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

ABSTRACT

Georeferenced surface soil samples from eleven tehsils in Satara district of Maharashtra were collected using Global Positing System (GPS) to study the variability in availability of major and micro nutrients.The stratified random sampling method was used to locate the sampling villages in each tehsils. The fertility maps were prepared using Geographical Information System for each nutrient. This 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.GPS based three hundred and thirty soil (330) samples at the depth of (0-20 cm) were collected from 11 tehsils across the Satara 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 Satara district varied from 6.00 to 9.43,0.10 to 0.98dS m^{-1},1.50 to 29.25 % and 0.72 to 7.80 g kg^{-1}respectively. Whereas available N,P,K and S in soils ranged from 63 to 539 Kg ha^{-1},6.67 to 42.41 Kg ha^{-1},158 to 1067 Kg ha^{-1} and 8.02 to 27.52 mg Kg^{-1} respectively. 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 low nutrient indices were found in respect to 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). The results obtained in the present study clearly showed a large variability in physio-chemical properties of soil across the Satara district. This information could aid in decision making for application of plant nutrients and selection of cropping sequence for higher monetary returns to the farmers and extension functionaries.

INTRODUCTION

Information technology has provided tools *viz.*Global Positioning System (GPS) which 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 of spatial variability and distribution of soil properties is critical for farmers attempting to increase nutrients use efficiency and crop productivity.

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 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 of soils and hence here is need to know the spatial variability of nutrients of the soil (Katkar*et al.*,2018).

Increasing population pressure and overexploitation of productive lands creates serious problem of lowering the fertility status of soil and it leads to deterioration of soil. The deficiency of nutrients directly effects on the growth of crops and crop response become poor (Jagtap *et al.,* 2018).Hencefor sustainability of the present agricultural system and for management of our 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 years.

Keeping this in view, the present investigation was undertaken to assess the status of major and micronutrients in soils and to identify and delineate areas of nutrient deficiencies in Satara 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, major and micronutrients status in soils of Satara district in the year 2022-2023.GPS based three hundred and thirty soil (330) samples at the depth of (0-20 cm)

were collected from 11 tehsils across the Satara district of Maharashtra at 5 kms grid were collected and analysed in the laboratory.

Description of the study area

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

Satara district of Maharashtra is situated between$17^0$50'to $18^0$11'North latitude and longitude of $73^0$33' to $74^0$54' East longitude. The total geographical area of the district is 10,48,000 ha and is divided into eleven tehsils (Phaltan,Khandala, Koregaon, Satara, Wadul, Dahiwadi, Wai, Mahabaleshwar, Medha, Patan, Karad).

The GPS data (Latitude, Longitude and Altitude) was recorded at each sampling site distributed over the entire district. Three hundred and thirty (330) 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 ,N,P,K,S and micronutrients (Zn, Fe, Cu, Mn and B).

Soil sampling and analysis

GPS based three hundred and thirty surface soil samples (0-20 cm) were collected from 11 tehsils across the Satara 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). Available N was estimated by alkaline permanganate method (Subbiah and Asija,1956), available P by Olsen's method (Watanabe and Olsen, 1965), available K by ammonium acetate extraction method (Jackson ,1967) and available S was estimated by turbidimetric method (Chesnin and Yien,1951). Soil samples were extracted with 0.005M diethylenetriamine pentaacetic 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).

Per cent samples low x 1+ per cent samples medium x 2

+ per cent sample high x3

Nutrient index = ……

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	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)

Chemical properties

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**

RESULTS AND DISCUSSION

Soil properties:

The pH of soils in Satara district was recorded slightly acidic to alkaline (6.00-9.43) (Table 2). The highest pH was observed in Medha tehsil (9.43) and lowest in Patan (6.00) with mean of 8.21. Maximum soil samples were found slightly to moderately alkaline in nature. All the soils were non-saline (0.10-0.98 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 0.72 to 7.80 g kg^{-1}.The highest organic carbon content found in Khandala tehsil (7.80) and lowest in Phaltan tehsil (0.72).Maximum soil samples were found low to medium organic carbon content. Calcium carbonate content in soils of the district varied from 1.50 to 29.25percent, which indicated, the soils are slightly 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 in Wai, Dahiwadi, Phaltan, Karad, Wai, Koregaon and Khandala tehsils.

Major nutrients status

Available nitrogen was noticed in range of 63 to 539 kg ha^{-1}, which showed wide spread deficiency and percent sample deficient is 94.5 (Table 3). The deficiency of available nitrogen might be due to very less addition of organic manures and heavy uptake under intensive cultivation of improved high yielding varieties of different crops. And the highest available nitrogen in the Satara tehsil (539) and lowest in wadul and Dahiwadi (63). Available P varied from very low to high (6.67 to 42.41 kg ha^{-1}) indicating 10.91 percent deficiency. The deficiency of available P ascribed to its fixation in the form of aluminum and iron phosphate due to slightly acidic nature of soil. The highest available phosphorus in koregaon tehsil(42.41) and lowest in Patan tehsil (6.67).The available K ranged from (158 to 1067) medium to very high and indicating 2.12 percent deficiency and highest in Satara tehsil (1067) and lowest in Phaltan tehsil (158).This could be attributed to more intense weathering ,release of liable K from organic residues, application of K fertilizers and upward translocation of K from lower depths along with capillary rise of ground water (Sharma and Anil Kumar , 2003).During post green revolution era , the available potassium was considered very high in many soils . The recent trends

indicated that slightly potassium deficiency occurred, showing response to its addition. The available Sulphur varied from low to high in the range from (8.02 to 27.52) and indicating very less 0.61 percent deficiency.The highest (27.52) and lowest (8.02) in Phaltan tehsil only. 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.

Micronutrients status

Data pertaining in (Table 4) to DTPA- Zn in soils of Satara district showed that DTPA- Zn of Satara district as a whole varied from 0.18 to 1.85 mg kg^{-1} the highest value in Satara tehsil (1.85) and lowest in Dahiwadi tehsil (0.18) and indicating 25.15 percent deficiency, whereas 61.82 percent samples of available Zn were noticed in medium category. The highest deficiency was showed in Dahiwadi followed by wadul. 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 (1.89 to 12.50 mg kg^{-1}) and highest in Satara tehsil (12.50) and lowest in Phaltan tehsil(1.89) and indicating 49.09 percent deficiency.

The DTPA -Cu in the soils of the study area ranged from (0.36 to 2.15) and highest in Wadul tehsil (2.15) and lowest in Karad tehsil (0.36) and indicating zero (0)deficiency. All the soils in Satara 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 (3.91 to 38.44) and highest range in Patan tehsil (38.44) and lowest range in Karad tehsil(3.91) and indicating zero (0) deficiency and all soils in the satara district were founded well sufficient in Mn- content.

$CaCl_2$ -B the available boron in soils of satara district ranged from(0.18 to 1.69 mg kg^{-1}) and highest range (1.69) and lowest (0.18) in Patan tehsil only and indicating 1.51 percentdeficiency.(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.

Nutrient indices

The nutrient indices indicated in (Table 5) across the Satara district ranged from 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. Fertility rating indicating in (Table 6) . Notably low fertility rating was recorded for N, Fe and high in K, Cu, Mn, B and for medium in P, S, Zn .In nutshell, overall fertility rating for nutrients in the soils of Satara district revealed low in N and Fe , marginal in P, S and Zn, high in K, Cu, Mn and B status . The area where the status of nutrients are 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 major nutrients,nitrogen (94.5 per cent) and phosphorous(10.91per cent) was found deficient. The micronutrients viz., zinc (25.15 percent),iron (49.09 per cent) and boron (1.51 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 Satara 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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Fig 1. Spatial variability of available Sulphur in soils of Satara district of Maharashtra

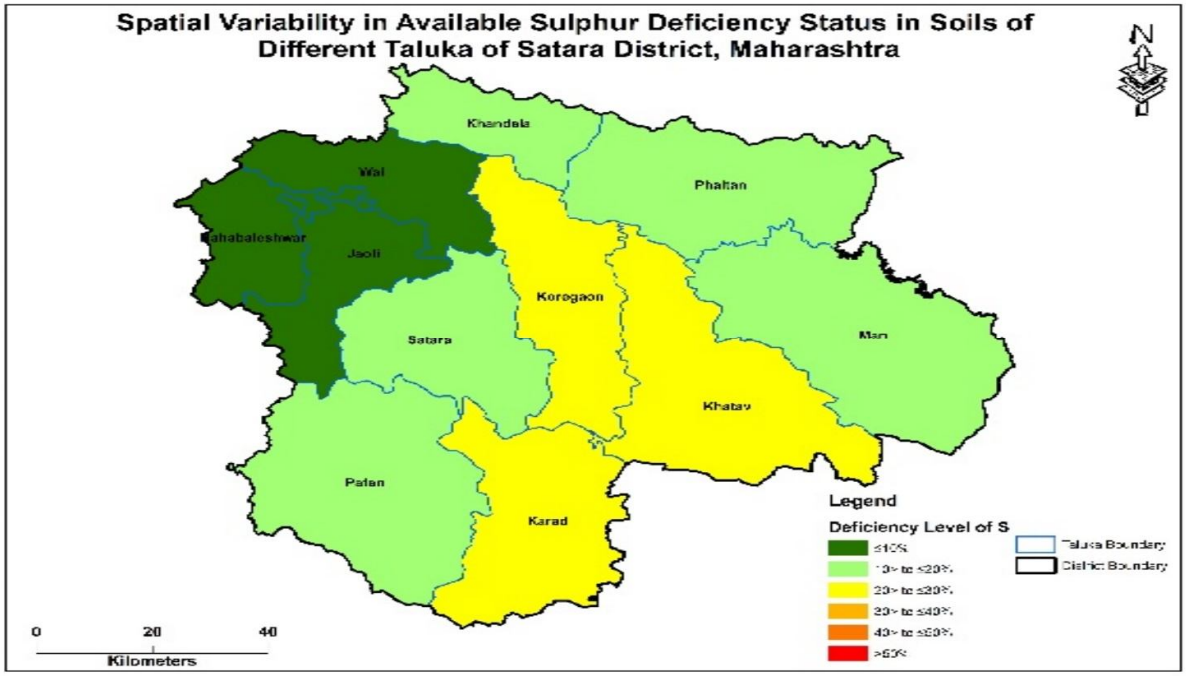


Fig 2. Spatial variability of available Zinc in soils of Satara district of Maharashtra

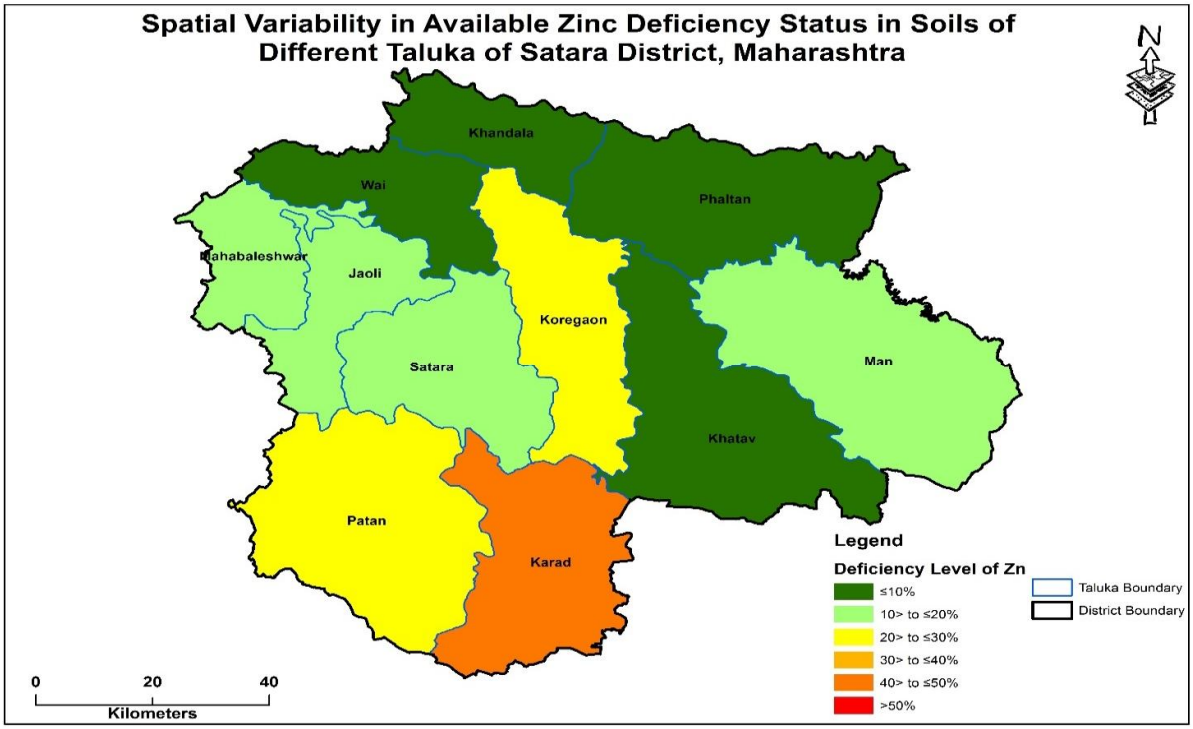


Fig 3. Spatial variability of available Fe in soils of Satara district of Maharashtra.

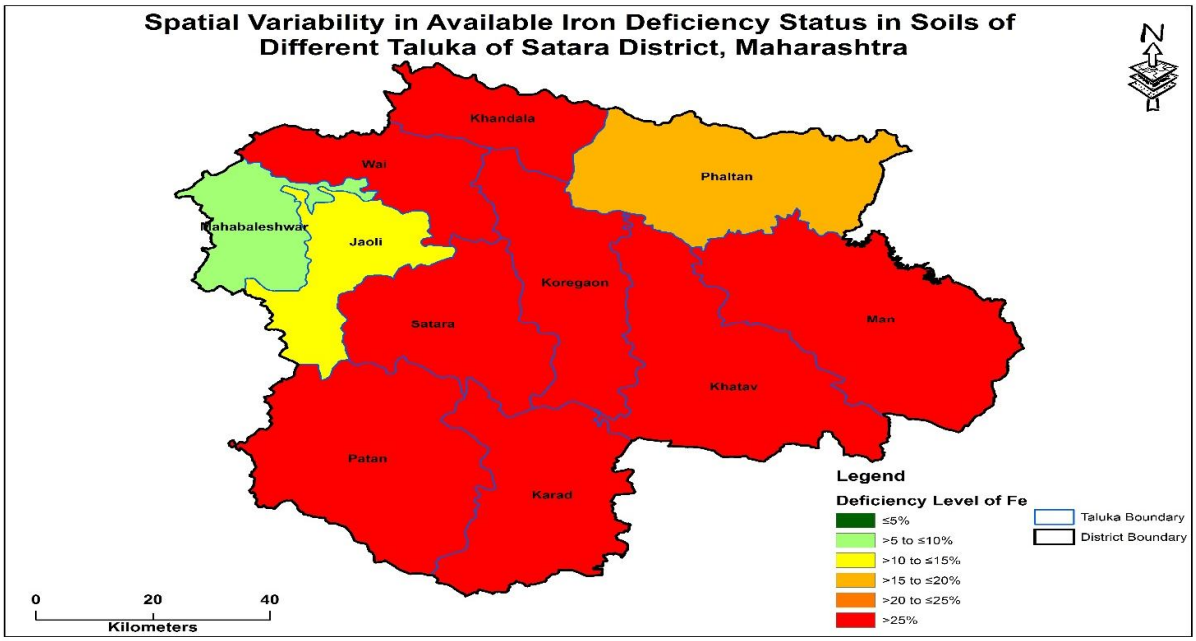


Fig.4. Spatial variability of available Cu in soils of Satara district of Maharashtra

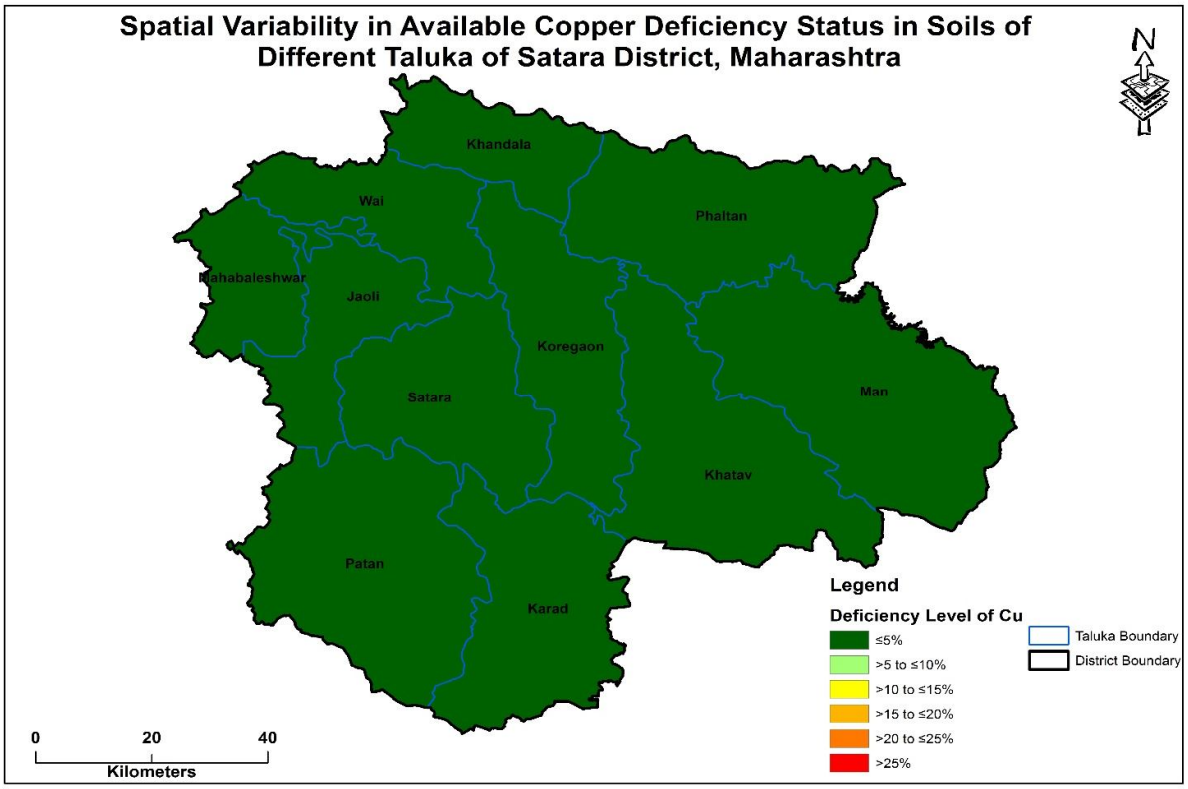


Fig.5. Spatial variability of available Mn in soils of Satara district of Maharashtra

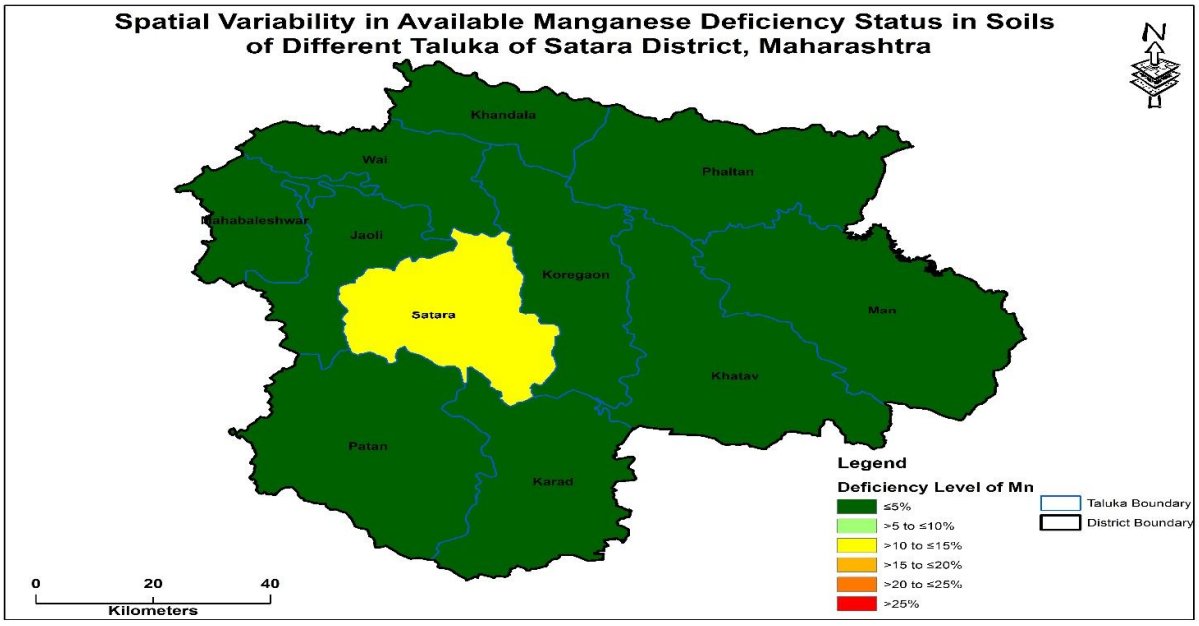
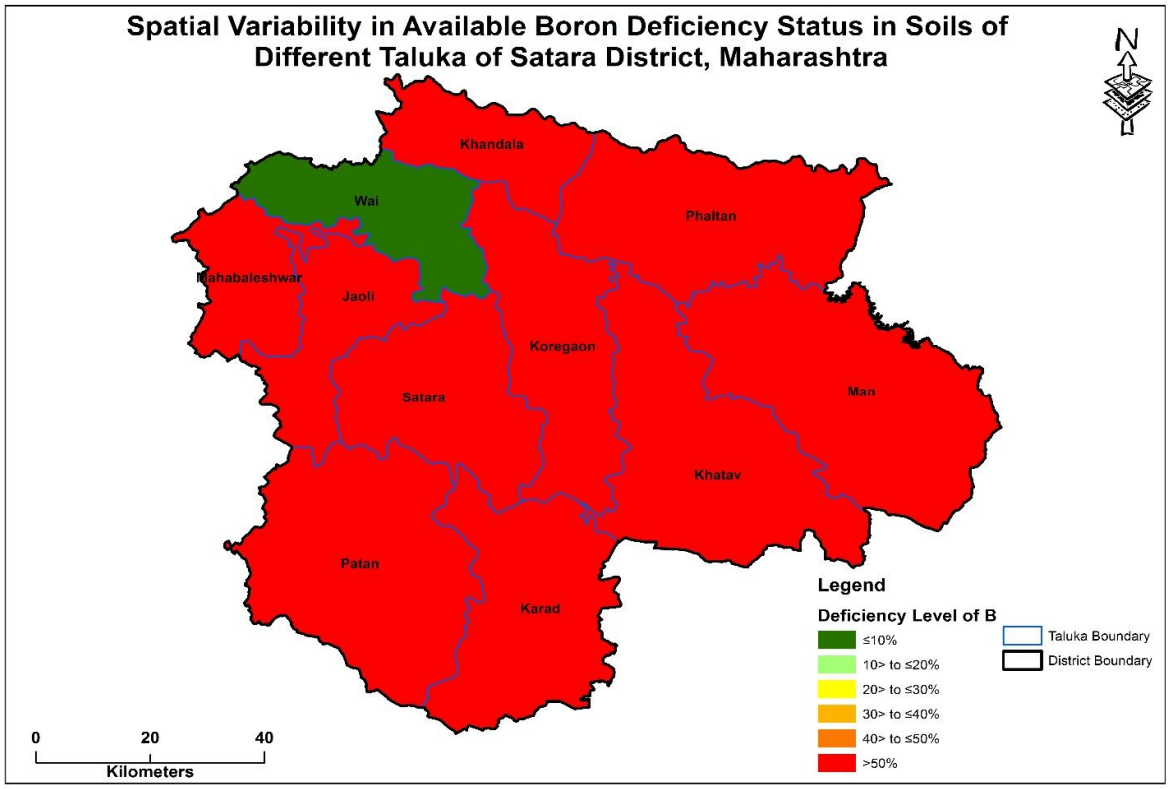


Fig.6. Spatial variability of available B in soils of Satara district of Maharashtra


Spatial Variability in Available Boron Deficiency Status in Soils of Different Taluka of Satara District, Maharashtra
N
Khandala
Wai
Phaltan
Mahabaleshwar
Jaoli
Koregaon
Satara
Man
Khatav
Patan
Karad
0
20
40
Kilometers
Legend
Deficiency Level of B
≤10%
10> to ≤20%
20> to ≤30%
30> to ≤40%
40> to ≤50%
>50%
Taluka Boundary
District Boundary