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Micronutrient status of salt affected soils of Siruguppa taluk in TBP irrigation command area

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Abstract
A study was conducted to assess available micro-nutrient (Fe, Mn, Cu and Zn) status and their relationship with soil properties of Siruguppa taluk in Bellary district by the aid of GPS and toposheet (1:50000 scale). A total of 78 soil samples (0-15 and 15-30 cm) collected during summer 2017 on a grid basis (5' x 5') from 20 grids (39 sampling points) were analysed for micro-nutrient status and mapped by geographic information system (GIS) technique. Majority of samples had DTPA-Zn (53.85 to 97.43%) in low category (< 1 ppm) and Cu (66.67 to 97.43%) in medium category (0.5 to 2.5 ppm) at surface and subsurface soils respectively. The maximum per cent of surface samples had DTPA-Fe (61.54) and Mn (89.74) in medium category while 74.36 and 56.41% of subsurface samples were in low category respectively. In general, DTPA extractable Zn, Fe, Mn and Cu had negative correlation with soil pH and positive correlation with organic carbon.

Keywords: DTPA-extractable micro-nutrient, Distribution map, Salt affected soils

Introduction
Salt affected areas are one of the most important degraded areas where soil productivity is reduced due to either salinization (EC> 4 dS m^{-1}) or sodicity (ESP > 15) or both. All soils contain some soluble salts, which is indeed essential for the healthy growth of plants. Many of these act as a source of essential nutrients. However, when quantity of salts in active root zone exceeds threshold limit the growth, yield and quality of most crops are adversely affected. Soil that contains excess salts which impair its productivity is called salt-affected soil. Salt affected soils usually occur in association with their normal counterparts, but distinguish themselves in having higher concentration of electrolytes and/or higher content of exchangeable sodium (Szaboles, 1989) [18].
Soil salinity and water logging are the twin problems of Tungabhadra Project (TBP) command due to unscientific land and water management and violation of cropping pattern over the decades. Nearly 96,215 ha accounting about 26.5 per cent (3.63 lakh ha) of the total area in the command is reported to be salt affected (Anonymous, 2012) [1] and about 1000 ha area is being added every year (IDNP, 2002) [2]. As reported by (Rashid *et al*., 2004) [10] even though micronutrients are required in relatively smaller quantities for plant growth, they are as important as macronutrient in rice production to obtain optimum yield and balanced nutrition. Most micronutrients are usually poorly available in salt affected soils, a fact which is generally attributed to the high soil pH (Naidu and Rengasamy, 1993) [6] and salt stress. Generally, the solubility of cationic trace elements decreases as pH increases, while the solubility of the anionic trace elements increases as the pH increases (Ilyas *et al*., 2007) [3]. Therefore, micronutrients such as copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) exhibit low levels of solubility in sodic soils, which may result in micronutrient deficiencies (Page *et al*., 1990) [7]. It is reported that presence of major nutrients affect crop uptake of micronutrient due to either negative or positive interactions (Kumar and Babel, 2011) [4].
Information on the characterization of salt affected soils through ground truth in the command is meagre or lacking and particularly no such information on micronutrient status and their distribution maps are available for soils of Siruguppa taluk, Bellary district, Karnataka. Hence, in view of the above the present study was undertaken.

Material and Methods

Study Area

The Tungabhadra irrigation command area in Karnataka meets irrigation requirements of crops in Bellary, Koppal and parts of Raichur districts. The study area *i.e.,* Siruguppa taluk in Bellary district is located at 15°37'30.22" N 76°53'42.78"E with an average elevation of 373 m (1223 ft) and geographical area of 1042 km^2 (Fig. 1). The major soils occurring in these are medium deep, red gravelly clay soils, deep black clayey soils and to some extent deep black calcareous clayey soils and deep alluvial clayey soils. The average annual rainfall of Siruguppa taluk is 645.00 mm. The major crops grown in these taluks include paddy, jowar, maize, cotton, sugarcane etc. Soil saturation paste method of analysis revealed that about 53.8 and 69.2 and 28.3 and 7.70 per cent of surface and sub-surface samples in Siruguppa taluk were reported to have pHe in the range of 7.5-8.5 and ECe >4 dS m^{-1} respectively. And about 66.7 and 15.4 per cent of surface and sub-surface samples reported to contain organic carbon >0.75 per cent (Shridhar, 2018) [15].

Collection of soil samples and mapping of salt affected soils

A total of 78 soil samples (0-15 and 15-30 cm) collected during May 2017 on a grid basis (5' x 5') from 20 grids (39 sampling points) were analysed for micro-nutrient status and mapped by geographic information system (GIS) technique. The collected soil samples were air dried under shade, powdered with a pestle and mortar, sieved through 2 mm sieve and stored in polythene bags until further analysis. The DTPA-extractable Fe, Mn, Cu and Zn content of these samples were determined by Atomic Absorption Spectrophotometer (AAS).

The analyzed soil samples were then interpolated for mapping of DTPA-extractable micronutrients by using Arc GIS Ver., 10.4 as per procedure detailed below:

Rectification of shape files of TBP command area

↓

Kriging according to the selected area

↓

Collecting information corresponding to the selected points

↓

Symbology according to mapping unit

↓

Descriptive analysis, area, map data and map layout

During the interpolation of the data in Arc. GIS, the values having marginal differences among the classes are either considered in the previous and/or next classes based on the lower frequency of occurrence.

Statistical analysis

Correlation coefficients (r) of DTPA-Zn, Fe, Mn and Cu with basic soil properties were worked out by following procedure as outlined by Snedecor and Cochran (1980) [16].

Karl Pearson correlation coefficient (product moment correlation coefficient)

$$r = \frac{\Sigma xy - n\bar{x}\bar{y}}{\sqrt{(\Sigma x^2 - n\bar{x}^2)\,(\Sigma y^2 - n\bar{y}^2)}}$$

Where,

r = correlation coefficient

x and y are variables

n = no. of observations in x and y

The 'r' value indicates degree of association between two variables. If 'r' value is positive, two variables are positively correlated and it is negative, then two variables are negatively correlated.

The significant of correlation coefficient was tested by t test. If $t_{table} < t_{calculated}$ value then 'r' is significant and if $t_{table} > t_{calculated}$ then it is non-significant.

$$t_{calculated}\ (|t|) = \frac{r}{\sqrt{(1-r^2)/(n-2)}}.$$

Results and Discussion

DTPA-extractable Fe, Mn, Zn and Cu contents, per cent distribution and their correlation with basic soil properties

DTPA- Fe

The DTPA extractable Fe content in surface soil (0-15 cm) varied from 0.75 to 17.29 ppm with a mean value of 5.13 ppm. At sub-surface (15-30 cm), it varied from 0.73 to 9.20 ppm with a mean value of 2.29 ppm. The mean DTPA extractable Fe content was higher in surface samples compared to sub-surface samples. Higher content of DTPA-Fe in surface soil might be due to accumulation of humic material in the surface soils besides prevalence of reduced condition in subsurface soils (Table 1). The maximum per cent of surface (61.54) and sub-surface (74.36) soil samples had DTPA-Fe in medium (2.5-10 ppm) and low category (<2.5 ppm) respectively, as per soil test fertility ratings (Tandon, 2017) [19] (Table 2) and the distribution of DTPA-Fe concentration in surface and sub-surface soils of Siruguppa taluk is depicted in Fig. 2a and 3a.

In salt affected soils of Nellore and Gudur divisions of Nellore district Andhra Pradesh, (Priyadarshini, 2011) [8] reported that the DTPA extractable iron content of surface soil samples varied from 0.6 to 140.7 ppm with a mean value of 31.0 ppm whereas in sub-surface samples it ranged from 0.8 to 149.2 ppm with a mean value of 24.4 ppm. About 100 per cent of surface and sub-surface samples were found to be above the critical limit (4.5 ppm) as per the ratings of (Lindsay and Norvell, 1978) [5]. Similarly, higher DTPA-Fe content in surface compared to subsurface soils was reported by (Suribabu *et al*., 2002) [17] and (Sharma *et al*., 2003) [14].

DTPA-Fe had significant and negative correlation with pHe ($r= -0.410^{**}$ and -0.347^{*}), but significant and positive correlation with organic carbon (r= 0.401* and 0.497**) at 0-15 and 15-30 cm respectively (Table 3). Higher pH is responsible for iron oxidation. The most readily available form of iron i.e., Fe^{2+} ions convert into less soluble form (Fe^{3+} ions) after oxidation and precipitate as insoluble $Fe(OH)_3$ which reduces its availability. Since, organic carbon acts as a store house of nutrients and chelating agent could increase the solubility and availability of iron.

(Sair Sarwar *et al*., 2007) [13] and (Vijay Kumar, 2009) [21] and (Priyadarhini, 2011) [8] studied correlation of micro nutrients with physicochemical properties of soil of district Paladin, Azad Kashmir, salt affected soils of Ongole division, Prakasam district and Nellore and Gudur divisions of Nellore district in Andhra Pradesh respectively. In general they revealed that the pH was negatively correlated with all micronutrient (Cu, Fe, Mn, Zn) while organic matter was positively correlated with Zn, Fe and Mn. Similar results were also observed by (Yeresheemi *et al.*, 1997) [23] for salt affected Vertisols of Upper Krishna Command, Karnataka .

DTPA- Mn

The DTPA extractable Mn content in surface soil (0-15 cm) varied from 4.66 to 31.08 ppm with a mean value of 11.33 ppm. At sub-surface (15-30 cm) soil it varied from 2.91 to 10.59 ppm with a mean of 5.15 ppm. The mean DTPA extractable Mn content was higher in surface samples compared to sub-surface samples (Table 1) in Siruguppa taluk. The maximum per cent of surface (89.74) and sub-surface (56.41) samples had DTPA-Mn content in medium (5-25 ppm) and low (<5 ppm) category respectively (Table 2) and the distribution of DTPA-Mn concentration in surface and sub-surface soils of Siruguppa taluk is depicted in Fig. 2b and 3b. Under irrigated cropping system, heavy nature of these soils (Sharma *et al*., 2003) [14] and granite gneiss parent material (Rajkumar, 1994) [9] might have contributed for the accumulation of reducible and soluble forms of manganese in the surface layers.

(Vijay Kumar, 2009) [21] reported that the average available manganese content of surface of soil was slightly higher (11.94 ppm) compared to sub-surface soil (10.99 ppm) respectively with a range of 1.46 to 48.25 ppm and 2.04 to 37.25 ppm respectively. Similarly, (Priyadarshini, 2011) [8] reported that the DTPA-Mn content of sub-surface soil was higher (11.5 ppm) compared to surface soil (9.1 ppm).

Similar to Fe, DTPA-Mn had significant and negative correlation with pHe (r= -0.496**) but significant and positive correlation with ECe (r= 0.428**) similar results were also observed by (Verma *et al*., 2005) [20], OC (r= 0.401*) and DTPA-Fe (r= 0.623**) at surface (0-15 cm) soil. At subsurface (15-30 cm) soil, DTPA-Mn had significant and positive correlation with DTPA-Fe (r= 0.358*) only (Table 3).Similar to Fe, increase in pH, convert divalent form of Mn i.e., Mn^{2+} into tri or tetra valent forms (Mn^{3+} and Mn^{4+}), which are water insoluble and hence not readily available to plants.

DTPA-Cu

The DTPA extractable Cu content in surface soil (0-15 cm) varied from 1.03 to 5.40 ppm with a mean value of 2.43 ppm. At sub-surface (15-30 cm) varied from 0.62 to 2.79 ppm with a mean value of 1.22 ppm. The mean DTPA extractable Cu contents were higher in surface samples compared to sub-surface samples (Table 1). The maximum per cent of surface (66.67) and sub-surface (97.43) samples had DTPA-Cu content in medium category (0.5-2.5), as per soil test fertility ratings (Tandon, 2017) [19] (Table 2) and the distribution of DTPA-Cu concentration in surface and sub-surface soils of Siruguppa taluk is depicted in Fig. 2c and 3c. Higher organic carbon content and consistent use of Cu based fungicide in control of paddy diseases could have resulted in sufficient or more than sufficient Cu content particularly in surface soils.

(Vijay Kumar, 2009) [21] reported that the average DTPA-Cu content of surface of soil was slightly higher (1.87 ppm) compared to sub-surface soil (1.78 ppm) respectively with a range of 0.22 to 8.10 and 0.24 to 6.54 ppm respectively. Similar to DTPA-Mn, (Priyadarshini, 2011) [8] reported that the DTPA-Cu content of sub-surface soil had higher (1.7 ppm) content compared to surface soil (1.3 ppm).

DTPA-Cu had significant and positive correlation with organic carbon (r= 0.380*) and DTPA-Fe (r= 0.388*) in surface soil only (Table 3). The organic matter may increase the availability copper in the soil due to formation of soluble complexing agents which may decrease fixation of copper in the soil. The results are in agreement with the findings of (Vijay Kumar, 2009) [21] who also reported significant positive correlation of DTPA-Cu with Mn (r= 0.3947**), Fe (r= 0.3542**) and Zn (r= 0.2293*).

DTPA-Zn

The DTPA extractable Zn content in surface soil (0-15 cm) varied from 0.11 to 6.26 ppm with a mean value of 1.23 ppm. At sub-surface (15-30 cm) varied from 0.05 to 1.04 ppm with a mean value of 0.30 ppm. The mean DTPA extractable Zn content was higher in surface samples compared to sub-surface samples (Table 1). Priyadarshini (2011) [8] reported that the DTPA-Zn content of surface soil had slightly higher (0.81 ppm) content compared to sub-surface soil (0.80 ppm). Maximum per cent of surface (53.85) and sub-surface (97.43) samples had DTPA-Zn in low (<1 ppm) category as per soil test fertility ratings (Tandon, 2017) [19] in Siruguppa taluk (Table 2) and the distribution of DTPA-Zn concentration in surface and sub-surface soils of Siruguppa taluk is depicted in Fig. 2d and 3d. The lower availability of DTPA-Zn in such soils could be due alkaline soil reaction and presence of CaCO3 which could cause precipitation of Zn as hydroxides and carbonates under alkaline pH range and/or fixation of zinc in the octahedral layers (Revathi *et al*., 2005) [12]. Similar observations were made by (Vijayashekar *et al*., 2000) [22] and (Ravi Kumar *et al*., 2007) [11].

(Vijay Kumar, 2009) [21] also reported lower available zinc content of surface soil samples ranged in salt affected soils of Ongole division, Prakasam district, Andhra Pradesh wherein it ranged from 0.17 to 3.64 ppm with a mean value of 0.70 ppm in surface soil and from 0.25 to 2.71 ppm with a mean value of 0.62 ppm in sub-surface soils respectively.

DTPA-Zn had significant and negative correlation with pHe (r= -0.334* and - 0.469**) but significant and positive correlation with organic carbon (0.438** and 0.364*), DTPA-Fe (r= 0.698** and 0.578**) and DTPA-Mn (r= 0.540** and 0.502**) at 0-15 and 15-30 cm respectively (Table 3).

From the study, it is clear that DTPA-Zn content in surface and sub-surface soils was in low category which needs to be supplied through organics and/or inorganic fertilizers for sustainable crop production in these soils. Further, correlation studies indicate that soil pH and organic carbon are the main soil characteristics which control the micronutrient availability in the study area.

Table 1: Available micronutrient status in salt affected soils of Siruguppa taluk, Bellary district, Karnataka.

S. No	Coordinates	DTPA extractable micronutrient (ppm)							
		Fe		Mn		Cu		Zn	
		Depth (cm)							
		0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	N 15˚29'06.7" E 76˚43'36.2"	12.51	1.31	11.81	5.43	4.09	0.81	6.26	0.23
2	N 15˚28'35.8" E 76˚44'44.1"	9.30	1.28	15.22	5.29	3.95	0.81	1.21	0.14
3	N 15˚27'44.9" E 76˚46'01.7"	3.28	0.73	15.23	3.20	3.21	0.72	2.48	0.08
4	N 15˚27'00.8" E 76˚47'43.8"	2.47	2.43	8.82	4.89	1.92	0.62	0.64	0.12
5	N 15˚26'17.4" E 76˚47'42.2"	2.29	1.36	7.59	4.91	2.22	0.99	0.47	0.12

6	N 15°25'07.9" E 76°48'42.5"	6.83	3.83	14.83	10.14	3.39	2.04	0.64	0.36
7	N 15°24'59.4" E 76°54'24.1"	5.84	1.46	12.99	7.12	5.40	1.62	1.50	0.16
8	N 15°24'44.7" E 76°57'21.5"	3.74	1.47	7.60	4.36	2.58	1.34	0.44	0.18
9	N 15°23'55.4" E 76°58'22.6"	3.28	1.23	6.55	3.76	1.95	1.27	0.98	0.15
10	N 15°23'55.9" E 77°00'52.4"	1.85	1.57	5.39	3.84	2.11	1.52	0.31	0.38
11	N 15°25'44.9" E 77°01'28.8"	0.75	0.84	6.42	4.44	1.37	1.03	0.11	0.05
12	N 15°27'26.0" E 76°59'01.7"	1.80	1.28	5.63	3.20	2.27	1.03	0.23	0.10
13	N 15°27'04.8" E 76°56'56.4"	6.60	1.76	9.42	3.48	3.11	1.26	0.58	0.18
14	N 15°28'33.5" E 76°56'56.2"	5.19	2.91	8.96	5.38	2.61	1.45	0.88	0.42
15	N 15°30'29.7" E 76°57'20.3"	3.38	1.79	8.36	6.98	2.21	1.13	0.54	0.22
16	N 15°32'25.6" E 76°55'44.1"	1.30	1.70	7.36	7.47	1.54	1.14	0.37	0.28
17	N 15°32'21.0" E 76°53'25.0"	2.61	2.20	6.20	6.82	2.92	2.20	0.52	0.90
18	N 15°32'37.6" E 76°51'57.3"	4.63	3.32	4.66	3.67	2.33	1.39	1.81	0.70
19	N 15°33'09.9" E 76°50'28.6"	10.35	1.46	10.81	3.09	2.72	0.99	1.39	0.19
20	N 15°32'08.7" E 76°49'26.2"	12.14	1.19	8.83	2.91	2.12	0.92	1.29	0.09
21	N 15°30'19.3" E 76°48'35.9"	3.11	1.30	7.86	4.64	2.25	1.28	1.80	0.12
22	N 15°34'23.6" E 76°50'27.8"	1.22	0.98	7.18	3.37	1.66	0.87	0.29	0.20
23	N 15°35'40.1" E 76°51'12.4"	3.06	8.50	6.73	3.82	3.24	1.49	0.45	0.41
24	N 15°36'46.9" E 76°52'17.0"	3.99	9.20	8.35	7.76	1.10	1.10	0.53	1.04
25	N 15°37'46.7" E 76°56'46.1"	4.20	2.65	8.24	6.01	1.73	0.81	1.02	0.51
26	N 15°37'43.1" E 76°59'16.5"	4.49	1.17	8.77	4.47	2.07	1.09	1.28	0.19
27	N 15°36'58.4" E 77°01'10.1"	8.42	1.59	14.55	3.62	3.71	0.94	1.21	0.23
28	N 15°38'37.3" E 77°02'37.0"	2.17	1.30	10.55	3.77	2.60	1.03	0.74	0.16
29	N 15°42'54.1" E 76°57'53.5"	1.72	1.44	6.47	5.11	1.72	0.91	0.55	0.17
30	N 15°40'43.1" E 76°57'49.8"	4.66	1.85	27.92	6.58	1.03	0.90	2.60	0.41
31	N 15°39'01.7" E 76°58'17.7"	5.93	3.01	23.82	5.60	2.27	1.67	1.52	0.35
32	N 15°38'32.4" E 76°52'55.9"	7.12	3.55	25.88	7.54	2.19	0.72	1.46	0.61
33	N 15°39'10.7" E 76°52'12.2"	4.51	1.48	13.41	5.47	2.26	0.88	0.62	0.09
34	N 15°40'15.1" E 76°53'01.4"	17.29	1.78	31.08	3.46	2.50	0.72	4.73	0.12
35	N 15°40'50.2" E 76°53'26.6"	14.43	4.46	21.74	3.23	2.45	2.45	2.70	0.14
36	N 15°40'58.2" E 76°54'21.1"	6.06	5.14	15.49	10.59	2.45	1.49	0.67	0.46
37	N 15°44'07.5" E 76°54'19.3"	2.79	1.83	8.65	7.55	1.80	1.06	1.73	0.88
38	N 15°45'37.6" E 76°57'59.1"	3.05	1.78	5.56	3.51	2.07	1.08	1.11	0.35
39	N 15°47'29.5" E 77°01'34.8"	1.74	1.28	7.00	4.22	1.76	2.79	0.34	0.16
Maximum		17.29	9.20	31.08	10.59	5.40	2.79	6.26	1.04
Minimum		0.75	0.73	4.66	2.91	1.03	0.62	0.11	0.05
Average		5.13	2.29	11.33	5.15	2.43	1.22	1.23	0.30

Table 2: Percent distribution of soil samples with respect to soil available micronutrient status.

Soil Depth (cm)	DTPA extractable micronutrient (ppm)											
	Fe			Mn			Cu			Zn		
	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
0-15	25.64 (10)	61.54 (24)	12.82 (5)	2.56 (1)	89.74 (35)	7.69 (3)	0	66.67 (26)	33.33 (13)	53.85 (21)	35.89 (14)	10.26 (4)
15-30	74.36 (29)	25.64 (10)	0	56.41 (22)	43.59 (17)	0	0	97.43 (38)	2.56 (1)	97.43 (38)	2.56 (1)	0

Note: Values in parenthesis indicate number of samples.

Table 3: Correlation coefficient (r) between micronutrient and soil properties in salt affected soils of Siruguppa taluk, Bellary district, Karnataka.

Soil properties	Soil Depth (cm)													
	0-15							15-30						
	pHe	ECe	OC	Fe	Mn	Cu	Zn	pHe	ECe	OC	Fe	Mn	Cu	Zn
pHe	1	-0.176	-0.435**	-0.410**	-0.496**	-0.178	-0.334*	1	0.093	-0.367*	-0.347*	-0.305	-0.154	-0.469**
ECe		1	0.281	-0.005	0.428**	0.061	0.197		1	-0.184	-0.168	-0.102	-0.153	-0.222
OC			1	0.401*	0.401*	0.380*	0.438**			1	0.497**	0.243	0.106	0.364*
Fe				1	0.623**	0.388*	0.698**				1	0.358*	0.233	0.578**
Mn					1	0.117	0.540**					1	0.147	0.502**
Cu						1	0.298						1	0.160
Zn							1							1

** Correlation is significant at 0.01 level (1%)

* Correlation is significant at 0.05 level (5%)

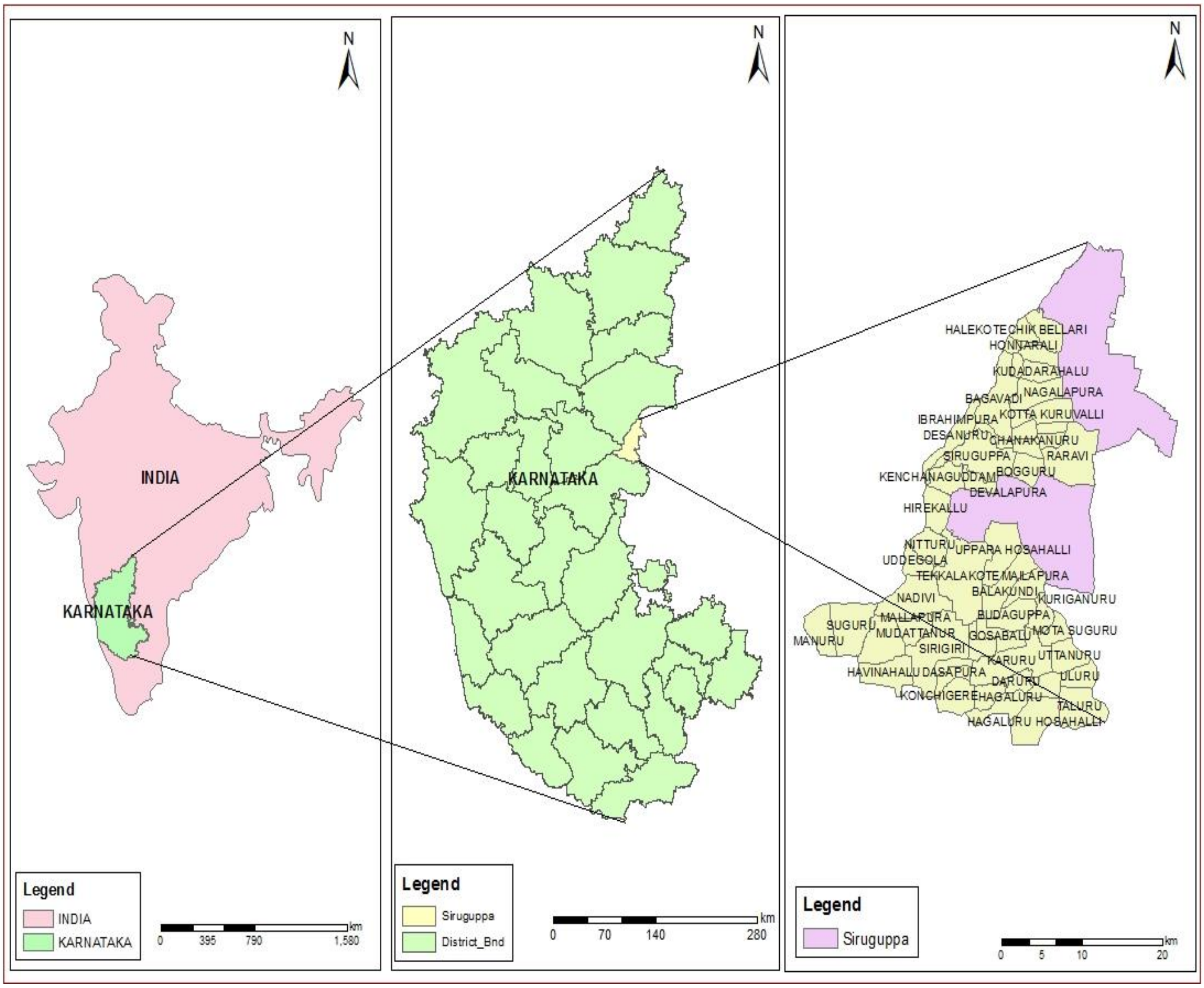
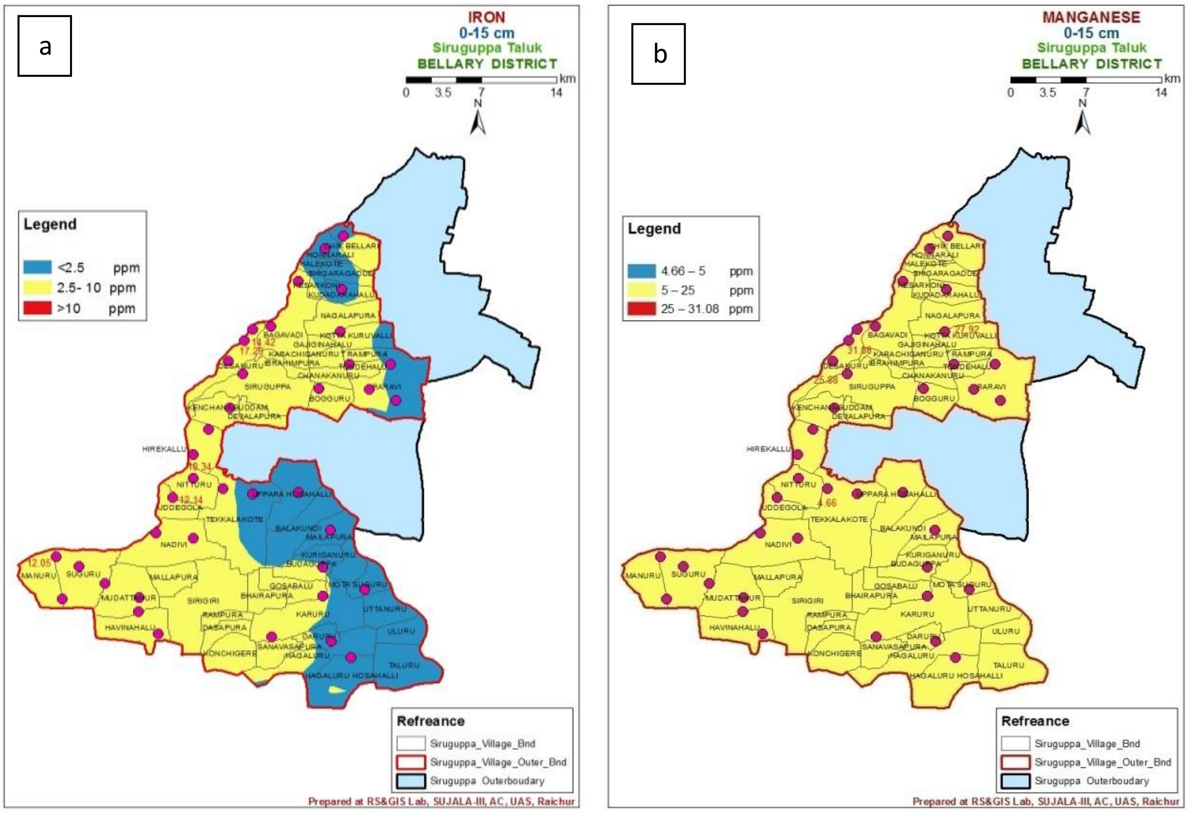


Fig 1: Location map of Siruguppa taluk



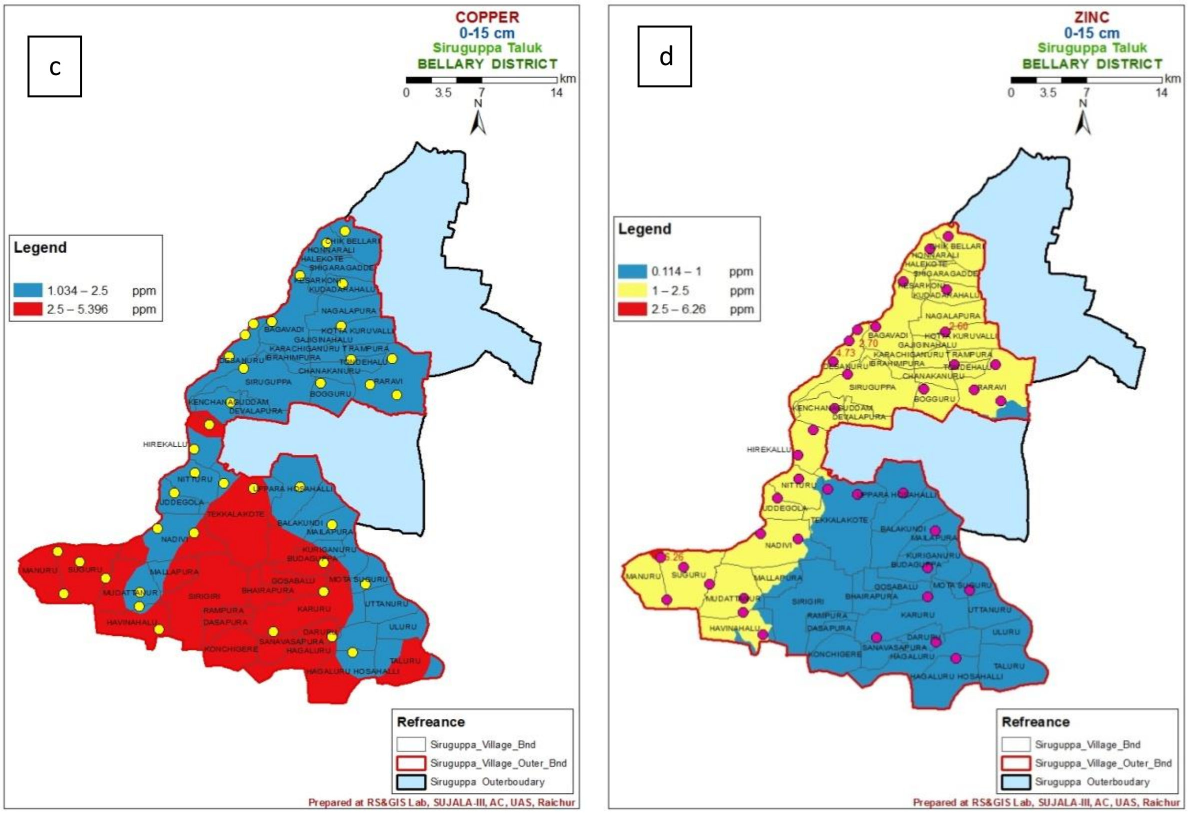
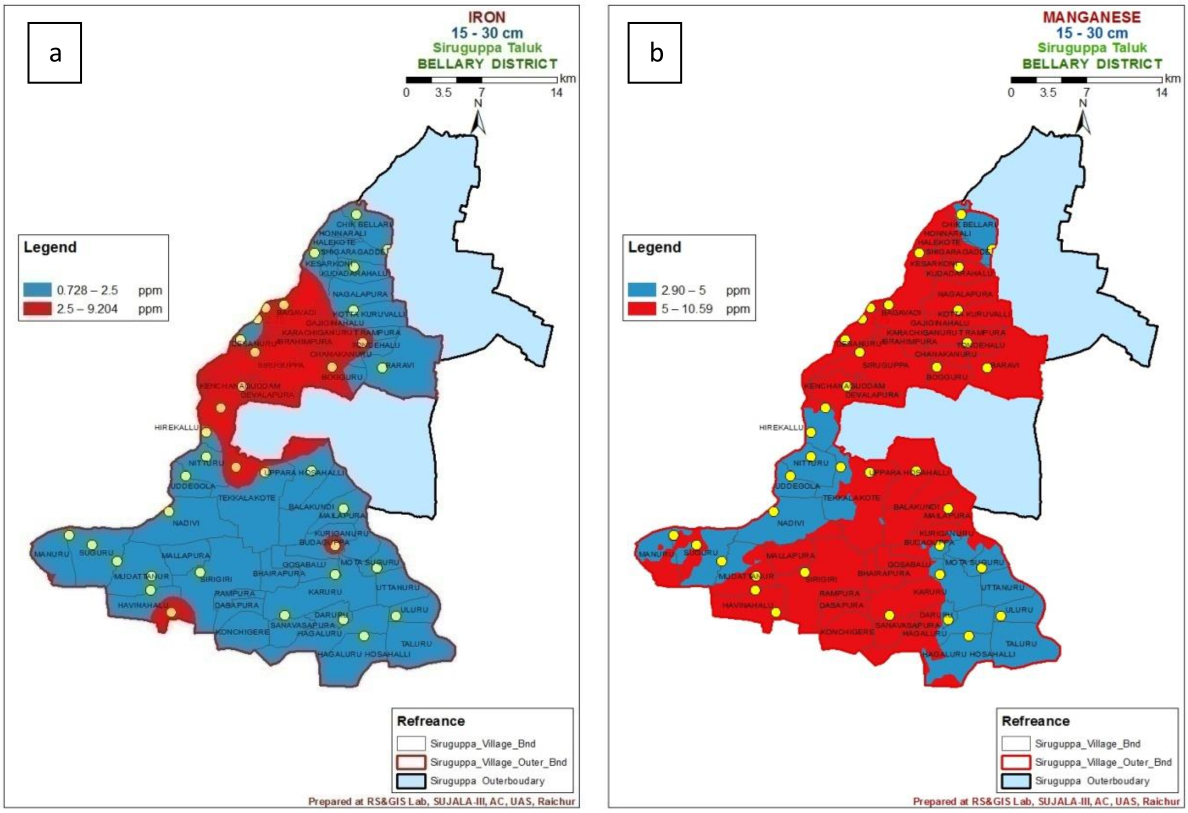


Fig 2: Distribution map of DTPA extractable (a) Fe, (b) Mn, (c) Cu and (d) Zn in surface (0-15 cm) soils of Siruguppa taluk.



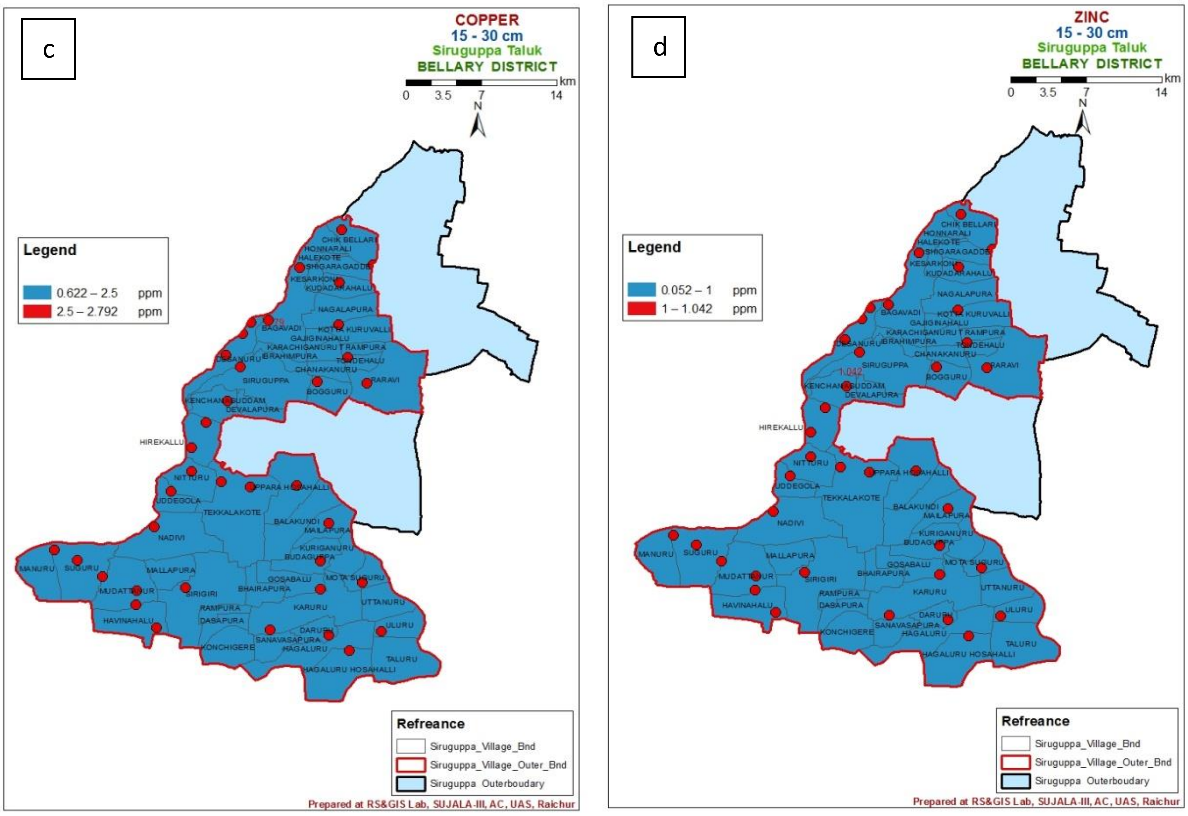


Fig 3: Distribution map of DTPA extractable (a) Fe, (b) Mn, (c) Cu and (d) Zn in subsurface soils (15-30 cm) of Siruguppa taluk.

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