-1})	<0.20	0.20-0.80	>0.80
12	Mn (mg kg^{-1})	<2.0	2.0-8.0	>8.0
13	B (mg kg^{-1})	<0.50	0.50-1.0	>1.0

(Source: Dr. DPKV, Akola)

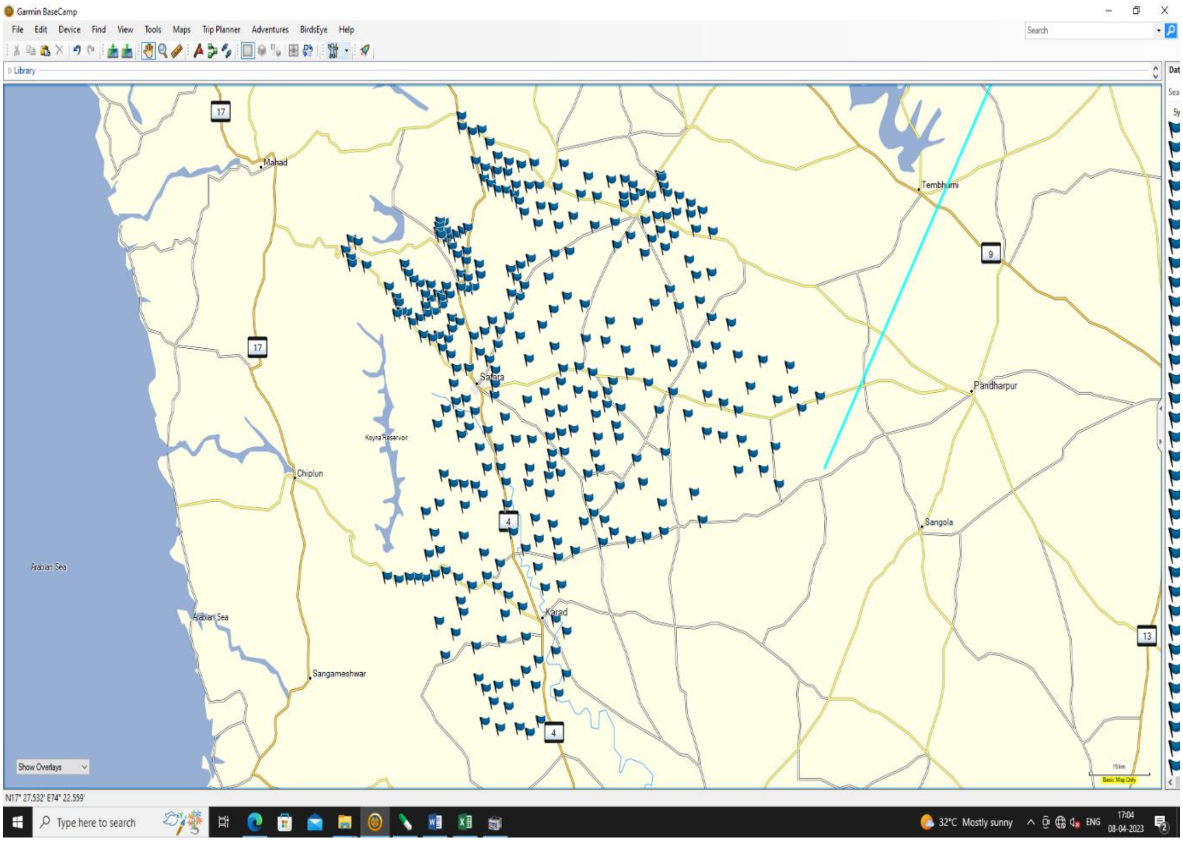

Fig. 1. Map of Samplings points of Satara district of Maharashtra

3. RESULTS AND DISCUSSION

3.1 Soil Chemical Properties

The soil pH values in Satara district ranged from 6.01 to 9.43, indicating a mildly acidic to alkaline state (Table 2). With an average pH of 8.21, Patan (6.00) has the lowest pH and Medha tehsil (9.43) the highest. The majority of soil samples were discovered to have a mildly to moderately alkaline character. With an average value of 0.32 dS m-1, within the usual range (<1 dS m-1), all the soils were non-saline (0.10-0.98 dS m-1) and appropriate for optimal plant growth. Soils exhibited a range of organic carbon contents from 0.72 to 7.80 g kg-1. Phaltan tehsil has the lowest organic carbon content (0.72) while Khandala tehsil has the highest (7.80).The majority of soil samples had low to medium levels of organic carbon. The district's soils ranged in calcium carbonate content from 1.50 to 29.25 percent, suggesting that the soils are naturally mildly calcareous. Elevated calcium carbonate is detrimental because it lowers soil micronutrient cation concentrations to a point where sensitive plants experience micronutrient deficiencies [18]. According to earlier writers, alkaline soils with limited soil organic matter are more likely to have boron deficiencies [19]. The tehsils of Wai, Dahiwadi, Phaltan, Karad, Koregaon, and Khandala have the highest calcium carbonate content.

3.2 Primary Nutritional Status

The variation of accessible nitrogen, which demonstrated widespread deficit and a 94.5 percent sample deficiency, was shown to be 63 to 539 kg ha-1 (Table 3). The lack of accessible nitrogen may result from the intense farming of enhanced, high-yielding crop cultivars with very little addition of organic manures and high absorption. Also, the Satara tehsil has the most nitrogen available (539 kg ha-1), whereas Wadul and Dahiwadi have the least nitrogen available (63 kg ha-1). The range of available P (6.67 to 42.41 kg ha-1) showed a 10.91 percent shortage. The soil's slightly acidic composition causes P to be fixed in the form of iron and aluminum phosphate, which accounts for the shortage of accessible P. Patan Tehsil has the lowest amount of available phosphorus (6.67 kg ha-1) while Koregaon Tehsil has the largest amount (42.41 kg ha-1). With a 2.12 percent shortfall, the available K ranged from 158 to 1067 kg ha-1, medium to extremely high. Satara tehsil had the greatest available K (1067 kg ha-1), while Phaltan tehsil had the lowest (158 kg ha-1).According to Sharma and Anil Kumar [20] this could be explained by more extreme weathering, the release of liable K from biological residues, the use of K fertilizers, the upward translocation of K from lower depths, and the capillary increase of ground water.In many soils during the post-Green Revolution era, the amount of accessible potassium was thought to be extremely high. Recent trends suggested that there was a modest potassium shortfall, which was responsive to addition of the mineral.

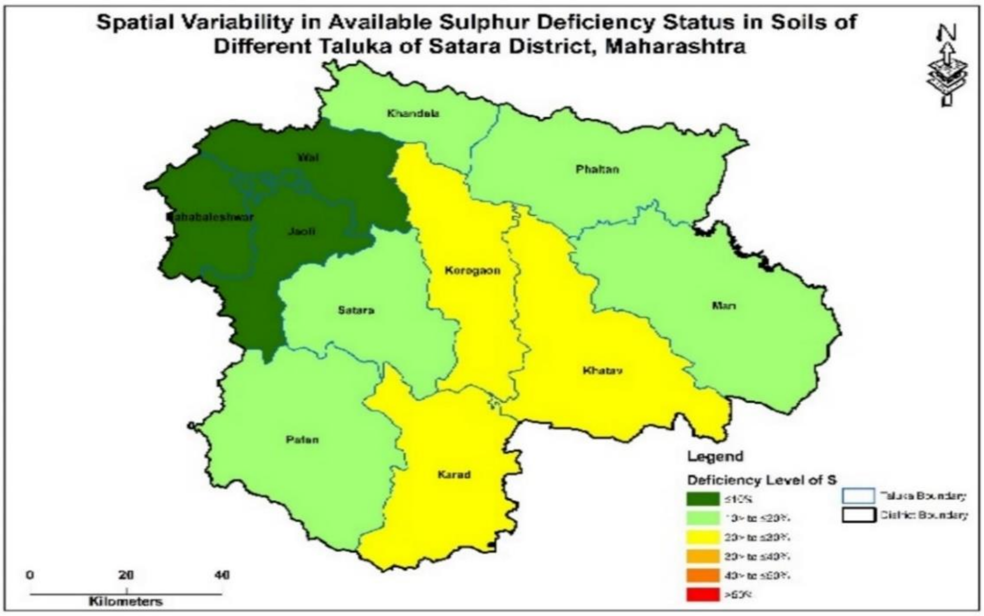

Fig. 2. Spatial variability of available Sulphur in soils of Satara district of Maharashtra

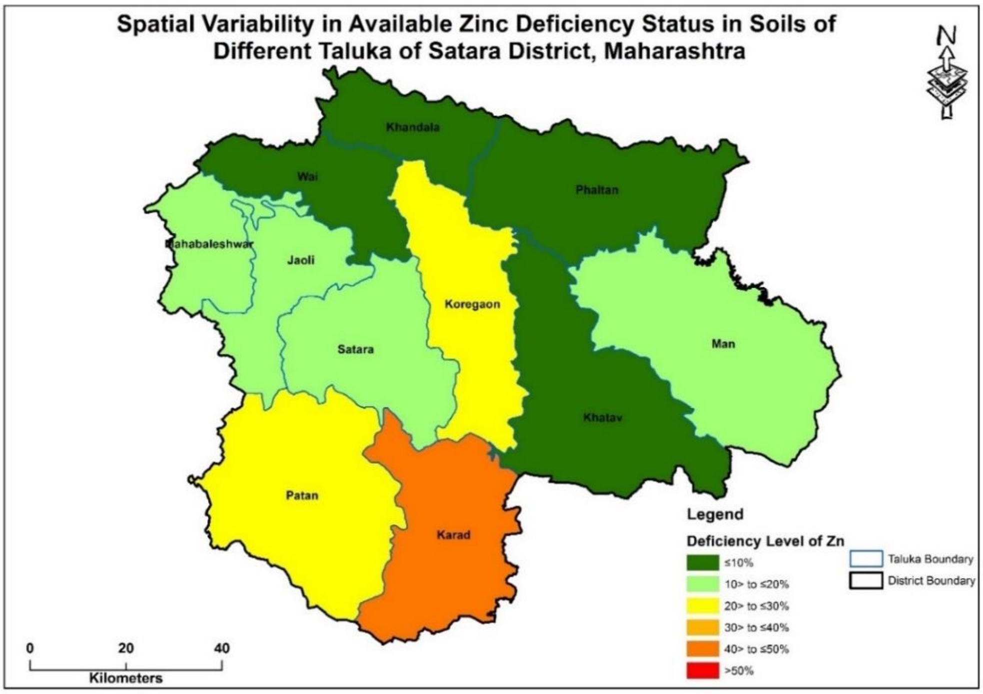

Fig. 3. Spatial variability of available Zinc in soils of Satara district of Maharashtra

Table 2. Chemical properties of soils in Satara 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	Phaltan	44	6.83-9.22	8.37	0.11-0.91	0.35	1.50-27.50	14.66	0.72-4.74	2.96
2	Khandala	26	7.59-8.76	8.36	0.11-0.55	0.20	5.75-22.5	14.02	1.74-7.80	3.37
3	Koregaon	31	7.38-8.84	8.27	0.12-0.62	0.17	6.00-23.25	14.85	1.14-5.04	2.97
4	Satara	31	6.51-8.73	8.08	0.12-0.92	0.38	6.25-20.75	13.08	1.02-4.44	2.99
5	Wadul	35	7.22-8.85	8.31	0.11-0.76	0.33	6.75-29.25	17.77	1.08-3.90	2.68
6	Dahiwadi	33	7.10-8.80	8.19	0.10-0.96	0.38	6.75-27.75	16.20	1.12-5.10	2.72
7	Wai	22	7.55-8.80	8.31	0.10-0.98	0.40	5.00-25.50	16.62	1.50-3.54	2.68
8	Mahabaleshwar	8	7.49-8.85	8.27	0.10-0.65	0.37	5.00-12.50	8.15	1.98-4.02	2.63
9	Medha	30	7.52-9.43	8.39	0.10-0.87	0.38	4.5-19.00	11.27	1.74-4.62	2.630
10	Patan	33	6.00-8.30	7.54	0.10-0.83	0.26	1.75-16.50	7.50	1.50-4.50	2.77
11	Karad	36	7.10-8.93	8.23	0.10-0.84	0.31	2.50-26.00	11.00	1.38-5.04	2.61
Satara district		330	6.00-9.43	8.21	0.10-0.98	0.32	1.50-29.25	13.52	0.72-7.80	2.83

Table 3. Major nutrients status in soils of Satara district

Sr. No.	Tehsil	Available Nitrogen kg ha^{-1}		Available Phosphorus kg ha^{-1}		Available Potassium kg ha^{-1}		Available Sulphur mg kg^{-1}	
		Range	PSD	Range	PSD	Range	PSD	Range	PSD
1	Phaltan	125-364	88.64	12.94-31.87	18.18	158-845	2.27	8.02-27.52	0
2	Khandala	125-351	84.62	8.34-34.62	46.15	162-1057	0	8.67-22.12	7.69
3	Koregaon	75-451	90.32	11.64-42.41	9.68	170-790	0	14.79-19.75	0
4	Satara	100-539	64.52	18.18-41.59	0	184-1067	6.45	15.15-19.60	0
5	Wadul	63-364	86.1	12.42-37.60	5.56	174-839	0	14.92-25.03	0
6	Dahiwadi	63-213	100	11.00-23.47	3.03	400-838	0	15.11-22.34	0
7	Wai	113-213	100	16.05-29.56	0	226-825	4.55	14.89-21.04	0
8	Mahabaleshwar	113-188	100	15.90-23.03	0	462-798	0	15.03-16.23	0
9	Medha	113-201	100	11.80-33.47	26.67	242-809	3.33	14.45-19.70	0
10	Patan	113-226	100	6.67-29.83	3.03	176-823	0	13.39-18.96	0
11	Karad	113-288	97.22	13.58-36.08	2.78	194-798	5.56	14.69-19.67	0
Satara district		63-539	94.5	6.67-42.41	10.91	158-1067	2.12	8.02-27.52	0.61

Table 4. Micronutrients status (mg kg^{-1}) of soil in Satara district

Sr. No	Tehsil	DTPA-Zn		DTPA-Fe		DTPA-Cu		DTPA-Mn		$CaCl_2$ - B	
		Range	PSD	Range	PSD	Range	PSD	Range	PSD	Range	PSD
1	Phaltan	0.27-1.50	18.18	1.89-5.86	29.55	0.49-1.93	0	4.65-22.99	0	0.72-1.36	0
2	Khandala	0.37-1.50	46.15	2.84-5.86	73.08	0.49-1.89	0	6.62-19.08	0	0.58-1.50	0
3	Koregaon	0.26-1.48	6.45	2.34-6.54	58.06	0.74-1.93	0	6.61-17.33	0	0.65-1.42	0
4	Satara	0.37-1.85	22.58	2.18-12.50	38.71	0.69-1.75	0	7.20-30.92	0	0.84-1.47	0
5	Wadul	0.27-1.25	61.11	2.30-11.18	58.33	1.01-2.15	0	5.00-28.14	0	0.76-1.30	0
6	Dahiwadi	0.18-1.58	72.73	2.25-5.26	81.82	1.01-1.98	0	4.56-34.00	0	0.66-1.32	0
7	Wai	0.46-1.69	9.09	3.21-7.45	31.82	0.78-1.86	0	8.05-37.00	0	0.57-1.36	0
8	Mahabaleshwar	0.52-1.69	12.5	3.43-5.32	50	0.88-1.94	0	12.34-24.82	0	0.65-1.05	0
9	Medha	0.43-1.76	0	2.55-7.65	60	0.82-1.96	0	6.35-34.88	0	0.77-1.36	0
10	Patan	0.44-1.75	9.09	4.40-10.78	0	0.46-1.97	0	10.32-38.44	0	0.18-1.69	15.15
11	Karad	0.43-1.80	8.33	2.59-6.55	63.89	0.36-1.93	0	3.91-36.24	0	0.85-1.66	0
Satara district		0.18-1.85	25.15	1.89- 12.50	49.09	0.36-2.15	0	3.91-38.44	0	0.18-1.69	1.51

Table 5. Nutrient index values of soil available nutrients in different tehsils of Satara district

			Nutrient Index								
Sr.No	**Name of the Tehsils**	**No. of Samples**	**N**	**P**	**K**	**S**	**Zn**	**Fe**	**Cu**	**Mn**	**B**
1	Phaltan	44	1.11	1.82	2.91	2.34	1.82	1.70	2.93	2.52	2.50
2	Khandala	26	1.15	1.62	2.85	1.96	1.54	1.27	2.88	2.50	2.27
3	Koregaon	31	1.10	2.10	2.90	2.00	1.94	1.42	3.00	2.29	2.71
4	Satara	31	1.35	2.13	2.81	2.00	1.81	1.61	2.97	2.81	2.84
5	Wadul	35	1.14	2.14	2.94	2.17	1.39	1.42	3.00	2.92	2.29
6	Dahiwadi	33	1.00	1.97	3.00	2.15	1.27	1.18	3.00	2.97	2.30
7	Wai	22	1.00	2.09	2.91	2.05	2.05	1.68	2.95	2.91	2.14
8	Mahabaleshwar	8	1.00	2.00	3.00	2.00	2.00	1.50	3.00	3.00	2.13
9	Medha	30	1.00	1.83	2.93	2.00	2.20	1.40	3.00	2.93	2.30
10	Patan	33	1.00	2.12	2.97	2.00	2.03	2.00	2.91	2.97	2.58
11	Karad	36	1.03	2.08	2.89	2.00	2.06	1.36	2.92	2.83	2.75
Satara district		330	1.12	1.99	2.92	2.08	1.88	1.51	2.96	2.77	2.47

Table 6. Nutrient index value Fertility rating of soil available nutrients in different tehsils of Satara district

			Value Fertility rating								
Sr.No	**Name of the Tehsils**	**No. of Samples**	**N**	**P**	**K**	**S**	**Zn**	**Fe**	**Cu**	**Mn**	**B**
1	Phaltan	44	L	M	H	H	M	M	H	H	H
2	Khandala	26	L	L	H	M	L	L	H	H	M
3	Koregaon	31	L	M	H	M	M	L	H	M	H
4	Satara	31	L	M	H	M	M	L	H	H	H
5	Wadul	35	L	M	H	M	L	L	H	H	M
6	Dahiwadi	33	L	M	H	M	L	L	H	H	M
7	Wai	22	L	M	H	M	M	M	H	H	M
8	Mahabaleshwar	8	L	M	H	M	M	L	H	H	M
9	Medha	30	L	M	H	M	M	L	H	H	M
10	Patan	33	L	M	H	M	M	M	H	H	H
11	Karad	36	L	M	H	M	M	L	H	H	H
Satara district		330	L	M	H	M	M	L	H	H	H

The range of accessible sulfur was 8.02 to 27.52 mg kg-1, with low to high values indicating a very slight shortage of 0.61 percent.The greatest (27.52 mg kg-1) and lowest (8.02 mg kg-1) were found exclusively in Phaltan tehsil. The soil may be losing sulphur due to the heavy crop cultivation and use of sulphur-free fertilizers. For the crops grown under intense cultivation to be productive and the land fertile, they must have a balanced diet.

3.3 Micronutrients Status

According to data in Table 4, the amount of DTPA-Zn in the soils of the Satara district ranged from 0.18 to 1.85 mg kg-1. The highest value was found in the Satara tehsil (1.85 mg kg-1) and the lowest in the Dahiwadi tehsil (0.18 mg kg-1), indicating a 25.15 percent deficiency. Meanwhile, 61.82 percent of the samples of Zn that were available fell into the medium category. Dahiwadi had the greatest shortage, followed by wadul. Alkaline soils typically have low levels of micronutrients and cations, which causes hidden hunger in crops cultivated on these soils [7]. Plants experience nutritional stress as a result of soil imbalance brought on by nutrient deficiencies. Zinc in the soil can be fixed by high pH and CaCO3 concentrations, which leads in a reduction of available zinc [21].

The micronutrients cations are extensively converted to their oxides and hydroxides in alkaline soil conditions (pH greater than 7.0), which eventually reduces their availability [22]. The level of DTPA-Fe varied greatly (1.89 to 12.50 mg kg-1), with Satara tehsil having the highest amount (12.50 mg kg-1) and Phaltan tehsil having the lowest (1.89 mg kg-1), suggesting a 49.09 percent deficiency.

There was no deficit found in any of the soils in the research region, with the highest concentration of DTPA-Cu (2.15 mg kg-1) being found in Wadul tehsil, and the lowest concentration (0.36 mg kg-1) in Karad tehsil. A considerable amount of copper was found in all of the Satara district's soils. In the swell-shrink soils of Maharashtra, Patil and Sonar [23] reported?

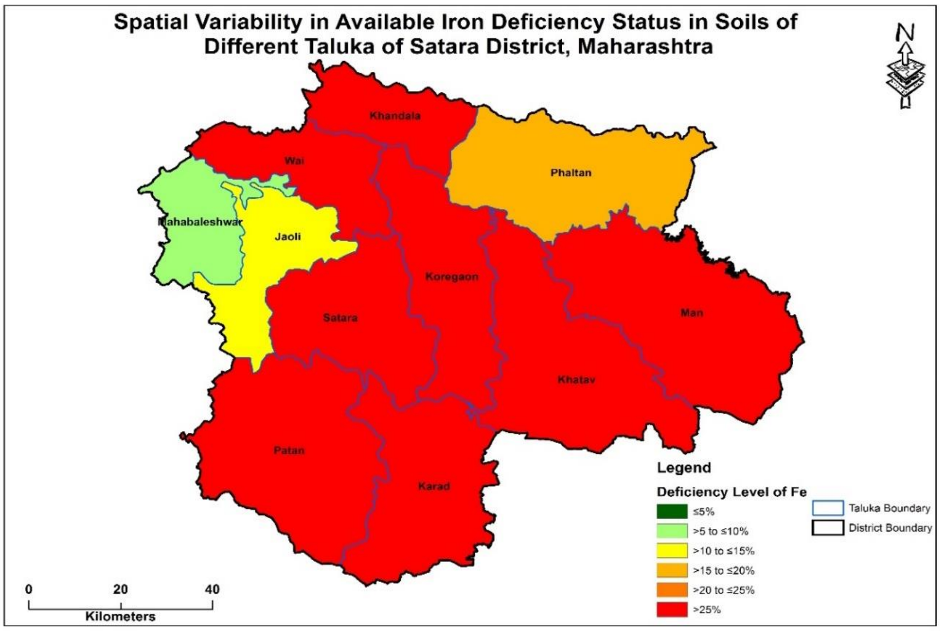

Fig. 4. Spatial variability of available Fe in soils of Satara district of Maharashtra

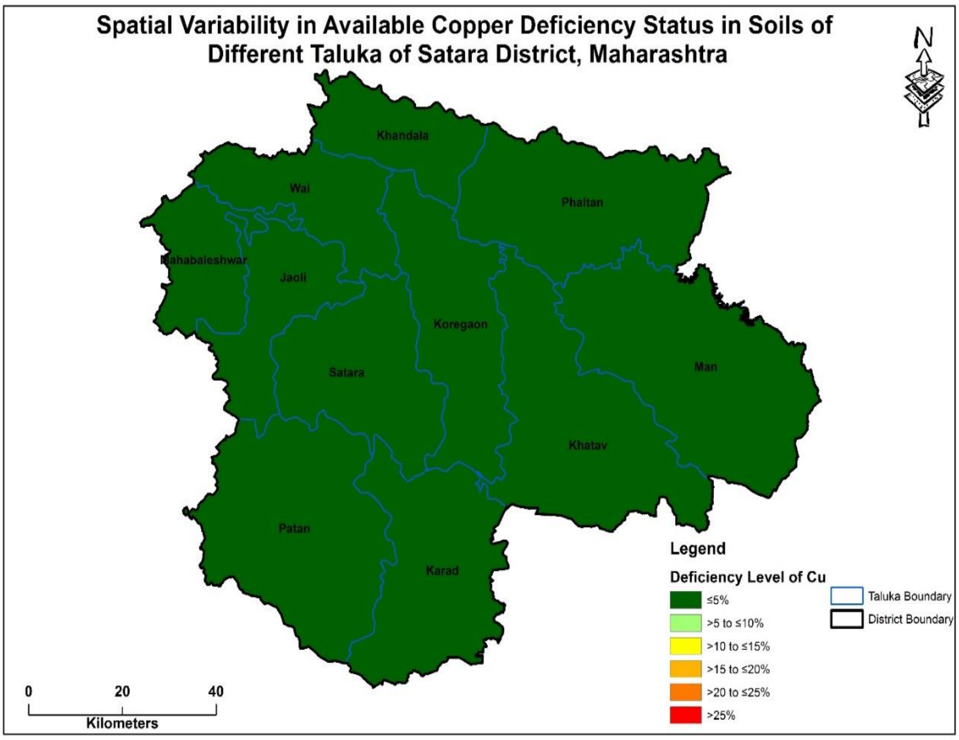

Fig. 5. Spatial variability of available Cu in soils of Satara district of Maharashtr

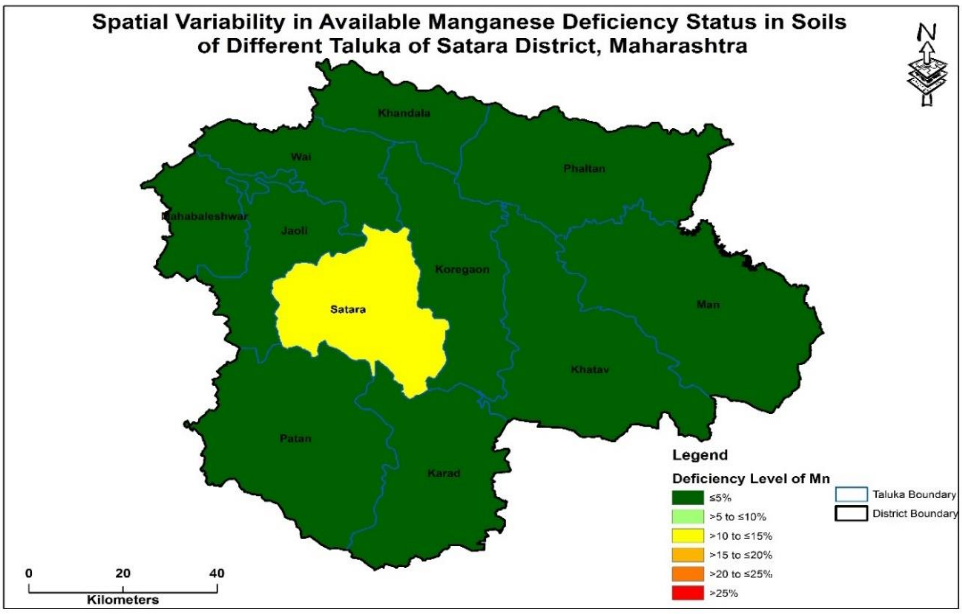

Fig. 6. Spatial variability of available Mn in soils of Satara district of Maharashtra

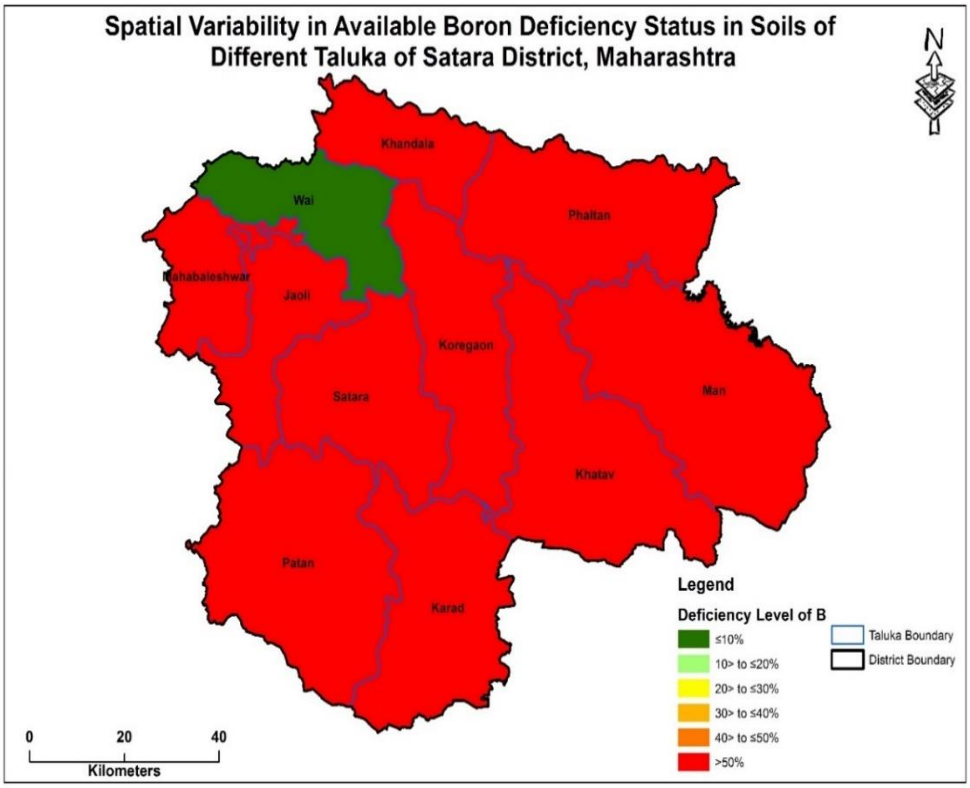

Fig. 7. Spatial variability of available B in soils of Satara district of Maharasht

The research revealed that the area's soils had DTPA-Mn levels ranging from 3.91 to 38.44 mg kg-1, with Patan tehsil having the highest range (38.44 mg kg-1) and Karad tehsil having the lowest range (3.91 mg kg-1). These results represents that there was no zero (0) deficiency and that around all of the Satara district's soils had enough Mn content.

CaCl2 -B: The range of accessible boron in the soils of Satara district was 0.18 to 1.69 mg kg-1, with Patan tehsil having the lowest (0.18 mg kg-

1) and highest (1.69 mg kg-1) levels, indicating a 1.51 percent shortage. Boron availability rises in acidic (low pH) soils and falls in alkaline (high pH) soils, which is the cause of boron shortage. compacted soils can hinder plants' absorption of boron [24] who revealed that potassium and phosphorus were readily available exhibited a positive correlation with Boron and there by availability of Boron getting increased with NPK additions.

3.4 Nutrient Indices

In Satara district, the nutritional indices as presented in (Table 5) were as follows: 1.0 -1.35 for N; 1.62-2.14 for P; 2.81-3.0 for K; 1.96-2.34 for S; 1.27-2.20 for Zn; 1.18-2.0 for Fe; 2.88 -3.0 for Cu; 2.29-3.0 for Mn; and 2.13-2.84 for B. The fertility rating in (Table 6) is indicated. Significantly low fertility ratings were noted for N and Fe, high ratings for K, Cu, Mn, and B, and medium ratings for P, S, and Zn. In summary, the soils in the Satara district had an overall fertility rating for nutrients that showed low levels of N and Fe, marginal levels of P, S, and Zn, and high levels of K, Cu, Mn, and B.

According to soil tests conducted by producers in districts where different crops cultivations are intensively, an area with a medium level of nutrients may soon exhibit a deficiency if proper care is not taken to add organic manures, inorganic fertilizers, and micronutrient fertilizers [7].

4. CONCLUSION

Systematic modeling of the spatial variation of macro- and micronutrients has been found to be facilitated by the GPS-GIS technique, which is based on information technology. Of the primary nutrients, it was discovered that phosphorus (10.91 percent) and nitrogen (94.5 percent) were lacking. The micronutrients zinc (25.15 percent), iron (49.09 percent), and boron (1.51%) all exhibited deficiencies. To keep the soil healthy, deficient minerals must be replenished with chemical fertilizers and/or organic manures. By using recommended amounts of organic manures and inorganic fertilizers in the areas of major and micronutrient deficiencies, the present state of the distribution of micronutrients in the soils of Satara district will be beneficial in suggesting efficient strategies and techniques of balanced nutrient application that will improve the yields.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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