The Pharma Innovation Journal 2022; 11(3): 1122-1128

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(3): 1122-1128

www.thepharmajournal.com
Received: 02-12-2021
Accepted: 07-02-2022

# Micronutrient status and their spatial variability in *Alfisols* soil of Damtari districts of Chhattisgarh-a GIS approach

**Ku Reena, Dashrath Singh, SG Rajput, Alok Kumar and PK Rajput**

**Ku Reena**
Research Scholar, Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

**Dashrath Singh**
Assistant Professor, Department of Soil Science and Agricultural Chemistry, BNPG College, Rath Hamirpur, Uttar Pradesh, India

**SG Rajput**
Associate Professor, Department of Soil Science and Agricultural Chemistry, BNPG College, Rath Hamirpur, Uttar Pradesh, India

**Alok Kumar**
Associate Professor, Department of Soil Science and Agricultural Chemistry, Indra Gandhi Krishi Vishwavidyalay, Raipur Chhattisgarh, India

**PK Rajput**
Assistant Professor, Department of Soil Conservation, Janta College, Bakewar, Etawah, Uttar Pradesh, India

**Corresponding Author:**
**SG Rajput**
Associate Professor, Department of Soil Science and Agricultural Chemistry, BNPG College, Rath Hamirpur, Uttar Pradesh, India

## Abstract
A systematic set of geo-referenced 670 soil samples was collected from Dhamtari district, soils comes under *Alfisols* order covering 119630 ha *i.e.* 29.18% entire area using GPS (Global positioning system) and the maps showing the spatial variability of individual micronutrient cation (Zn, Cu, Mn and Fe) were generated using Arc Info GIS (Geographic information system). The multi-micronutrient status map was also generated by integrating the individual micronutrient map in GIS. The descriptive statistics on soil characteristics indicated that the pH of the soils varied from 4.8 to 7.9 (mean = 6.3). The electrical conductivity (EC) ranged from 0.02 to 0.91 dS $m^{-1}$ (mean = 0.20 dS $m^{-1}$). The organic carbon (OC) ranged from 0.07 to 1.25% (mean = 0.56%). The DTPA-Fe, Mn, Zn and Cu ranged from 7.40 to 93.50, 0.24 to 66.50, 0.11 to 3.88 and 0.21 to 6.00 mg $kg^{-1}$, respectively, while the mean 40.92, 22.72, 0.80 and 2.50 mg $kg^{-1}$. Organic carbon, EC and pH were the important factors in controlling the micronutrient availability. The GIS-aided thematic maps indicate the toxicity of Fe, Mn and Cu were 93.70%, 40.39% and 73.02% respectively, while the 40% deficiency of Zn under was found. The soil of Dhamtari district under *Alfisol* soil was observe a severe toxicity of cationic micro nutrient except Zn, the Zn deficiency due to rise based cropping system.

**Keywords:** Systematic, alfisol, global positioning system (GPS), geographic information system (GIS), DTPA extractable micronutrient

## Introduction
*Alfisols* are locally called Dorsa soils. Most *Alfisols* fields are bonded and levelled. Impact of drought is relatively less in this situation. They constitute the major land situation which has traditionally been used for growing oilseed and pulse crops as relay crops (utera) on residual soil moisture especially after irrigated rice and effective rainfall. Soil micro-nutrients are as essential as primary and secondary nutrients for the development and crop growth. The addition of micro nutrients to fertilizers in the optimum amounts and in degraded soils ensures the sustainability of cropping through balanced nutrition and ultimately sustainable development of the fertilizer industry. There has been a substantial increase in food production from about 51 million tonnes (Mt) in 1950 to about 211.32 Mt in 2001-2002. To steer these agricultural achievements towards the path of an evergreen revolution, there is a need to blend the traditional knowledge with frontier technologies. Information and Communication Technology (LCT), Space Technology (Remote Sensing), Geographical Information Systems (GIS), Ground Positioning System (GPS) are the tools of such frontier technologies, which would help in generation of agricultural management systems and formulating plans for sustainable agricultural development. The adoption of major technological developments in agriculture by the farmers generally takes much time and efforts in our country, as majority of farmers are small and marginal, illiterate and resource-poor. But we must get started, step-wise of course, as we are already far behind the developed world. In the present study an attempt has been made to assess the micronutrient status of soils in Dhamtari district to evaluate the magnitude of micronutrient (Fe, Cu, Zn and Mn) deficiencies and to map their spatial variability using GPS and GIS.

## Study Area
Dhamtari is abbreviated from “Dhamma” and “Tarai". District is situated in the fertile plains of Chhattisgarh, which includes seventy-eight villages for evaluation of soil fertility status of Dhamtari district.

This district is situated between 20°40′ N, 81°33′ East longitude. The total area of district is 2029 Km², and 305 m above the mean sea level. The *Alfisols* group of the soil covered under the different village of the Dhamtari block in Dhamtari district of Chhattisgarh has been taken for fertility evaluation of various aspects and seventy-seven villages 670 soil samples comes under *Alfisols* (study area). The area covering 119630 ha *i.e.* 29.18% entire area using GPS (Global positioning system) and the maps showing the spatial variability of individual micronutrient of Dhamtari district. The state shares its boundaries with the 6 Indian states *i.e.* Madhya Pradesh on the northwest, Uttar Pradesh on the north, Jharkhand on the north-east, Orissa on the south-east, Andhra Pradesh on the south and Maharashtra on the south-west. The use of plant nutrients in a balanced manner is the prime factor for efficient fertilizer program. Balanced nutrient use ensures high production level and helps to maintain the soil health. Chhattisgarh State has five major soils type *i.e. Entisols, Inceptisols, Alfisols, Vertisols and Mollisols.* Almost all soils are deficient in nitrogen and phosphorus and medium to high in potassium. Zinc deficiency is emerging and commonly observed in *Alfisols and Vertisols* of this region. Elevation 333 to 636 meter, terrain is generally flat, much cut up by Nallas slope is toward North and drainage the tract is drained by Mohandas and its tributaries.

## Materials and Methods

### Collection of soil samples

The soil fertility status in *Alfisols* of Dhamtari district, a systematic survey was carried out; Six hundred seventy surface (0-15 cm depth) soil samples were collected from different villages using GPS marked. The sampling points were taken from the cadastral map of different villages by locating in such that from each 10 ha area may represent one grid based soil sample.

### Analysis of samples

The soil samples were air-dried, ground and sieved through 2 mm plastic sieve. The samples were analyzed for pH, electrical conductivity (EC) and organic carbon (OC). The pH was determined by potentiometric method (Jackson 1973), EC with solubridge method (Chopra and Kanwar 1976) and OC by wet digestion method (Walkley and Black 1934) [21]. The available Zn, Fe, Cu and Mn were extracted using DTPA (Lindsay and Norvell 1978) [7] and their concentration was determined using atomic absorption spectrophotometer.

### Generation of maps

The flow diagram showing the various steps followed in preparation of maps in fig. 1. The location of sampling sites was fed into the GIS environment. After analyzing the samples for the DTPA-extractable micronutrients (Fe, Mn Zn, & Cu) and hot water soluble boron were categorized as deficient and sufficient as per the critical limits given in table 1. The values (deficient or sufficient) were tagged with each geo referenced point and hard print of the maps was taken out. The points having similar values were grouped and marked as a polygon manually and the maps for individual micronutrients were digitized using Arc GIS (Sharma *et al.* 2006; 2008) [16, 17]. The maps thus generated for individual micronutrient (Fe, Cu, Mn and Zn) were integrated in Arc GIS (union of layers) to prepare multi-micronutrient status map.

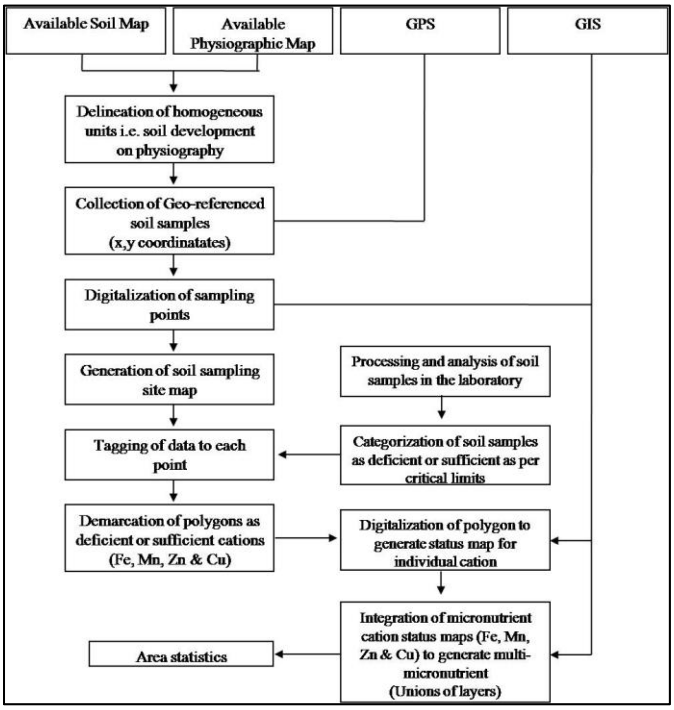


**Fig 1:** Flow diagram showing the various steps followed in preparation of maps

## Results and Discussion

The present investigation was taken *Alfisol* of Dhamtari district of Chhattisgarh was under taken for fertility evaluation. Soil characteristics data obtained for different soil mapping units was mapped using Arc-GIS 9.2 software. Thematic maps of soil pH, EC and OC are presented in fig. 2 and those of DTPA extracted Fe, Mn, Zn and Cu are depicted in fig. 3.

### GIS-Approached mapping of Physico-chemical properties

The $pH_2$ of soils of piedmont and *Alfisol* soil eco-subregion varied from 4.8 to 7.9 (Table 1). The $EC_2$ of soil solution ranged from 0.02 to 0.91 dS $m^{-1}$ (mean = 0.20 ±0.09 dS $m^{-1}$). The organic carbon content of the soil ranged from 0.07 to 1.25% (mean = 0.56 ±0.16%) (Table 1). This may due to slow decomposition rate of organic carbon with acidic in nature and less salt attentiveness. The variation of EC was not predominant within *Alfisol* soil. Keeping in view the importance of pH in controlling availability of most of nutrients, the pH range in Chhattisgarh in Dhamtari district under *Alfisol* soil has been divided into 4 categories and 143 polygons for mapping (Table 2). First category is in the strongly acidic range (4.8-5.4) has only 11337 hectares representing 8.75% area of the district. The pH of state is in slightly alkaline range varying from 6.1 to 6.5 and occupying 7.92% area of the distinct. In general, the pH of *Alfisol* soil varying from 4.8 to 6.5 and occupying 81.47% area of the distinct. The moderately acidic to neutral pH may be attributed to the reaction of applied nitrogenous fertilizer material in abundance and high rainfall and irrigation, which resulted in the leaching of basic cations on the exchangeable complex of the soil Kumar *et al.*, (2009) [6]. Soil samples having < 0.25% OC are denoted as very low in available OC. In the Dhamtari district under *Alfisol* soil only 11 polygons having 4405 ha represent about 3.68%, while the 39 polygons having 37030 ha occupying 30.69% samples with range 0.26-0.50 found low categories (Table 2). Sixty-two per cent, 86 polygons and 74060 ha area of the district is medium in available OC (0.50-0.75). About 3.46% of state area has OC content greater than 0.75%. As rice- rice cropping system has been practiced in Dhamtari district since long and stubbles of these crops left in the soil after harvest and their subsequent decomposition might have resulted in an increase of organic matter in the soil over a period of time. Similar finding were also reported by Bali *et al.* (2010) [14] and Sharma *et al.* (2008) [17].

**Table 1:** Descriptive statistics of soil characteristics

| Statistical measure | Minimum | Maximum | Mean | Median | S.D. | C.V. |
|---|---|---|---|---|---|---|
| pH | 4.8 | 7.9 | 6.3 | 6.4 | ± 0.5 | 7.90 |
| EC (dS $m^{-1}$) | 0.02 | 0.91 | 0.20 | 0.19 | ± 0.09 | 45.93 |
| OC (%) | 0.07 | 1.25 | 0.56 | 0.56 | ± 0.16 | 28.80 |
| Fe (mg $ha^{-1}$) | 7.40 | 93.50 | 40.93 | 39.74 | ± 15.49 | 37.86 |
| Mn (mg $ha^{-1}$) | 0.24 | 66.50 | 22.72 | 22.38 | ± 9.21 | 40.53 |
| Zn (mg $ha^{-1}$) | 0.11 | 3.88 | 0.80 | 0.62 | ± 0.58 | 72.56 |
| Cu (mg $ha^{-1}$) | 0.21 | 6.00 | 2.50 | 2.54 | ± 1.02 | 40.56 |

**Table 2:** Area statistics (%) of soil pH, electrical conductivity and organic carbon in *Alfisols* soils of Dhamtari district

| Rating | Status | No of polygons | Area (ha) | % area of Dhamtari districts | % area within *Alfisols* | Mean |
|---|---|---|---|---|---|---|
| **pH Soil: Water (1:2)** | | | | | | |
| 4.8-5.5 | Strongly acid | 21 | 33397 | 8.15 | 27.92 | 5.28 |
| 5.6-6.0 | Moderately acid | 42 | 31582 | 7.70 | 26.40 | 5.82 |
| 6.1-6.5 | Slightly acid | 44 | 32480 | 7.92 | 27.15 | 6.30 |
| 6.6-7.9 | Neutral | 36 | 22171 | 5.41 | 18.53 | 6.76 |
| **EC (dS $m^{-1}$)** | | | | | | |
| 0.02-0.42 | Non Saline | 125 | 107318 | 26.18 | 89.71 | 0.19 |
| 0.42-0.66 | Non Saline | 16 | 11629 | 2.84 | 9.72 | 0.48 |
| 0.67-0.85 | Non Saline | 1 | 55 | 0.01 | 0.05 | 0.68 |
| 0.86-0.91 | Non Saline | 1 | 628 | 0.15 | 0.52 | 0.91 |
| **Organic Carbon (%)** | | | | | | |
| 0.07-0.25 | Very Low | 11 | 4405 | 1.07 | 3.68 | 0.19 |
| 0.26-0.50 | Low | 39 | 37030 | 9.03 | 30.96 | 0.42 |
| 0.51-0.75 | Medium | 86 | 74060 | 18.06 | 61.91 | 0.62 |
| 0.76-1.25 | High | 7 | 4134 | 1.01 | 3.46 | 0.83 |

## GIS-Approached mapping of micronutrients

DTPA-extractable Fe content in *Alfisol* varied from 7.40 to 93.50 mg $kg^{-1}$ with an average amount of available Fe was 40.93 mg $kg^{-1}$ (Table 1) and shows in fig.3. Considering 4.5 (this is missing in reference) mg $kg^{-1}$ (Table 2) DTPA-extractable Fe as critical limit (Lindsay and Norvell, 1978) [7]. while the data reveals that the *Alfisol* soil were found beyond critical limit *i.e.* marginal to heavy toxicity was originate in Dhamtari district soils. The most of soil observed to be Fe toxicity is 83% with 112 polygons considered 99760 ha, reaming 29 polygons as 76% and area as sufficient to high categories. Only 2 polygons 986 ha *i.e.* 0.82% trifling area were classified as marginal categories. Higher amount of available Fe content in *Alfisol* of Dhamtari district might be due to its topography and cultivation of rice which induced prolonged submergence coupled with reducing conditions. This order of the soils in study area is not deficient in Fe as the amount of Fe required by crops is being released by Fe bearing minerals in these soils. The soil pH had reverse effect on the availability of Fe content in soil. Rajeswar *et al.* (2009) [12] in soils of Garikapadu of Krishna District of Andhra Pradesh have also reported the similar trends in available Fe content. DTPA-Fe reviled a negative and highly significant correlation (r = -0.315**) with pH (Table7) which confirms the basic chemistry of Fe availability in various pH level of the soil. Talukdar *et al.* (2009) [20] and Somasundaram *et al.* (2009) [18] also reported significant negative correlation of available Fe with pH of the soil. The correlation of Fe level with EC showed a negative and non significant result (r = -0.072), Similar observations were also reported by Somasundaram *et al.* (2009) [18]. The DTPA-Fe indicated negative and highly significant correlation (r = -0.215**) with soil organic C (Table 7), Similar observation was found by Mogia and Bandyopadhyay (1993) [9] in South Andaman.

Map generated Arc-GIS info for the present field study clearly indicated that DTPA-extractable Mn in soils (*Alfisols*) was varied from 0.24 to 64.50 mg $kg^{-1}$ with an average content of available Mn was 22.72 mg $kg^{-1}$ (Table 1). Considering 3.5 mg $kg^{-1}$ (Table 4) DTPA-extractable Mn as critical limit (Lindsay and Norvell, 1978) [7]. the data revealed that 0.19% *i.e.* 222 ha area were found to be deficient in available Mn and 93.7% occupying 125 polygons and 122088 ha area found to be toxic level (Table 4). The Mn bearing minerals in the parent material might be the reason for higher Mn content in the soils and due to better supply of Mn to rice in flooded soil as Mn is soluble in relatively acidic and reduced soil condition (Mandal and Haldar, 1980) [8]. Like Fe availability, Mn status also resulted a negative and significantly highly correlation with pH (r = -0.284**) and Soil organic C (r = -0.209**) table 7. it may be due to the formation of insoluble higher valent oxides of Mn at high pH (Sahoo *et al.*, 1995) [15]. Bansal and Takkar (1985) [3] reported that the DTPA-extractable Mn decreased significantly with increase in soil pH. Rai *et al.* (1970) [11] claimed a negative correlation between available Mn and organic C level in deep black soils of Madhya Pradesh.

**Table 3:** Area statistics (%) of soil available iron (Fe) in *Alfisols* soils of Dhamtari district

| Rating | Statistics | No of polygons | Area (ha) | % area of Dhamtari districts | % area within *Alfisols* | Mean |
|---|---|---|---|---|---|---|
| 7.40-10.00 | Marginal | 2 | 986 | 0.24 | 0.82 | 7.77 |
| 10.01-18.00 | Sufficient | 4 | 1028 | 0.25 | 0.86 | 14.64 |
| 18.01-27.00 | Higher | 25 | 17829 | 4.35 | 14.90 | 26.86 |
| 27.01-39.00 | Toxic | 21 | 55047 | 13.43 | 46.02 | 33.42 |
| 39.01-55.00 | Toxic | 66 | 36973 | 9.02 | 30.91 | 42.70 |
| 55.01-93.50 | Toxic | 25 | 7740 | 1.89 | 6.47 | 63.14 |

**Table 4:** Area statistics (%) of soil available Manganese (Mn) in *Alfisols* soils of Dhamtari district

| Rating | Statistics | No of polygons | Area (ha) | % area of Dhamtari districts | % area within *Alfisols* | Mean |
|---|---|---|---|---|---|---|
| 0.20-3.50 | Deficient | 2 | 222 | 0.05 | 0.19 | 1.22 |
| 3.51-7.50 | Sufficient | 6 | 1096 | 0.27 | 0.92 | 5.78 |
| 7.51-10.00 | Higher | 10 | 6224 | 1.52 | 5.20 | 8.98 |
| 10.01-20.00 | Toxic | 34 | 34534 | 8.42 | 28.87 | 15.82 |
| 20.01-30.00 | Toxic | 67 | 71286 | 17.39 | 59.59 | 24.78 |
| 30.01-66.50 | Toxic | 24 | 6268 | 1.53 | 5.24 | 36.60 |

In this study the spatial distribution of DTPA-Zn in soils of Dhamtari district under *Alfisols* five different categories was overlaid on the soil map layer. The DTPA-Zn in soils varied considerably and ranged from 0.11 to 3.90 mg $kg^{-1}$ (Table 1). Based on critical limit 0.6 mg $kg^{-1}$, 48323 ha *i.e.* 40.4% area within *Alfisol* and 11.78% area of the total geographical area of Dhamtari district was observed to be affected by Zn deficiency with a mean value of 0.41 mg $kg^{-1}$. There are 62 polygons in this deficient class in table 5. It covers the areas of rice-rice based copping system. Similar finding with respect to available Zn content was also reported by Rajeswar *et al.* (2009) [12] and Kumar, Ajay *et al.* (2009) [2] in soils of Andhra Pradesh and Utter Pradesh, respectively. A significant and negative relationship (r = -0.158*) was observed with pH (Table 7), thereby indicating that availability of Zn decreases with increase in soil pH. This positive relationship might be attributed to the increased availability of Mn, Zn and Cu under low pH condition which increased solubility of oxides and hydroxides of these micronutrients. Similar relation was also observed by Bali *et al.* (2010) [14] and Talukdar *et al.* (2009) [20]. A significant and negative relationship (r = -0.128*) was observed with EC. No significant correlation found between available Zn and Organic C (r = 0.114) in *Alfisol* for Dhamtari district. Similar result observed by Kumar *et al.* (2009) [6] in Dumka series of Santhal Paraganas Region of Jharkhand. DTPA-extractable Cu content in soils under study area varied from 0.21 to 6.00 mg $kg^{-1}$ with an average content of available Cu was 2.50 mg $kg^{-1}$ (Table 1). Taking to 0.2 mg $kg^{-1}$ table 6, DTPA-extractable Cu as critical limit (this is missing in reference), only 1.10% soil samples occupying 6 polygons *i.e.* 1454 ha area were found to be sufficient in available content of Cu and 98.40% soil sample found to be in higher to toxic level (Table 6). Almost similar content of available copper was also reported by Kumar *et al.* (2009) [6] and Rajput and Polara (2011) for Saurastra region of Gujarat. A significant negative correlation (r= 0.206*) was observed between soil pH and available Cu (Table 7). A negative relationship (r = -0.109) was found between available Cu and electrical conductivity. A significant negative correlation (r = -0.135*) was observed between organic C and available Cu (Table 7). Significant and negative correlation between available Cu and organic C was observed by Kumar *et al.* (2009) [6] in Santhal Paraganas Region of Jharkhand, Agrawal and Motiramani (1966) [1] in soils of Madhya Pradesh.

**Table 5:** Area statistics (%) of soil available Zinc (Zn) in *Alfisols* soils of Dhamtari district

| Rating | Status | No of polygons | Area (ha) | % area of Dhamtari districts | % area within *Alfisols* | Mean |
|---|---|---|---|---|---|---|
| 0.11-0.40 | Deficient | 52 | 46423 | 11.32 | 38.81 | 0.31 |
| 0.41-0.60 | Deficient | 10 | 1900 | 0.46 | 1.59 | 0.51 |
| 0.61-1.20 | Marginal | 61 | 28291 | 6.90 | 23.65 | 0.81 |
| 1.21-2.40 | Sufficient | 14 | 41691 | 10.17 | 34.85 | 1.68 |
| 2.41-3.90 | Higher | 6 | 1325 | 0.32 | 1.11 | 2.95 |

**Table 6:** Area statistics (%) of soil available copper (Cu) in *Alfisols* soils of Dhamtari distric

| Rating | Statistics | No of polygons | Area (ha) | % area of Dhamtari districts | % area within *Alfisols* | Mean |
|---|---|---|---|---|---|---|
| 0.21-0.40 | Marginal | 1 | 466 | 0.11 | 0.39 | 0.28 |
| 0.41-0.80 | Sufficient | 6 | 1454 | 0.35 | 1.22 | 0.67 |
| 0.81-1.60 | Higher | 33 | 30361 | 7.41 | 25.38 | 1.28 |
| 1.61-2.70 | Toxic | 32 | 22857 | 5.57 | 19.11 | 2.19 |
| 2.71-6.00 | Toxic | 71 | 64492 | 15.73 | 53.91 | 3.39 |

**Table 7:** Correlation between Physico-chemical properties and micronutrient

| $R^2$ | pH | EC | OC | Fe | Mn | Zn | Cu |
|---|---|---|---|---|---|---|---|
| pH | 1.000 | | | | | | |
| EC | 0.108 | 1.000 | | | | | |
| OC | -0.124 | 0.003 | 1.000 | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fe | -0.315** | -0.072 | -0.215** | 1.000 | | | |
| Mn | -0.284** | -0.101 | -0.209** | 0.204* | 1.000 | | |
| Zn | -0.158* | -0.128* | -0.114 | 0.146* | 0.166* | 1.000 | |
| Cu | 0.206* | -0.109 | -0.135* | 0.104 | 0.070 | 0.099 | 1.000 |

*Significant at 1% level **Significant at 5% level

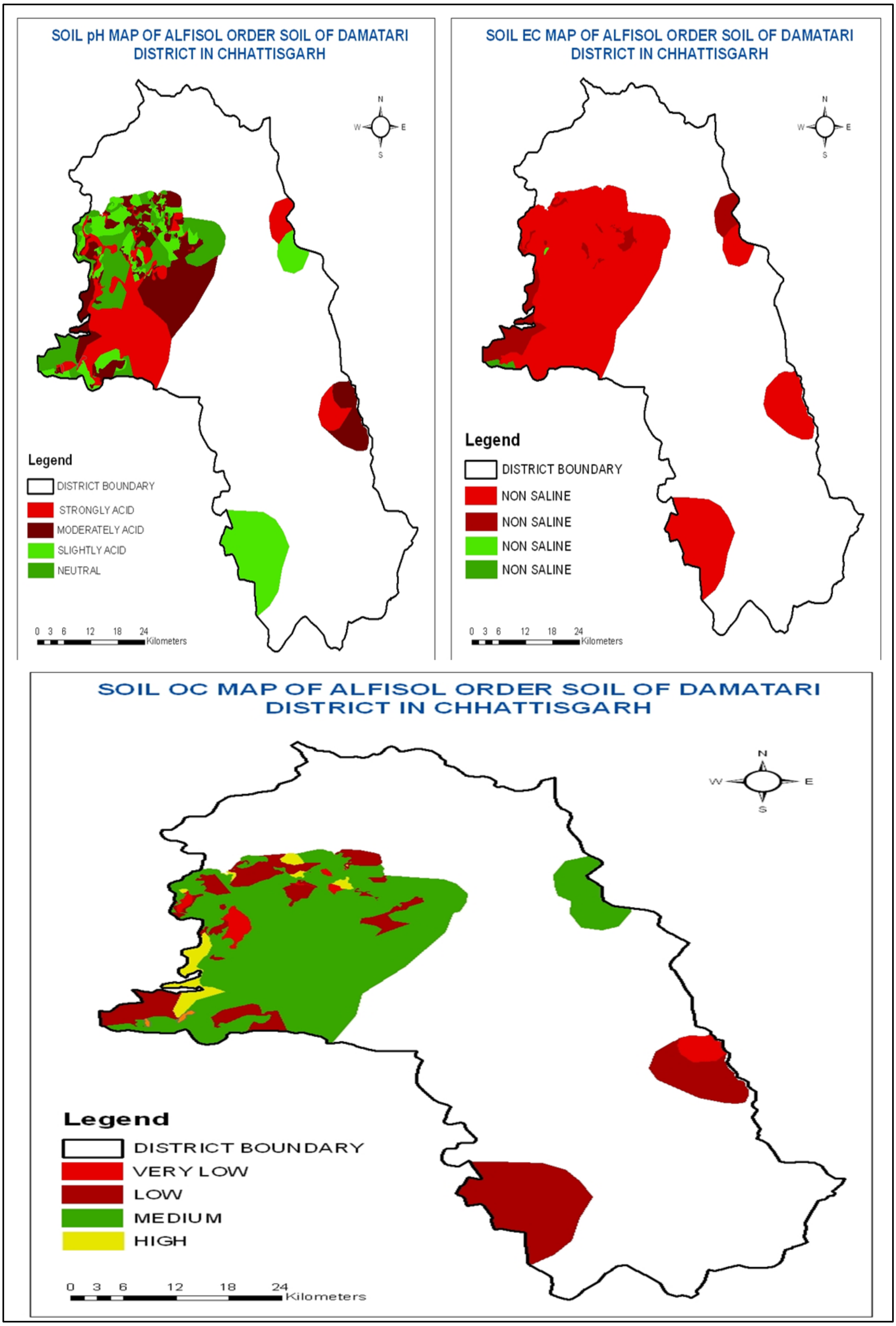


**Fig 2:** Soil pH, EC and OC status of *Alfisol* soil of Dhamtari District of Chhattisgarh

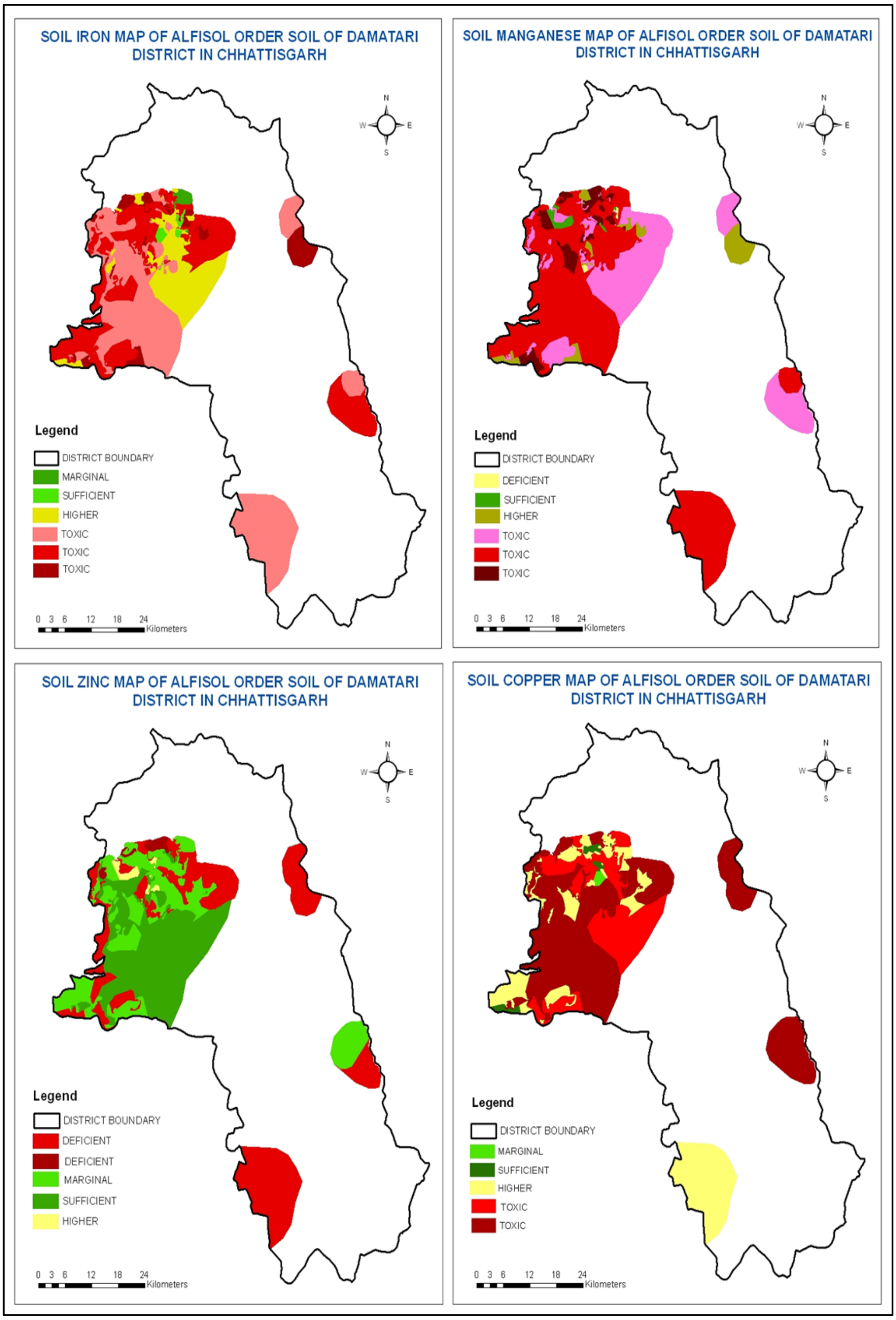


**Fig 3:** Soil Fe, Mn, Zn and Cu status of *Alfisol* soil of Dhamtari District of Chhattisgarh

## References


1. Agrawal HP, Motiramani DP. Copper status of soils of Madhya Pradesh. Journal of Indian Society of Soil Science. 1966;14:161-171.
2. Ajay K, Vipin K, Jagpal S. Status of micronutrient cation in soil of southern western plane of Uttar Pradesh. Annuals of Plant and Soil Research. 2009;11:90-91.
3. Bansal RL, Takkar PN. Distribution of Zn, Fe, Cu and Mn in soils and wheat plants of Jalandhar district (Punjab). Journal of Research PAU. 1985;22:25-32.
4. Jackson ML. Soil chemical analysis, Pentice hall of India Pvt. Ltd., New Delhi. 1967.
5. Jatav GK, Reena Ku, Bhagat RK, Meena SK. Distribution of Dtpa-Extractable Micronutrients In Inceptisol of Baloda Block in Janjgir District of Chhattisgarh, Agriculture for Sustainable Development. 2013;1:111-114.
6. Kumar Rakesh, Sarkar AS, Singh KP, Agarwal BK, Karmakar S. Appraisal of available Nutrients status in Santhal Paraganas Region of Jharkhand. Journal of Indian Society of Soil Science. 2009;57:366-369.
7. Lindsay WL, Norvell WA. Development of DTPA soil

test for Zn, Fe, Mn and Cu. Soil Science Society of America Journal. 1978;42:421-428.
8. Mandal LN, Haldar M. Influence of phosphorus and zinc application on the availability of zinc, copper, iron, manganese and phosphorus in waterlogged rice soils. Soil Science. 1980;130:251-257.
9. Mongia AD, Bandyopadhyay AK. Soil nutrients under natural and planted forest in Island ecosystem. Journal of Indian Society of Soil Science. 1993;42:43-46.
10. Piper CS. Soil and Plant analysis. Inter science publisher Inc., New York. 1967.
11. Rai MM, Shitalegy DB, Pal AR, Vakil P, Gupta SK. Available micronutrient status of deep black soils of Madhya Pradesh. Journal of Indian Society of Soil Science. 1970;18:383-389.
12. Rajeswar M, Rao CS, Balaguravaiah D, Khan MAA. Distribution of available Macro and Micronutrients in soils Garikapadu of Krishna District of Andhra Pradesh. Journal of Indian Society of Soil Science. 2009;57:210-213.
13. Rajput SG, Polara KB. Fertility status of cultivated soils in coastal Bhavnagar district of Saurashtra region of Gujarat, Journal of the India Society of Soil Science. 2012;60:317-320.
14. SK Bali, Raj-Kumar, HS Hundal, Kuldeep Singh, Bhupinder Singh. GIS-aided Mapping of DTPA Extractable Zinc and Soil Characteristics in the State of Punjab. Journal of the Indian Society of Soil Science. 2010;58:189-199.
15. Sahoo AK, Sah KD, Gupta SK. Organic carbon status in the suderbans mangrove soils. Journal of Indian Society of Soil Science. 1995;43:265-267.
16. Sharma PK, Sood Anil, Setia RK, Verma VK, Mehra D, Tur NS, *et al*. Use of information technology for mapping of DTPA-extractable micronutrients in soils of Amritsar district, Punjab. Journal of the Indian Society of Soil Science. 2006;54:465-474.
17. Sharma PK, Sood Anil, Setia RK, Verma VK, Mehra D, Tur NS, *et al*. Mapping of macronutrients in soils of Amritsar district (Punjab)- A GIS approach. Journal of the Indian Society of Soil Science. 2008;56:34-41.
18. Somasundaram J, Singh RK, Parandiyal AK, Prasad SN. Micronutrient Status of Soils under Different Land Use Systems in Chambal Ravines. Journal of Indian Society of Soil Science. 2009;57:307-312.
19. Sood Anil, Sharma PK, Tur NS, Nayyar VK. Micronutrient Status and their Spatial Variability in Soils of Muktsar District of Punjab – A GIS Approach, Journal of the Indian Society of Soil Science. 2009;57:300-306.
20. Talukdar MC, Basumatary A, Datta SK. Status of DTPA-extractable cationic Micronutrients in soils under Rice and Sugarcane Ecosystems of Golaghat district in Assam. Journal of Indian Society of Soil Science. 2009;57:313-316.
21. Walkley A, Black CA. An examination of the degtjareff method for determining the soil organic matter and a proposed modification of the chromic acid titration method. Soil Science. 1934;37:29-38.