International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating: 5.29
IJABR 2025; 9(3): 280-284
www.biochemjournal.com
Received: 25-12-2024
Accepted: 29-01-2025

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Mapping the distribution of micro nutrients in soils of Washim district: A spatial analysis

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i3d.3932

Abstract
Soil nutrient mapping and analysis were conducted in the Washim district during 2023-2024 using grid sampling technique with grid of 5 km total 204 georeferenced surface soil samples (0-20) collected randomly with GPS assistance. The soil samples using GPS representing each square by dividing toposheet of district and from each square the representative soil sample was collected so that the sampling sites were well distributed in the district. The soil pH ranged from neutral to strongly alkaline (6.48-8.82), with Electrical conductivity (EC) values ranging from 0.12 to 0.98 dS m^{-1}. Organic carbon varying between 3.15 to 19.80 g kg^{-1}. Calcium carbonate of Washim district soils ranged from 1.13 to 22.63 percent which indicates that soil is non-calcareous to calcareous in nature. Available zinc content ranged from 0.28 to 2.65 mg kg^{-1}, the zinc deficiency was recorded to the extent of 43.63% in soils of Washim district. Available iron ranged from 3.28 to 30.08 mg kg^{-1}, the iron deficiency was recorded to the extent of 39.71% in soils of Washim district. Available copper content ranged from 1.12 to 15.55 mg kg^{-1}, copper deficiency was not recorded in soils of Washim district. Available manganese content ranged from 8.24 to 52.92 mg kg^{-1}, manganese deficiency was not recorded in soils of Washim district. Available Boron ranged from 0.01 to 7.88 mg kg^{-1}, the boron deficiency was recorded to the extent of 33.83% in soils of Washim district. Nutrient indices indicated medium range for available zinc (3.99), iron (4.02), boron (4.42). Nutrient indices indicated high range for copper (6.00) and manganese (5.99). Overall, the soil fertility in the Washim district is characterized by medium level of zinc, iron and boron along with high availability of copper and manganese.

Keywords: Micronutrients, GPS, nutrient indices, deficiency

1. Introduction
Soils are inherently heterogeneous, with dynamic properties that change over time and space due to various interacting factors (Ramzan *et al*., 2017) [1]. Soil fertility, a key determinant of crop productivity, is influenced by soil pH, organic matter, texture, and biological activity. Continuous nutrient depletion due to intensive cropping necessitates periodic soil fertility assessment. In India micronutrient deficiency in soil was reported by (Shukla *et al*., 2019) [2] according to results from the analysis of more than 2.0 lakh soil samples collected from 508 districts of the country, on average 36.5, 12.8, 7.1 and 4.2% of soils are deficient in Zn, Fe, Mn and Cu respectively. More than 50% of samples are found deficient in Zn in 110 districts of the country over the years, Zn deficiency has declined in soils of the country because of regular and more use of Zn fertilizer whereas deficiency of Fe and Mn increased slightly.
Most of the times soil sampling will be done without geographic reference. The results of such samples will be of little use and continuous monitoring of soil fertility status will be very difficult. Indian agriculture in recent years progressed dramatically owing to modernization, mechanization and use of advance technologies. Using these advance technologies like GIS, GPS and remote sensing can evaluate the spatial variability of soil fertility for precise nutrient management in a large area easily and effectively in very less time. Global Positioning System (GPS) helps in evaluating the soil fertility status of soil time to time and also helps in making critical decisions on nutrient management (Patil *et al.*, 2017) [3].
Unfortunately, due to intensive cultivation practices and inadequate use of chemical fertilizers, the fertility and productivity of agricultural soil are declining. Moreover, the heavy application of chemical fertilizers and their diminishing responses pose alarming

concerns. Therefore, it is imperative to enhance productivity without causing any hazardous effects on the soil, ensuring the maintenance of the resource base for future generations.
Recognizing these challenges, the present study was taken up with the objectives to assess the status of micronutrients in soils and to identify areas of micronutrient deficiencies in Washim district Maharashtra.

2. Materials and Methods

2.1 Study Area

The Washim district is located in the Western region of Vidarbha 20.1390° N, 77.1025° E. The district has a geographical area of 5150 sq. km. It is bounded on its North by Akola and Amaravati districts, Yavatmal district on its East and South, Hingoli district on South and Buldhana district on its West, it is on the Western end of the Vidarbha region. Washim was earlier a part of Akola till 1999. Washim district includes six talukas (tehsils) Malegaon, Washim, Risod, Manora, Mangrulpir, and Karanja. Total area covered by Washim district is 5150 km^2. The district forms part of Deccan Plateau with slope towards southeast from Sahyadri hills and has a varied topography consisting of hills, plains and undulating topography near riverbanks. The district forms a part of Godavari and Tapi basins. The Balaghat Plateau comprises of low-lying hills forming water divide. Many of the tributaries to Godavari and Tapi rivers originate from the Balaghat Plateau. Penganga River is the main river flowing through the district.
The soil of the district is basically derived from Deccan Trap Basalt and major part of the district is occupied by medium black soil of 25-50 cm depth occurring in the plains in entire south western, north eastern and northern parts of the district, whereas the shallow black soil of 7.5 to 25 cm depth occurs in restricted hilly parts of the district in central elongated part and the northern peripheral part. Four soil series Mangrulpir, Vaijapur, Wardha and Bahadura have been identified in the district. The district comprises of 43.6% shallow, 9.93% medium black and 46.4% black soils.
The climate of the district is characterized by a hot summer and general dryness throughout the year except during the South-West monsoon season, i.e. June to September. The mean minimum temperature is 12 °C and mean maximum temperature is 42 °C. The normal annual rainfall over the district varies from 872 mm (Risod) to about 966 mm (Washim). The average annual rainfall for the period 2002-2011 ranges from 788.39 mm (Manora) to 1124.75 mm (Washim). The grid survey of district was carried out, the soil samples from dominant cropping system in the summer season Random surface soil samples representing different soils were collected from six tehsil of Washim district. With the grid sampling method about 5 km range or distance from previous sample. From each taluka minimum of 30-35 surface soil samples (0-20 cm) total 204 samples in Washim district were collected. The record of surveyed fields latitude, longitude using GPS with mean sea level was maintained. Soil pH and EC were determined in soil: water suspensions (1:2.5 w/v) as described by Jackson (1973) [4]. Organic carbon was determined by Walkley and Black wet-oxidation method as given by Walkley and Black (1934) [5]. Free $CaCO_3$ was determined by rapid titration method (Piper, 1966) [6]. The available zinc, iron, copper and manganese were extracted with 0.005M diethylene triamine penta acetic acid (DTPA) and the concentrations of nutrients were determined on Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978) [7]. The nutrient indices were calculated by using the formula given by Parker *et al.* (1951) [8] and Hadole *et al* (2024) [9]. Formula for Nutrient Index:

$$\text{Nutrient index} = \frac{\text{\% samples acute x 1 + \% samples deficient x 2 + \% samples latent x 3 + \% samples marginal sufficient x 4 + \% samples adequate x 5 + \% samples high x 6}}{100}$$

3. Results and Discussion

3.1 Soil properties

The soil pH for Washim district, showing values ranging from 6.48 to 8.82 (Table 2) indicated a pH range from neutral to strongly alkaline. The highest pH of 8.29 was observed in soils of Karanja tehsil, while the lowest pH of 7.82 was recorded in Malegaon tehsil. The alkaline nature of the soil is likely attributed to the presence of adequate free lime content in the soil Priyanka *et al.* (2018) [10]. Soil electrical conductivity (EC) values ranging from 0.09 to 0.88 dS m^{-1} (Table 2), it shows that the soils in Washim district are predominantly non-saline, making them favourable for healthy plant growth. EC exceeding 1.0 dS m^{-1} indicates the presence of soluble salts, posing a risk to plant cultivation, Jackson (1967) [11]. The calcium carbonate content ($CaCO_3$) ranges from 1.13 to 22.63 percent (Table 2), which indicates that soil is non-calcareous to calcareous in nature. The highest content of calcium carbonate was recorded in Mangrulpir tehsil. High levels of $CaCO_3$ in soil can raise pH levels and lower the solubility of soil micronutrients, leading to nutritional and metabolic disorders in plants. These results are in accordance with the results reported by Katkar *et al.* (2013) [12]. Organic carbon content varied from 3.15 to 19.80 g kg^{-1} (Table 2). The organic carbon variation could be noticed in every tehsil with highest content observed in Risod tehsil, Malegaon tehsil and Karanja tehsil.

3.2 Status of micronutrient

All available micronutrient can be categories into acute deficient, deficient, latent deficient, marginal sufficient, adequate, high, categories.
The available zinc in all over Washim district ranged from 0.28 to 2.65 mg kg^{-1} with a mean of 1.11 mg kg^{-1} (Table 3). Shows the moderate available zinc content in soils of Washim and major soil samples were found in latent (24.51%) category of available zinc followed by adequate (22.55%), high (19.61%), deficient (18.63%) and marginal sufficient (14.22) category. while acute deficiency was observed in only one sample from Washim tehsil. The zinc deficiency was recorded to the extent of 43.63 % in soils of Washim district. The nutrient index value (Table 3) across the district was found in medium range i.e. (3.99). The highest nutrient index value was recorded in Malegaon tehsil at 5.73, followed by Manora and Karanja tehsil (4.45) and (4.20), respectively. Similar results reported by Surwase *et al.* (2016) [13] soil micronutrients status in Kalmeshwar tehsil, district Nagpur observed that, the DTPA-Zn was in the range of 0.62-1.14 mg kg^{-1}. The available iron in all over Washim district ranged from 3.28 to 30.08 mg kg^{-1} with a mean of 8.25 mg kg^{-1} (Table 4) shows that Washim district had moderate available iron contains in soils. Soil samples from all tehsils, including Washim, Mangrulpir, Manora, Karanja, Malegaon, and Risod, were found to be in the latent deficient (26.47%) category of available iron, followed by marginal sufficient (25.98%) and high

(20.59%) categories. In the adequate and deficient categories, some samples were found at 13.73% and 13.24%, respectively. No soil samples were found in the acute deficient category. Iron deficiency was recorded to the extent of 39.71% in the soils of Washim district. The nutrient index value (Table 4) across the district was found to be in the medium range, that is (4.02). The highest nutrient index was recorded in Manora tehsil at (4.66), followed by Malegaon and Risod tehsils with values of (4.65) and (4.48), respectively. The lowest nutrient index value was observed in Washim tehsil, at (3.03). Mahashabde and Patel (2012) reported that available Fe range from 9.5-14.8 mg kg^{-1} from Shirpur tehsil region. The available copper in all over Washim district ranged from 1.12 to 15.55 mg kg^{-1} with a mean of 2.90 mg kg^{-1} (Table 5) showed that Washim district had very high available copper contains in soils. Soil samples from all tehsils, including Washim, Mangrulpir, Manora, Karanja, Malegaon, and Risod, were found in the high (100%) category of available copper. No acute deficiency was observed in any tehsils of Washim district. The copper deficiency was recorded to the extent of 0% in soils of Washim district. The nutrient index value (Table 5) in all over the district was found in high range *i.e.* (6.00). Magare *et al*. (2022) [15] studied that available Copper content in soils of Amravati district varies from 0.78 to 5.42 with a mean value of 3.37 mg kg^{-1}. The available manganese in all over Washim district ranged from 8.24 to 52.92 mg kg^{-1} with mean of 23.14 mg kg^{-1} (Table 6) shows that Washim district had very high available manganese contains in soils. In all tehsil most of the soil samples were found in high (97.06%) category of available manganese followed by only six sample found in adequate category (2.94%). The manganese deficiency was recorded to the extent of 0% in soils of Washim district. The nutrient index value (Table 6) in all over the district was found in high range *i.e.* (5.97). Magare *et al*. (2022) [15] studied that available Mn content in soils of Amravati district ranged from 5.68 to 35.41 with mean value of 16.21 mg kg^{-1}. The available boron in all over Washim district ranged from 0.01 to 7.88 mg kg^{-1} with mean of 1.86 mg kg^{-1} (Table 7) shows that Washim district had moderate available boron contains in soils. In all tehsils most of the soil sample were found in High (56.37%) category of available boron followed by Acute category (14.22%), Acute deficiency of available boron was observed in Manora, Karanja, Malegaon tehsil such as (17.24%), (28.57%), (37.84%), respectively. The boron deficiency was recorded to the extent of 33.83% in soils of Washim district. The nutrient index value (Table 7) in all over the district was found in high range *i.e.* (4.42). Highest nutrient index was found in Risod tehsil (6.00) followed by Mangrulpir, Washim, Manora tehsil (5.97), (5.57) and (4.21).

Table 1: Categories of micronutrients

Categories / Nutrient	Acute Deficient	Deficient	Latent Deficient	Marginal Sufficient	Adequate	High
N (kg ha^{-1})	< 130	130-250	250-370	370-510	510-650	>650
P (kg ha^{-1})	< 10	10-20	20-30	30-40	40-50	>50
K (kg ha^{-1})	< 90	90-130	130-180	180-250	250-350	>350
S (mg kg^{-1})	< 7.50	7.50-15.0	15.10-22.50	22.50-30.00	30.00-40.00	>40.00
B (mg kg^{-1})	<0.20	0.20-0.50	0.50-0.70	0.70-0.90	0.90-1.10	>1.10
Zn (mg kg^{-1})	<0.30	0.31-0.60	0.61-0.90	0.91-1.2	1.21-1.80	>1.80
Fe (mg kg^{-1})	<2.50	2.50-4.50	4.51-6.50	6.51-8.50	8.51-10.50	>10.50
Cu (mg kg^{-1})	<0.20	0.20-0.40	0.41-0.60	0.61-0.80	0.81-1.0	>1.00
Mn (mg kg^{-1})	<1.0	1.10-3.0	3.10-5.0	5.0-7.0	7.10-9.0	>9.00
Categories of Nutrient Index Value (NIV).						
NIV INDEX	LOW		MEDIUM		HIGH	
	<3.34		3.34-4.66		>4.66	

Table 2: Chemical properties of soil in Washim district.

S. N	Tehsil	pH (1:2.5)		EC (dS m^{-1})		$CaCO_3$ (%)		Org. carbon (g kg^{-1})	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Mangrulpir	6.48-8.38	7.91	0.11-0.88	0.23	2.00-15.88	8.39	3.95-12.15	6.50
2	Manora	7.63-8.39	8.08	0.11-0.42	0.18	2.88-21.75	8.02	3.20-8.22	5.89
3	Karanja	7.17-8.80	8.29	0.13-0.67	0.17	2.75-17.13	6.61	4.87-14.01	8.15
4	Malegaon	6.79-8.78	7.82	0.13-0.77	0.26	1.13-15.38	5.38	5.68-15.29	8.84
5	Risod	7.1-8.76	8.05	0.09-0.30	0.17	2.38-22.63	7.66	3.15-19.8	9.48
6	Washim	6.81-8.82	8.10	0.1-0.37	0.16	3.50-17.00	6.84	4.54-11.71	7.55
	District	6.48-8.82	8.04	0.09-0.88	0.20	1.13-22.63	7.09	3.15-19.80	7.78

Table 3: Tehsil wise status and Nutrient indices of available Zn in soils of Washim district

Tehsils	Range (mg kg^{-1})	Mean	No. of samples						NIV
			Acu.	Def.	Lat.	Mar. Suf.	Ade.	High	
Mangrulpir	0.40-1.82	0.99	0	4 (11.43)	13 (37.14)	10 (28.57)	7 (20.00)	1 (2.86)	3.66
Manora	0.46-2.20	1.13	0	3 (10.34)	6 (20.69)	5 (17.24)	5 (17.24)	10 (34.48)	4.45
Karanja	0.58-2.12	1.25	0	2 (5.71)	10 (28.57)	4 (11.43)	17 (48.57)	2 (5.71)	4.20
Malegaon	1.31-2.65	1.87	0	0	0	0	10 (27.03)	27 (72.97)	5.73
Risod	0.34-1.68	0.77	0	12 (36.36)	11 (33.33)	6 (18.18)	4 (12.12)	0	3.06
Washim	0.28-1.74	0.67	1 (2.86)	17 (48.57)	10 (28.57)	4 (11.43)	3 (8.57)	0	2.74
District	0.28-2.65	1.11	1 (0.49)	38 (18.63)	50 (24.51)	29 (14.22)	46 (22.55)	40 (19.61)	3.99

(Figures in parenthesis are percentage)

Table 4: Tehsil wise status and Nutrient Indices of available Fe in soils of Washim district

Tehsils	Range (mg kg^{-1})	Mean	No. of samples						NIV
			Acu	Def.	Lat.	Mar. Suf.	Ade.	High	
Mangrulpir	3.28-17.75	7.14	0	5 (14.29)	9 (25.71)	10 (28.57)	7 (20.00)	4 (11.43)	3.89
Manora	5.34-13.28	8.56	0	0.00	6 (20.69)	9 (31.03)	3 (10.34)	11 (37.93)	4.66
Karanja	3.83-9.89	6.40	0	3 (8.57)	17 (48.57)	9 (25.71)	6 (17.14)	0.00	3.51
Malegaon	3.53-19.54	9.82	0	1 (2.70)	9 (24.32)	6 (16.22)	7 (18.92)	14 (37.84)	4.65
Risod	5.32-30.08	10.36	0	0.00	5 (15.15)	16 (48.48)	3 (9.09)	9 (27.27)	4.48
Washim	4.82-18.18	7.66	0	18 (51.43)	8 (22.86)	3 (8.57)	2 (5.71)	4 (11.43)	3.03
District	3.28-30.08	8.25	0	27 (13.24)	54 (26.47)	53 (25.98)	28 (13.73)	42 (20.59)	4.02

(Figures in parenthesis are percentage)

Table 5: Tehsil wise status and Nutrient Indices of available Cu in soils of Washim district

Tehsils	Range (mg kg^{-1})	Mean	No. of samples						NIV
			Acu	Def.	Lat.	Mar. Suf.	Ade.	High	
Mangrulpir	1.39-5.53	2.81	0	0	0	0	0	35 (100)	6.00
Manora	1.78-15.55	3.34	0	0	0	0	0	29 (100)	6.00
Karanja	1.83-4.02	2.86	0	0	0	0	0	35 (100)	6.00
Malegaon	1.70-9.05	3.45	0	0	0	0	0	37 (100)	6.00
Risod	1.37-8.13	3.20	0	0	0	0	0	33 (100)	6.00
Washim	1.12-4.95	1.87	0	0	0	0	0	35 (100)	6.00
District	1.12-15.55	2.90	0	0	0	0	0	204 (100)	6.00

(Figures in parenthesis are percentage)

Table 6: Tehsil wise status and Nutrient Indices of available Mn in soils of Washim district

Tehsils	Range (mg kg^{-1})	Mean	No. of samples						NIV
			Acu	Def.	Lat.	Mar. Suf.	Ade.	High	
Mangrulpir	8.24-25.66	13.85	0	0	0	0	6 (17.14)	29 (82.86)	5.83
Manora	10.66-30.44	18.59	0	0	0	0	0	29 (100)	6.00
Karanja	15.98-44.24	29.28	0	0	0	0	0	35 (100)	6.00
Malegaon	11.47-47.40	27.07	0	0	0	0	0	37 (100)	6.00
Risod	11.95-52.92	25.71	0	0	0	0	0	33 (100)	6.00
Washim	9.97-51.12	23.65	0	0	0	0	0	35 (100)	6.00
District	8.24-52.92	23.14	0	0	0	0	6 (2.94)	198 (97.06)	5.97

(Figures in parenthesis are percentage)

Table 7: Tehsil wise status and Nutrient Indices of available B in soils of Washim district

Tehsils	Range (mg kg^{-1})	Mean	No. of samples						NIV
			Acu	Def.	Lat.	Mar. Suf.	Ade.	High	
Mangrulpir	1.00-6.30	2.58	0	0	0	0	1 (2.86)	34 (97.14)	5.97
Manora	0.04-6.44	1.62	5 (17.24)	5 (17.24)	2 (6.90)	0	1 (3.45)	16 (55.17)	4.21
Karanja	0.03-1.59	0.53	10 (28.57)	9 (25.71)	7 (20.00)	3 (8.57)	2 (5.71)	4 (11.43)	2.71
Malegaon	0.01-5.16	0.60	14 (37.84)	14 (37.84)	2 (5.41)	4 (10.81)	0	3 (8.11)	2.22
Risod	2.41-7.88	4.15	0	0	0	0	0	33 (100)	6.00
Washim	0.61-5.60	1.83	0	0	1 (2.86)	3 (8.57)	6 (17.14)	25 (71.43)	5.57
District	0.01-7.88	1.86	29 (14.22)	28 (13.73)	12 (5.88)	10 (4.90)	10 (4.90)	115 (56.37)	4.42

(Figures in parenthesis are percentage)

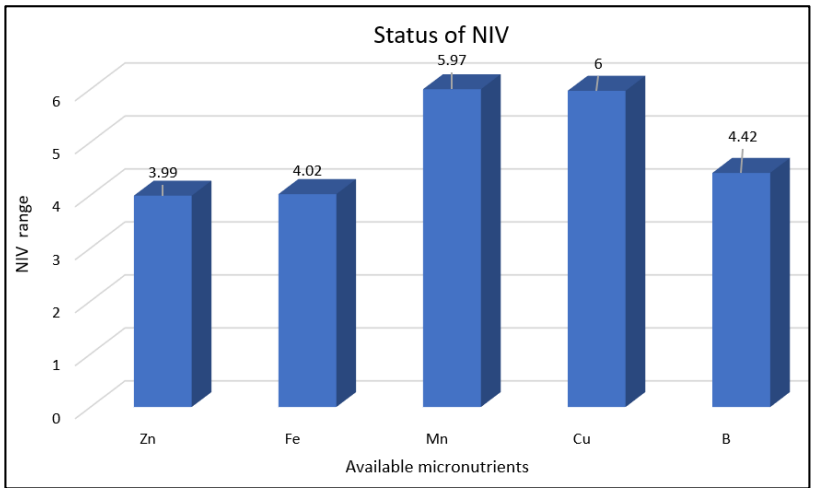

Fig 1: Status of nutrient index values in Washim district

4. Conclusion

The available zinc content in the soils of Washim district ranged between 0.28 to 2.65 mg kg^{-1}. Zinc deficiency was found 43.63% in the soils, with acute deficiency being notably common. The nutrient index value was classified as medium (3.99). The available iron content in the soils of Washim district ranged from 3.28 to 30.08 mg kg^{-1}. Iron deficiency was observed 39.71% in the soils, although acute deficiency was not detected. The nutrient index value was classified as medium (4.02). The available copper content in the soils of Washim district ranged from 1.12 to 15.55 mg kg^{-1}. The copper deficiency was not recorded in the soils of Washim district. The nutrient index value was classified as high (6.00). The available manganese content in the soils of Washim district ranged from 8.24 to 52.92 mg kg^{-1}. Manganese deficiency was not observed in the soils of Washim district. The nutrient index value was classified as high (5.97). The available boron content in the soils of Washim district varied from 0.01 to 7.88 mg kg^{-1}. Boron deficiency was observed 33.83% in the soils of Washim district. The nutrient index value was classified as medium (4.42).

5. Acknowledgement

I wish to express my profound sense of gratitude and sincere thanks to Head department of soil science Dr. Panjabaro Deshmukh Krishi Vidyapeeth Akola and project coordinate and All India Coordinated Research Project of Micro and Secondary Nutrients and Pollutant Elements, for providing facilities during the course of investigation Dr, PDKV Akola.

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